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ABSTRACT

Average-based versus High- and Low-Impact Indicators for the Evaluation of Scientific Distributions*

Albarrán et al. (2009a) introduced a novel methodology for the evaluation of citation distributions consisting of a pair of high- and a low-impact measures defined over the set of articles with citations below or above a critical citation level CCL. Albarrán et al. (2009b) presented the first empirical applications to a situation in which the world citation distribution in 22 scientific fields is partitioned into three geographical areas: the U.S., the European Union, and the rest of the world. In this paper, we compare our results with those obtained with average-based indicators. For reasonable CCLs, such as the 80th percentile of the world citation distribution in each field, the cardinal differences between the results obtained with our high-impact index and the mean citation rate are of a large order of magnitude. When, in addition, the percentage in the top 5% of most cited articles or the percentage of uncited articles are used, there are still important quantitative differences with respect to the high- and low-impact indicators advocated in our approach when the CCL is fixed at the 80th or the 95th percentile.

JEL Classification: I23 and I32
Keywords: citation distributions and measuring scientific performance

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I. INTRODUCTION

Albarrán *et al.* (2009a) introduced a novel methodology for the evaluation of the scientific performance of research units working in the same homogeneous field, namely, a scientific field where the number of citations received by any two papers is comparable independently of the journal in which they have been published. Albarrán *et al.* (2009b) presented the first empirical applications of such an approach to a situation in which the world citation distribution in a given field is partitioned into three geographical areas: articles with at least one author working in a research institution in the U.S.; in the EU, namely, the 15 countries forming the European Union before the 2004 accession, or in any other country of the rest of the world (RW hereafter). In this paper we complete the illustrative nature of Albarrán *et al.* (2009b) with a comparison of our results with those that can be obtained using average-based indicators.

It should be recalled that our starting point is the well known fact that citation distributions are highly skewed, so that their upper and lower parts are typically very different. Consequently, we suggest using two indicators to describe this key feature of a citation distribution: a high- and a low-impact measure defined over the sets of articles with citations above and below an appropriately selected *critical citation level* (CCL hereafter). As in Albarrán *et al.* (2009b), in this paper we use two families of high- and low-impact indicators that satisfy a set of very useful properties for empirical work. Since these indices are based on Foster, Greer and Thorbecke's (1984) contribution to the measurement of economic poverty, we will refer to them as the FGT high- and low-impact families.

It is clear that a single statistic of centrality –such as the mean citation rate (MCR hereafter) or the median– may not adequately summarize the asymmetries presented by a typically skewed citation distribution (see *inter alia* Bornmann *et al.*, 2008 and, in a different context, Glänzel, 2002). In particular, authors from the Leiden group are very aware of the need to include in their battery of indicators some that capture what takes place at the tails of any citation distribution. Thus, together with average-based indicators, since its inception this group has always measured the percentage of papers with no citations at all (see, *inter alia* Moed *et al.*, 1985, 1988, 1995, and van Raan, 2004). More recently, the Leiden group has turned its attention to the upper tail of the distribution and has included the percentage of papers in the top 5% of most cited papers as an indicator of scientific excellence (see Tijssen *et al.*, 2002, and van Leeuwen *et al.*, 2003, as well as Aksnes and Sivertsen, 2004).

To understand the value added by our approach, note how this last indicator might be improved upon by taking into account the following two considerations. Firstly, fix the CCL equal to the number of citations that define the top 5% of highly-cited papers. Consider a situation in which two research units A and B make the same percentage contribution to the world top 5%, but the citations received by the articles of unit A are barely above the CCL, while most of the articles of unit B have citations well above that line. It might be desirable that a measure of high-impact takes into account not only the *incidence* aspect of that phenomenon – captured by the relative percentage contribution to the top 5%– but also the *intensity* aspect reflected in the aggregate gap between the citations actually received by each of the highly-cited papers and the CCL. Unit B will exhibit a greater high-impact level than unit A according to a measure that takes into account this second aspect, while any indicator based on the share of papers of a certain type would only capture the incidence aspect.[1]

Secondly, consider two research units that are equally ranked in terms of the incidence and intensity aspects of the high-impact phenomenon. Assume that most of the highly cited papers of unit C have a similar number of citations above the CCL, while a large part of the citations received by unit D are concentrated in a few articles of, say, Nobel prize category. In such situations it might be desirable that a high-impact measure takes into account the citation *inequality* among the set of high-impact papers, in which case unit D will exhibit a greater high-

[1] Assume that the CCL is four, and consider two equal sized citation distributions A and B with the same number of high-impact articles. The two sets of high-impact articles are (5, 8, 15) and (5, 10, 15). A reasonable high-impact indicator that takes into account the intensity aspect would rate distribution B strictly above distribution A.

impact level than unit C.[2] Note that the MCR itself is sensitive to the incidence and the intensity aspects of a citation distribution but fails to respond to distributional changes at either tail of a distribution that maintains the MCR constant. Instead, one of the key features of our approach is that different members of the FGT families of indicators successively incorporate the incidence, the intensity, and the citation inequality of the high- and low-impact aspects of the phenomena in question (See Albarrán *et al.*, 2009a for a full discussion of the properties possessed by the different approaches).

This paper uses a large sample acquired from Thomson Scientific (TS hereafter) consisting of 3,6 million articles published in 1998-2002, as well as the more than 28 million citations they received during a five-year citation window. We focus on the case in which homogeneous fields are identified with the 20 natural sciences and the 2 social sciences distinguished by TS. The paper contains two empirical exercises. Firstly, the high- and low-impact results obtained in Albarrán *et al.* (2009b) are compared with those obtained using exclusively the MCR. Secondly, the results using high- and low-impact indicators for different CCLs are compared with those obtained using the percentage of articles in the top 5% of highly-cited papers, as well as the percentage of articles with no citations at all. In both cases, ordinal and cardinal comparisons will be performed.

The rest of this paper is organized into three Sections. Section II introduces the FGT families of high- and low-impact indicators, as well as the type of comparisons that will be made in the empirical part of the paper. Section III presents the data and the empirical findings, while Section IV discusses the results and offers some conclusions.

II. NOTATION, DEFINITIONS AND METHODS

[2] Assume that the CCL is four, and consider two equal sized citation distributions C and D with the same number of high-impact articles. Assume also that two articles of unit C receive ten citations each, while those of unit D receive five and fifteen citations. A reasonable high-impact indicator that takes into account the citation inequality would rate unit D strictly above unit C.

II. 1. Notation

A discrete citation distribution of papers published in a given year is a non-negative vector $\boldsymbol{x} = (x_1, \ldots, x_i \ldots, x_n)$, where $x_i \geq 0$ is the number of citations received by the *i*-th article over a certain number of years since its publication date –a period known as the citation window. Given a distribution $\boldsymbol{x}$ and a positive CCL, $z > 0$, classify as low- or high-impact articles all papers with citation $x_i \leq z$, or $x_i > z$. Denote by $n(\mathbf{x})$ the total number of articles in the distribution, and by $l(\mathbf{x}; z)$ and $h(\mathbf{x}; z) = n(\mathbf{x}) - l(\mathbf{x}; z)$ the number of low- and high-impact articles. A *low-impact index* is a real valued function L whose typical value $L(\mathbf{x}; z)$ indicates the low-impact level associated with the distribution $\boldsymbol{x}$ and the CCL z, while a *high-impact index* is a real valued function H whose typical value $H(\mathbf{x}; z)$ indicates the high-impact level associated with the distribution $\boldsymbol{x}$ and the CCL z.

II. 2. The FGT Family of Low- and High-impact Indicators

Given a citation distribution $\boldsymbol{x}$ and a CCL z, the FGT family of low-impact indicators, originally introduced in Foster *et al.* (1984) for the measurement of economic poverty, is defined by:

$$L_\beta(\mathbf{x}; z) = [1/n(\mathbf{x})]\ \Sigma_{i=1}^{l(\mathbf{x}; z)} (\Gamma_i)^\beta,\ 0 \leq \beta,$$

where $\Gamma_i = \max\{(z - x_i)/z, 0\}$ is the *normalized low-impact gap* for any article with x_i citations with $\Gamma_i \geq 0$ for low-impact articles, while $\Gamma_i = 0$ for high-impact articles. The class of FGT high-impact indicators is defined by

$$H_\beta(\mathbf{x}; z) = [1/n(\mathbf{x})]\ \Sigma_{i=l(\mathbf{x}; z)+1}^{n(\mathbf{x})} (\Gamma^*_i)^\beta,\ 0 \leq \beta,$$

Where $\Gamma^*_i = \max\{(x_i - z)/z, 0\}$ is the *normalized high-impact gap* with $\Gamma^*_i > 0$ for high-impact articles, while $\Gamma^*_i = 0$ for low-impact articles.[3]

[3] It should be observed that many common indices widely used in the income poverty literature, which in our context can be taken as low-impact indicators, are also functions of the normalized low-impact gaps (see footnote 18

It will be sufficient to understand the differences involved in the use of the members of these two classes for parameter values $\beta = 0$, 1, and 2. Firstly, note that the high- and low-impact indices obtained when $\beta = 0$ coincide with the proportion of high- or low-impact papers:

$$H_0(\boldsymbol{x}; z) = h(\boldsymbol{x}; z)/n(\boldsymbol{x}), \tag{1}$$

and

$$L_0(\boldsymbol{x}; z) = l(\boldsymbol{x}; z)/n(\boldsymbol{x}).$$

Of course, $H_0(\boldsymbol{x}; z) + L_0(\boldsymbol{x}; z) = 1$, so that if $H_0(\boldsymbol{x}; z)$ changes, then $L_0(\boldsymbol{x}; z)$ must change in the opposite direction.

Secondly, consider the high-impact index corresponding to the parameter value $\beta = 1$, or the *per-article high-impact gap ratio*:

$$H_1(\boldsymbol{x}; z) = [1/n(\boldsymbol{x})]\, \Sigma_{i = l(\boldsymbol{x}; z) + 1}^{n(\boldsymbol{x})}\, \Gamma^*_i.$$

This convenient high-impact indicator represents the surplus of citations actually received by high-impact articles above the CCL. Similarly, the member of the FGT family of low-impact indicators for $\beta = 1$, or the *per-article low-impact gap ratio*, is equal to:

$$L_1(\boldsymbol{x}; z) = [1/n(\boldsymbol{x})]\, [\Sigma_{i = 1}^{l(\boldsymbol{x}; z)}\, \Gamma_i].$$

This low-impact indicator represents the minimum number of citations required to bring all low-impact articles to the CCL. Denote by $\mu_H(\boldsymbol{x})$ and $\mu_L(\boldsymbol{x})$ the MCR of high- and low-impact articles. It can be shown that $H_1(\boldsymbol{x}; z) = H_0(\boldsymbol{x}; z)H_I(\boldsymbol{x}; z)$ and $L_1(\boldsymbol{x}; z) = L_0(\boldsymbol{x}; z)L_I(\boldsymbol{x}; z)$, where

$$H_I(\boldsymbol{x}; z) = [1/h(\boldsymbol{x}; z)]\, \Sigma_{i = l(\boldsymbol{x}; z) + 1}^{n(\boldsymbol{x})}\, \Gamma^*_i = [\mu_H(\boldsymbol{x}) - z]/z,$$

and

$$L_I(\boldsymbol{x}; z) = [1/l(\boldsymbol{x}; z)]\, \Sigma_{i = 1}^{l(\boldsymbol{x}; z)} \Gamma_i = [z - \mu_L(\boldsymbol{x})]/z.$$

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in Albarrán *et al.*, 2009a). Furthermore, it is not difficult to convert low-impact indices into high-impact ones as we have done for the original FGT family.

The indices H_1 and L_1 are said to be monotonic in the sense that one more citation among high- or low-impact articles increases H_1 or decreases L_1. Therefore, while H_0 and L_0 only capture what has been referred to in the Introduction as the incidence of the high- and low-impact aspects of any citation distribution, H_1 and L_1 capture both the incidence and the intensity of these phenomena.

Thirdly, the high- and low-impact members of the FGT families obtained when $\beta = 2$ can be expressed as:

$$H_2(\boldsymbol{x}; z) = H_0(\boldsymbol{x}; z)\{[(H_1(\boldsymbol{x}; z)]^2 + [1 - H_1(\boldsymbol{x}; z)]^2 (\mathrm{C_H})^2]\},$$

$$L_2(\boldsymbol{x}; z) = L_0(\boldsymbol{x}; z)\{[(L_0(\boldsymbol{x}; z)]^2 + [1 - L_1(\boldsymbol{x}; z)]^2 (\mathrm{C_L})^2]\},$$

where $(\mathrm{C_H})^2$ and $(\mathrm{C_L})^2$ are the squared coefficient of variation (that is, the ratio of the standard deviation over the mean) among the high- and low-impact articles, respectively. In so far as $\mathrm{C_H}$ and $\mathrm{C_L}$ are two measures of citation inequality, H_2 and L_2 simultaneously cover the incidence, the intensity, and the citation inequality aspects of the high- and low-impact phenomenon they measure.

II. 3. Comparisons Between Geographical Areas Using FGT Indicators

Recall from Albarrán *et al.* (2009a) that the FGT family of high-impact indicators is decomposable in the sense that, given a CCL z and a given parameter value β, the overall high-impact measure for any field with citation distribution $\boldsymbol{x}$ can be expressed as:

$$H_\beta(\boldsymbol{x}; z) = \Sigma_k\ \omega_k\ H_\beta(\boldsymbol{x}^k; z),$$

where $H_\beta(\boldsymbol{x}^k; z)$ is the high-impact index value for area k = U.S., EU, RW, and ω_k is the area's publication share in the field. Similarly, the overall low-impact measure can be expressed as:

$$L_\beta(\boldsymbol{x}; z) = \Sigma_k\ \omega_k\ L_\beta(\boldsymbol{x}^k; z),$$

where $L_\beta(\boldsymbol{x}^k; z)$ is the low-impact index value for area k. To interpret the results below adequately, it is important to make it explicit that, from a normative point of view, for any area k it is preferable to have a high $H_\beta(\boldsymbol{x}^k; z)$ and a low $L_\beta(\boldsymbol{x}^k; z)$.

In order to quantify the relative situation of any area, it is convenient to refer to the ratio $\omega_k H_\beta(x^k; z)/H_\beta(\boldsymbol{x}; z)$ as area k's observed contribution (OC hereafter) relative to the overall high-impact level for that β. We may ask: what is this area's relative expected contribution (EC hereafter) to that level? Clearly, its publication share ω_k. Thus, the ratio OC/EC = $H_\beta(\boldsymbol{x}^k; z)/H_\beta(\boldsymbol{x}; z)$ is greater than, equal to, or smaller than one as area k OC is greater than, equal to, or smaller than this area EC, namely its publication share ω_k. Similarly, the ratio $L_\beta(\boldsymbol{x}^k; z)/L_\beta(\boldsymbol{x}; z)$ is greater than, equal to, or smaller than one as area k OC is greater than, equal to, or smaller than area k EC, or ω_k.

II. 4. Comparisons With the MCR

The results obtained with our approach in Albarrán *et al.* (2009b) will be first compared with those obtained using only the MCR. We distinguish between ordinal and cardinal comparisons. Among ordinal comparisons, the following two will be examined. Firstly, we say that the MCR can be considered a good *ordinal indicator of scientific performance across geographical areas* for some parameter value β and CCL z if for any two areas k and l we have that

$$MCR(\boldsymbol{x}^k) > MCR(\boldsymbol{x}^l) \Rightarrow H_\beta(\boldsymbol{x}^k, z) > H_\beta(\boldsymbol{x}^l, z) \text{ and } L_\beta(\boldsymbol{x}^k, z) < L_\beta(\boldsymbol{x}^l, z). \qquad (2)$$

That is, if area k has a greater MCR, then it must have a greater high-impact level and a smaller low-impact level than area l. In the empirical Section III we will test if expression (2) is the case for parameter values $\beta = 0, 1, 2$, and when the CCL is fixed in each field at the 80th percentile of the world citation distribution.

Secondly, it is also interesting to compare the ranking of fields in a geographical area according to our indicators and the MCR. Of course, in the heterogeneous case, $MCR(\mathbf{x_i}^{\mathbf{k}})$ and $MCR(\mathbf{x_j}^{\mathbf{k}})$ are not directly comparable for fields i and j. However, it is meaningful to compare the relative indicators $MCR(\mathbf{x_i}^{\mathbf{k}})/MCR(\mathbf{x_i})$ and $MCR(\mathbf{x_j}^{\mathbf{k}})/MCR(\mathbf{x_j})$. On the other hand, since the high- and low-impact indicators capture aspects of the shape of citation distributions independently of the size and the scale of the distributions in question, the high-impact indicators $H_\beta(\mathbf{x_i}^k;\ z_i)$ and $H_\beta(\mathbf{x_j}^k;\ z_j)$ are comparable across fields (for a full discussion of the heterogeneous case see Section IV in Albarrán *et al.*, 2009a). Therefore, it is said that the MCR for a given area k is a good *ordinal indicator of scientific performance across fields* for some parameter value β if for some fields i and j and CCLs z_i and z_j we have that

$$MCR(\mathbf{x_i}^{\mathbf{k}})/MCR(\mathbf{x_i}) > MCR(\mathbf{x_j}^{\mathbf{k}})/MCR(\mathbf{x_j}) \Rightarrow$$

$$H_\beta(\mathbf{x_i}^k; z_i) > H_\beta(\mathbf{x_j}^k; z_j) \text{ and } L_\beta(\mathbf{x_i}^k; z_i) < L_\beta(\mathbf{x_j}^k; z_j). \quad (3)$$

That is, if area k has a greater mean ratio in field i than in field j, then it must have a greater high-impact level and a smaller low-impact index in field i than in field j. We will test expression (3) for the three areas when $\beta = 2$ and the CCL is fixed in each field at the 80th percentile.

From a cardinal point of view, one might be tempted to take $MCR(\mathbf{x}^{\mathbf{k}})$ as a high-impact indicator satisfying the monotonicity property according to which one more citation is always desirable. However, such MCR is computed for all articles in area k, and not only for those in the high-impact set. Therefore, a comparison between $MCR(\mathbf{x}^{\mathbf{k}})$ and $H_\beta(\mathbf{x}^k; z)$ for all areas in a given field would do little justice to the mean-based indicator. Fortunately, note that the mean citation rate of a field as a whole, $MCR(\mathbf{x})$, is also decomposable in the sense that

$$MCR(\mathbf{x}) = \Sigma_k\ \omega_k\ MCR(\mathbf{x}^{\mathbf{k}}),$$

where $MCR(\mathbf{x}^k)$ is the mean citation rate in area k. Thus, the ratio $MCR(\mathbf{x}^k)/MCR(\mathbf{x})$ is greater than, equal to, or smaller than one as area k OC to the world MCR is greater than, equal to, or smaller than area k EC to that magnitude, that is, ω_k. Hence, it is directly comparable with the ratio $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$. This will be done for values $\beta = 0, 1, 2$ when the CCL is fixed in each field at the 80th percentile of the world citation distribution.

II. 5. Comparisons With Other Indicators in the Leiden Triad

It remains to explore the possibility of completing the MCR, as is done in the Leiden triad, with the percentage of articles in the top 5% of highly-cited ones and the percentage of articles with no citations at all.

Given the citation distribution of a homogeneous field, $\mathbf{x}$, let $p_5(\mathbf{x})$ and $p_5(\mathbf{x}^k)$ be the percentage of articles in the top 5% for the entire distribution and for area k, respectively. For comparative purposes with $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$, the ratio $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ can be computed. One interesting option is to fix the CCL at the 95th percentile, and compare $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ with $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$. Taking into account equation (1), it can be seen that in this case $p_5(\mathbf{x}) = H_0(\mathbf{x}; z)$, and $p_5(\mathbf{x}^k) = H_0(\mathbf{x}^k; z)$, so that any discrepancy between $p_5(\mathbf{x}^k)/p_5(\mathbf{x}) = H_0(\mathbf{x}^k; z)/H_0(\mathbf{x}; z)$ and $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ can be unambiguously attributed to the fact that H_0 does not take into account the intensity and the inequality aspects of the high-impact phenomenon. Since it might be interesting to include comparisons between the two approaches for different CCLs, in Section III $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ will be compared with $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ when z is fixed both at the 95th and the 80th percentile.

Similarly, let $p_0(\mathbf{x})$ and $p_0(\mathbf{x}^k)$ be the percentage of uncited articles for the entire distribution and for area k. For comparative purposes with $L_\beta(\mathbf{x}^k; z)/L_\beta(\mathbf{x}; z)$, the ratio $p_0(\mathbf{x}^k)/p_0(\mathbf{x})$ can be computed. In Section III, $p_0(\mathbf{x^k})/p_0(\mathbf{x})$ will be compared with $L_2(\mathbf{x^k}; z)/L_2(\mathbf{x}; z)$ when z is fixed both at the 95th and the 80th percentile.

III. EMPIRICAL RESULTS

III. 1. The Data

In this paper, only research articles or, simply, articles are studied. The key assumption that permits the linkage between theoretical concepts and the data is the identification of the 20 natural sciences and the two social sciences distinguished by TS with the homogeneous fields defined in the Introduction. After the elimination of observations with missing values for some variables, this paper refers to 3,654,675 articles published in 1998-2002 with a five-year citation window. Articles are assigned to geographical areas according to the institutional affiliation of their authors as recorded in the TS database on the basis of what had been indicated in the by-line of the publications. In any field, an article might be written by one or more scientists working in only one of the three geographical areas, or it might be co-authored by scientists working in two or three of them. In every internationally co-authored article a whole count is credited to each contributing area. Finally, as indicated in Section II this paper studies the cases where the CCL in each field is fixed at the 80th or the 95th percentiles of the world citation distribution.[4]

The information about the ratios $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$ and $L_\beta(\mathbf{x}^k; z)/L_\beta(\mathbf{x}; z)$ for every k, every field, and every β in the two FGT families of high- and low-impact indicators when the CCL is equal to the 80th percentile is in Tables B.1 and B.2 in the Appendix of Albarrán *et al.* (2009b). The information for every k and every field about the ratios $MCR(\mathbf{x^k})/MCR(\mathbf{x})$, $p_5(\mathbf{x^k})/p_5(\mathbf{x})$ and $p_0(\mathbf{x^k})/p_0(\mathbf{x})$ that we associate with the Leiden triad is in Table 1.

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[4] See Albarrán *et al.* (2009b) for some descriptive statistics about the number of articles and publication shares by authorship type (Table 1), the classification of articles by scientific field and geographical area (Table 2), and the absolute number of citations at the CCL in every field, the multiple of the mean that this number represents, and the percentage of the total number of citations received by the high-impact articles in each case (Table 3).

Table 1 around here

III. 2. A Comparison of FGT Indicators and MCRs

Starting with ordinal comparisons, consider the testing of expression (2) in Section II.4:

$$MCR(\mathbf{x^k}) > MCR(\mathbf{x^l}) \Rightarrow H_\beta(\mathbf{x}^k, z) > H_\beta(\mathbf{x}^l, z) \text{ and } L_\beta(\mathbf{x}^k, z) < L_\beta(\mathbf{x}^l, z). \quad (2)$$

To learn about the ranking of areas in every field with the information in Table 1, note that for any two areas *k* and *l* within the same field we have that

$$MCR(\mathbf{x^k})/MCR(\mathbf{x}) > MCR(\mathbf{x^l})/MCR(\mathbf{x}) \Rightarrow MCR(\mathbf{x^k}) > MCR(\mathbf{x^l}).$$

The ranking of areas in Table 1 according to the MCR is always the same in all fields: the U.S. above the EU, and the latter above the RW. However, as we saw in Section III.1 in Albarrán *et al.* (2009b), when the CCL is fixed at the 80th percentile and all values of β =0, 1, 2 are considered, the implication (2) is not satisfied on only two occasions: in Immunology the EU has a lower high-impact level than the RW according to H_2, and in Engineering the U.S. has a greater low-impact level than the EU according to L_2.[5] Since both cases arise for indicators responsive to distributional considerations, it is not surprising that the MCR approach fails to register the same order. It can be concluded that, except for these two instances, when there are only three areas under contention the MCR behaves as a good ordinal indicator of scientific performance.

Next, consider the testing of expression (3) in Section II.4:

$$MCR(\mathbf{x_i^k})/MCR(\mathbf{x_i}) > MCR(\mathbf{x_j^k})/MCR(\mathbf{x_j}) \Rightarrow$$

$$H_\beta(\mathbf{x_i}^k; z_i) > H_\beta(\mathbf{x_j}^k; z_j) \text{ and } L_\beta(\mathbf{x_i}^k; z_i) < L_\beta(\mathbf{x_j}^k; z_j). \quad (3)$$

Given a CCL equal to the 80th percentile of the corresponding world citation distribution, let us choose one member of each of the two FGT families of indicators; it seems preferable to select the one with the best properties, namely the one that captures the incidence, the intensity, and the citation inequality, that is when β = 2. Then, expression (3) can be tested using a non-parametric

[5] The Immunology and the Engineering cases are illustrated in Figures 1 and 3 below.

statistic of the degree of correspondence between two rankings (such as Kendall's tau or Spearman's coefficient), as well as a linear correlation coefficient such as Pearson's. The results are mixed. In the high-impact case, it is found that the ratio $MCR(\mathbf{x}_i^k)/MCR(\mathbf{x}_i)$ constitutes an acceptable ordinal indicator across fields only in the U.S. case, where the Kendall, Spearman, and Pearson coefficients are 0.52, 0.71, and 0.46 (all of them statistically significant), and less so in the EU, where these coefficients are 0.29, 0.43, and 0.21 (although the latter is not significant). In the low-impact case these coefficients are far from being statistically significant (only for the RW a marginally significant negative relationship can be found in a couple of cases).

Next, the comparison between the ratios $MCR(\mathbf{x}^k)/MCR(\mathbf{x})$ and $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$ when z = 80th percentile of the world citation distribution in each field is illustrated in Figure 1. In each field and each area, the three bars in Figure 1 reflect the ratios $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$ for $\beta = 0, 1,$ and 2; the red color is for the U.S., blue for the EU, and green for the RW. The ratios $MCR(\mathbf{x}^k)/MCR(\mathbf{x})$ appear as a horizontal black line for each of the three areas. As indicated in Albarrán *et al.* (2009b), considering only the percentages of high-impact articles ($\beta = 0$), or adding up the aggregate citation gap between high-impact articles and the CCL ($\beta = 1$), or including the effect of distributional considerations ($\beta = 2$) generates important differences in all areas. Specifically, the relative scientific performance of the U.S. with respect to the high-impact characteristics of citation distributions is essentially reinforced for all sciences as β increases. The opposite is the case for the RW, while for the EU the results are more mixed: except for some important exceptions, the high-impact performance of the EU leaves much to be desired as β increases.

Figure 1 around here

In this scenario, Figure 1 clearly illustrates that judging the U.S. relative situation in terms of the mean-based indicator would seriously underestimate the results obtained using the high-impact indicators, especially in the case of H_2. For concreteness, columns 1 to 3 in Table 2 present the numerical differences between $H_\beta(\mathbf{x}^k; z)/H_\beta(\mathbf{x}; z)$, when $\beta = 2$ and z = 80th percentile of the citation distribution in every field, and $MCR(\mathbf{x}^k)/MCR(\mathbf{x})$. The discrepancies in the U.S. amount to a percentage between 8% and 20% in ten fields, between 20% and 30% in nine fields, and between 30% and 40% in the remaining three fields. The underestimation is of a smaller order of magnitude for four fields in the EU and two fields –Immunology and Computer Science– in the RW. However, the relative situation of the EU would be overestimated in 11 fields by a relatively small percentage below 20%, and by a rather large margin above 22% in seven fields. Finally, the ratio $MCR(\mathbf{x}^k)/MCR(\mathbf{x})$ would present the RW in a much more favorable position than the ratio $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ in as many as 20 fields.

From a cardinal point of view, the conclusion is that using only the MCR generates a very different solution from our approach to the evaluation problem. In the next Sub-section, we investigate the consequences of using the remainder of the Leiden indicators.

Table 2 around here

III. 3. A Comparison of FGT Indicators and Other Leiden Indicators

Figure 2 illustrates the comparison between the percentage of the top 5% of most highly-cited articles in each area, $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$, and the ratio $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ when z is fixed at the 80th and the 95th percentile of the world citation distribution in each field. The ratios $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ for the two CCLs are depicted as the left- and the right-handed bars in each area, while the ratio $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ appears as the horizontal black line in each case. In the first place, as indicated in Albarrán *et al.* (2009b), note that, with some exceptions, the impact of this change on the relative positions of the three geographical areas is relatively small.[6] In the second place, the

[6] For example, the relative situation of the U.S. improves in 17 cases as the CCL is raised. However, it turns out that only in nine fields do these increases represent more than 15% of the level that the U.S. already achieves when the CCL is fixed at the 80th percentile.

relative situation of the U.S. when the ratio $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ is considered improves in only three fields (Pharmacology and Toxicology, Chemistry, and Space Science), and remains essentially constant in four cases (Immunology, Computer Science, Geosciences, and Economics and Business). Thus, as before, Figure 2 illustrates that in a majority of cases judging the U.S. relative situation in terms of the $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ ratio would underestimate the results obtained using the high-impact indicator $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$. However, the order of magnitude of such reductions is rather moderate. To see this, columns 4 to 6 in Table 2 present the differences between $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ and $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ in every area and in every field when z = 95th percentile. The worsening of the U.S. situation is below 10% in seven fields, and above this percentage in only 12 cases. The relative position of the EU would be overestimated in fewer fields than before, and by a smaller margin (in 11 cases below 20%, and in seven above that percentage). In the RW, the relative situation of Immunology and Computer Science is still better according to H_2, about the same in Space Science, and it remains overestimated by the ratio $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ in the remaining 19 fields but by a smaller margin than in column 3.

Figure 2 around here

On the other hand, we find some similarities between $p_5(\mathbf{x}^k)/p_5(\mathbf{x})$ and $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ as ordinal indicators across fields. But we cannot conclude that a strong correspondence between them exists. Using $H_2(\mathbf{x}^k; z)/H_2(\mathbf{x}; z)$ with z = 95th percentile, a moderately positive rank correlation for the US and the EU is found. In particular, for the two areas Kendall's tau coefficients are 0.49 and 0.45 and Spearman's coefficients are 0.65 and 0.55 (all of them statistically significant). However, the Kendall and Spearman coefficients are 0.30 and 0.35 and only marginally significant (p-value = 0.11) for the Rest of World. Moreover, all the Pearson linear correlation coefficients are insignificant.

Finally, Figure 3 illustrates the comparison between the percentage of the uncited articles in each area, $p_0(\mathbf{x^k})/p_0(\mathbf{x})$, and the ratio $L_2(\mathbf{x^k}; z)/L_2(\mathbf{x}; z)$ when the CCL in each field is fixed at the 80th and the 95th percentile of the world citation distribution. As in Figure 2, the ratios $L_2(\mathbf{x^k}; z)/L_2(\mathbf{x}; z)$ are depicted as the left- and the right-handed bars in each area, while the ratio $p_0(\mathbf{x^k})/p_0(\mathbf{x})$ appears as the horizontal black line in each case. Also, the differences in every area between $L_2(\mathbf{x^k}; z)/L_2(\mathbf{x}; z)$, when z = 80th percentile, and $p_0(\mathbf{x^k})/p_0(\mathbf{x})$ are in columns 7 to 9 in Table 2.

Figure 3 around here

Note that the change in the CCL has a minimal impact on the relative positions of all areas in every field: only the RW tends to improve somewhat, while the U.S. tends to slightly worsen as the CCL is raised. In any case, the ranking of areas in terms of their contribution to world low-impact levels places the U.S. in the first place, then the EU, and finally the RW in 17 cases; in three fields there is a draw between the U.S. and the EU in first place (Mathematics, Plant and Animal Science, and Geosciences), while in two cases the UE is slightly ahead of the U.S. (Engineering, and Environmental and Ecology). Interestingly enough, this is exactly the ranking obtained with the ratio $p_0(\mathbf{x^k})/p_0(\mathbf{x})$. Finally, from a quantitative point of view, the more remarkable fact is that according to the percentage of articles without citations the RW is worse off than according to the low-impact indicator. The EU and, above all, the U.S. are correspondingly better off according to the percentage of uncited articles. Quantitative differences in Table 2 are greater than 20%, approximately, in six fields for the RW, four fields for the U.S., and two fields for the EU.

In this case, the divergences between $p_0(\mathbf{x^k})/p_0(\mathbf{x})$ and $L_2(\mathbf{x^k}; z)/L_2(\mathbf{x}; z)$ as ordinal indicators across fields are larger than before. We only find a statistically significant correlation between them for the U.S., where Kendall's, Spearman's and Pearson's coefficients are 0.44, 0.36

and 0.45. For the EU and the Rest of the World, these correlations are clearly insignificant in all cases.

In brief, completing the mean-based indicator with the percentage of articles in the top 5% in this particular dataset worsens the relative situation of the U.S. and brightens that of the RW and, on most occasions, that of the EU. On the other hand, using the percentage of articles without citations worsens the relative situation of the RW and improves that of the U.S. The discrepancies for geographical areas in many fields have a considerable order of magnitude.

IV. CONCLUSIONS

Albarrán *et al.* (2009a) introduced a novel methodology for the evaluation of citation distributions in terms of a pair of high- and low-impact indicators. Albarrán *et al.* (2009b) applied this approach to a situation in which the world is partitioned into the U.S., the EU, and the RW using a large sample that covered the 22 broad scientific fields distinguished by TS. This paper has compared the results in the latter paper with those obtained with alternative methodologies.

We have first examined how far we can go using only the MCR. It turns out that the MCR is a good ordinal indicator of scientific performance when the task is the ranking of only three geographical areas in each field. However, it performs as an acceptable ordinal indicator across fields only for high-impact levels in the U.S. and low-impact levels in the RW. Furthermore, for a reasonable CCL fixed in every field at the 80th percentile of the world distribution, the cardinal differences between the results obtained with our high-impact indicator and the MCR are of a large order of magnitude: the discrepancies are greater than 20% half of the time. Consequently, in most fields the view according to both procedures is very different indeed. In particular, under the MCR criterion the U.S. situation systematically worsens, especially in Physics, Mathematics, and Materials Science. Correspondingly, in these three instances the situation in the other areas dramatically improves. In addition, the situation in the EU considerably improves in Economics and Business, and Computer Science, while the situation in the RW always improves except in Immunology and Computer Science.

These results are at variance with the more optimistic conjecture by Moed *et al.* (1995), which referes to relatively small research units within a field, according to whom "Preliminary results suggest that the mean of the distribution correlates rather well to other statistics of the distribution, such as the median, the percentage of papers not cited, and the 90th percentile." In our opinion, the important differences found between the two approaches serve to confirm that a mean-based indicator alone does not suffice to adequately represent what takes place in highly skewed citation distributions. This conclusion justifies the use of other, complementary indicators, such as those included in the Leiden triad.

On the one hand, it is true that the percentage of articles among the top 5% is an excellent ordinal indicator of what is achieved with high-impact indicators within every field. Similarly, in every field the percentage of articles without citations orders all areas exactly as our low-impact indicators do. When used as ordinal indicators across fields, in general both approaches produce reasonably similar rankings. However, our statistical analysis points to some important divergences on some occasions (in particular, for the comparisons of the rankings according to the percentage of uncited articles and our low impact indicator). More importantly, there are still large quantitative differences between the geographical areas' relative situation according to both approaches. In the first place, as with the MCR, when we use the percentage of articles in the top 5% the relative situation of the U.S. appears as much weaker than when we use a high-impact indicator that incorporates the incidence, the intensity, and the citation inequality aspects. Correspondingly, the relative situation of the EU and, above all, the RW appears reinforced. In almost one third of the cases the differences between the two approaches are greater than 20%, and there are distortions in about 13 of the 22 fields. In the second place, differences between the results obtained with the percentage of uncited articles or our low-impact indicator that incorporates the incidence, the intensity, and the citation inequality aspects are not that large:

differences are greater than 20% in only 16.5% of the cases, and there are serious distorsions in only six fields. The main impact of using the Leiden rather than the low-impact indicator is to exaggerate the bad situation of the RW.

In brief, this paper has shown that, from a cardinal point of view, for assessing the relative situation of only three areas, following the Leiden or the new approach makes a considerable difference.[7] As Moed *et al.* (1995) eloquently point out (after assessing research groups for many years using the MCR and the percentage of articles without citations), "An important step would in fact be to develop indicators of the impact of a group's very best articles, and compare the results to those obtained by applying the citation per publication ratio." This is indeed the step taken in important papers that have been already referred to, namely, Tijssen *et al.* (2002) and van Leeuwen *et al.*, (2003). In our view, this is also the step that this paper has attempted to take by introducing high-impact indicators. The difference, of course, is that we have provided an integrated framework in which any citation distribution can be conveniently described by a pair of high- and low-impact indices whose properties appear to be useful in the empirical work. Thus, the question boils down to the following choice: what is preferable, to complete the MCR with percentage indicators of what happens at both tails of a citation distribution, or to use two high- and low-impact indices on the grounds advocated in this and our companion papers?

[7] Guerrero-Botes *et al.* (2010) compares both approaches for 41 countries and four residual regional areas, and for ten regions.

REFERENCES

Aksnes, D., and G. Sivertsen (2004), "The Effect of Highly Cited Papers on National Citation Indicators", *Scientometrics*, **59**: 213-224.

Albarrán, P., I. Ortuño, and J. Ruiz-Castillo (2009a), "The Measurement of Low- and High-impact in Citation Distributions: Technical Results", Working Paper 09-57, Economics Series 35, Universidad Carlos III.

Albarrán, P., J. Crespo, I. Ortuño, and J. Ruiz-Castillo (2009b), "High- and Low-impact Citation Measures: Empirical Applications", Working Paper 09-58, Economics Series 36, Universidad Carlos III.

Bornmann, L., R. Mutz, C. Neuhaus1, and H-D. Daniel (2008), "Citation Counts for Research Evaluation: Standards of Good Practice for Analyzing Bibliometric Data and Presenting and Interpreting Results", *Ethics in Science and Environmental Politics*, **18**: 93-102.

Foster, J.E., J. Greeer, and E. Thorbecke (1984), "A Class of Decomposable Poverty Measures", *Econometrica*, **52**: 761-766.

Glänzel, W. (2002), "Coauthorship Patterns and Trends in the Sciences (1980-1998): A Bibliometric Study with Implications for Database Indexing and Search Strategies", *Library Trends*, **50**: 461-473.

Guerrero-Botes, V., F. de Moya-Anegón, and J. Ruiz-Castillo (2010), "A Worldwide Ranking for 28 Scientific Fields Using Scopus Data, the SCImago Ranking of Journals, Mean Citation Rates and High- and Low-impact Indicators", mimeo.

Moed, H. F., W. J. Burger, J. G. Frankfort, and A. F. J. van Raan (1985), "The Use of Bibliometric Data for the Measurement of University Research Performance", *Research Policy*, **14**: 131-149.

Moed, H. F., and A. F. J. van Raan (1988), "Indicators of Research Performance", in A. F. J. van Raan (ed), *Handbook of Quantitative Studies of Science and Technology*, North Holland: 177-192.

Moed, H. F., R. E. De Bruin, and Th. N. van Leeuwen (1995), "New Bibliometrics Tools for the Assessment of National Research Performance: Database Description, Overview of Indicators, and First Applications", *Scientometrics*, **133**: 381-422.

Tijssen, R, M. Visser, and T. van Leeuwen (2002), "Benchmarking International Scientific Excellence: Are Highly Cited Research Papers an Appropriate Frame of Reference", *Scientometrics*, **54**: 381-397.

Van Leeuwen, T., M. Visser, H. Moed, T. Nederhof, and A, van Raan (2003), "The Holy Grail of Science Policy: Exploring and Combining Bibliometric Tools In Search of Scientific Excellence", *Scientometrics*, **57**: 257-280.

Table 1. The Contribution To MCRs, the Top 5% of Highly Cited Articles, and Articles With Zero Citations In Area k = U.S., EU, and RW*

(1) The Contribution To MCRs In Area k, $MCR(x^k)/MCR(x)$
(2) The Contribution To the Top 5% of Highly Cited Articles In Area k, $p_5(x^k)/p_5(x)$
(3) The Contribution To the Articles With Zero Citations In Area k, $p_0(x^k)/p_0(x)$

	UNITED STATES			EUROPEAN UNION			REST OF THE WORLD		
SCIENTIFIC FIELDS	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
LIFE SCIENCES									
Clinical Medicine	1.27	1.44	0.75	0.94	0.89	1.13	0.79	0.67	1.21
Biology & Biochemistry	1.33	1.58	0.56	0.97	0.88	0.87	0.74	0.60	1.57
Neuroscience & Behav. Science	1.24	1.48	0.60	0.95	0.86	1.11	0.77	0.58	1.46
Molecular Biology & Genetics	1.25	1.40	0.69	0.96	0.88	0.78	0.73	0.62	1.76
Psychiatry & Psychology	1.11	1.20	0.86	0.93	0.89	1.11	0.82	0.66	1.27
Pharmacology & Toxicology	1.28	1.61	0.92	1.04	1.03	0.95	0.79	0.59	1.12
Microbiology	1.30	1.61	0.53	1.02	0.95	0.80	0.73	0.55	1.73
Immunology	1.19	1.34	0.66	0.94	0.88	1.12	0.84	0.73	1.39
PHYSICAL SCIENCES									
Chemistry	1.51	2.04	0.59	1.10	1.04	0.69	0.75	0.59	1.38
Physics	1.43	1.69	0.74	1.09	1.11	0.90	0.76	0.63	1.26
Computer Science	1.34	1.54	0.87	0.93	0.86	1.01	0.77	0.65	1.14
Mathematics	1.25	1.45	0.87	1.06	1.06	0.90	0.78	0.67	1.20
Space Science	1.27	1.42	0.69	0.97	0.95	1.10	0.75	0.63	1.38
OTHER PH. SCIENCES									
Engineering	1.19	1.39	0.95	1.09	1.09	0.90	0.83	0.71	1.13
Plant & Animal Science	1.18	1.32	0.83	1.13	1.21	0.85	0.80	0.66	1.28
Materials Science	1.41	1.76	0.80	1.07	1.06	0.89	0.83	0.72	1.16
Geoscience	1.29	1.54	0.73	1.05	0.97	0.75	0.76	0.64	1.49
Environment & Ecology	1.15	1.35	0.92	1.05	0.99	0.86	0.83	0.71	1.26
Agricultural Sciences	1.26	1.45	0.74	1.15	1.21	0.78	0.75	0.60	1.37
Multidisciplinary	1.91	2.33	0.63	1.24	1.28	0.92	0.54	0.36	1.19
SOCIAL SCIENCES									
Social Sciences, General	1.11	1.24	0.94	0.95	0.84	1.01	0.78	0.59	1.17
Economics & Business	1.25	1.46	0.86	0.83	0.66	1.06	0.70	0.51	1.26

*** In Any Field and Any Column, A Cell Value is Greater, Equal, Or Smaller Than One When the Geographical Area Contributes To the Worldwide Level More, the Same, Or Less Than the Area's Publication Share In the Original Citation Distribution. The number Between Brackets Indicate the Column Ranking**

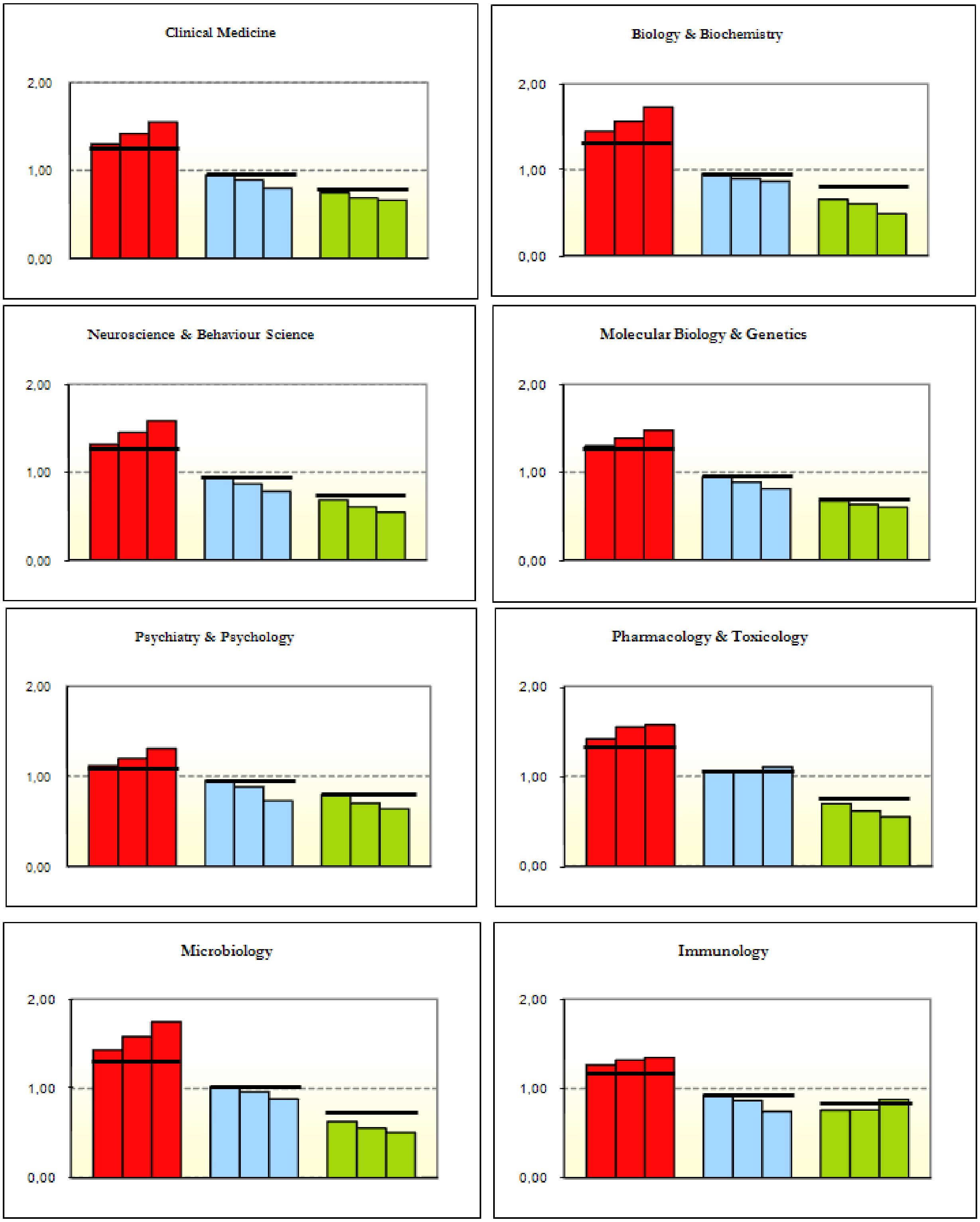
Table 2. The Contribution To MCRs, the Top 5% of Highly Cited Articles, and Articles With Zero Citations In Area k = U.S., EU, and RW

(1) Difference In % Between $H_2(x^k; z)/H_2(x; z)$ With CCL = 80th percentile and $MCR(x^k)/MCR(x)$
(2) Difference In % Between $H_2(x^k; z)/H_2(x; z)$ With CCL = 95th percentile and $p_5(x^k)/p_5(x)$
(3) Difference In % Between $L_2(x^k; z)/L_2(x; z)$ With CCL = 80th percentile and $p_0(x^k)/p_0(x)$

	UNITED STATES			EUROPEAN UNION			REST OF THE WORLD		
SCIENTIFIC FIELDS	(1) Diff. In %	(2) Diff. In %%	(3) Diff. In %	(1) Diff. In %	(2) Diff. In %%	(3) Diff. In %	(1) Diff. In %	(2) Diff. In %%	(3) Diff. In %
LIFE SCIENCES									
Clinical Medicine	18.1	9.0	**22,7**	-17.2	-15.4	-8.3	-20.3	-2.6	-7.1
Biology & Biochemistry	23.2	11.5	**42,7**	-12.7	-2.4	11.3	-51.9	-38.8	-26.5
Neuroscience & Behav. Science	21.8	11.5	26.6	-21.4	-18.1	-8.6	-41.4	-13.7	-22.1
Molecular Biology & Genetics	15.6	8.7	16.0	-18.0	-14.7	20.8	-22.0	-7.7	-42.1
Psychiatry & Psychology	14.7	12.7	7.5	-28.3	-46.3	-6.6	-28.0	-8.8	-13.3
Pharmacology & Toxicology	18.8	- 3.7	- 9.4	6.2	11.5	0.5	-44.3	-13.6	0.5
Microbiology	25.5	14.2	29.9	-15.4	-18.7	14.7	-44.5	-14.0	-35.9
Immunology	11.7	1.0	20.0	-26.0	-32.8	-7.6	4.2	26.0	-19.9
PHYSICAL SCIENCES									
Chemistry	24.2	- 5.6	17.4	5.9	15.7	19.0	-41.8	-15.8	-16.1
Physics	31.2	22.1	7.4	-12.8	-20.0	2.5	-34.3	-14.8	-10.5
Computer Science	16.5	4.3	1.8	-76.6	-69.1	0.1	16.7	30.6	-4.2
Mathematics	36.2	33.3	2.8	-31.2	-50.9	3.3	-44.2	-33.1	-6.5
Space Science	8.0	- 3.6	10.4	0.4	3.9	-8.3	-18.5	0.2	-13.7
OTHER PH. SCIENCES									
Engineering	26.4	20.7	- 1.4	-4.78	-9.0	3.7	-36.8	-29.1	-4.7
Plant & Animal Science	24.9	22.7	7.2	-4.80	-22.2	5.2	-33.6	-15.1	-11.9
Materials Science	37.9	29.9	5.2	-13.5	-19.0	3.8	-33.6	-26.6	-6.0
Geoscience	16.6	0.6	7.6	-6.6	1.8	16.3	-20.8	-3.2	-21.5
Environment & Ecology	24.2	17.5	- 0.1	-11.0	-9.8	7.4	-37.9	-33.2	-11.6
Agricultural Sciences	24.3	18.4	11.4	1.6	-2.9	8.9	-42.9	-30.5	-13.9
Multidisciplinary	24.0	9.8	9.4	-10.7	-22.3	-1.3	-62.7	-8.8	-2.8
SOCIAL SCIENCES									
Social Sciences, General	16.0	10.6	0.7	-28.0	-24.8	-0.8	-58.7	-40.6	-5.0
Economics & Business	16.7	4.2	3.7	-34.0	-7.7	0.0	-52.8	-17.7	-8.3

* In Any Field and Any Column, A Cell Value is Greater, Equal, Or Smaller Than One When the Geographical Area Contributes To the Worldwide Level More, the Same, Or Less Than the Area's Publication Share In the Original Citation Distribution. The number Between Brackets Indicate the Column Ranking

Figure 1. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th Percentile, According To Members of the FGT Family of High-impact Indicators When b = 0, 1, 2. Mean Citation Rates Appear As Black Horizontal Lines



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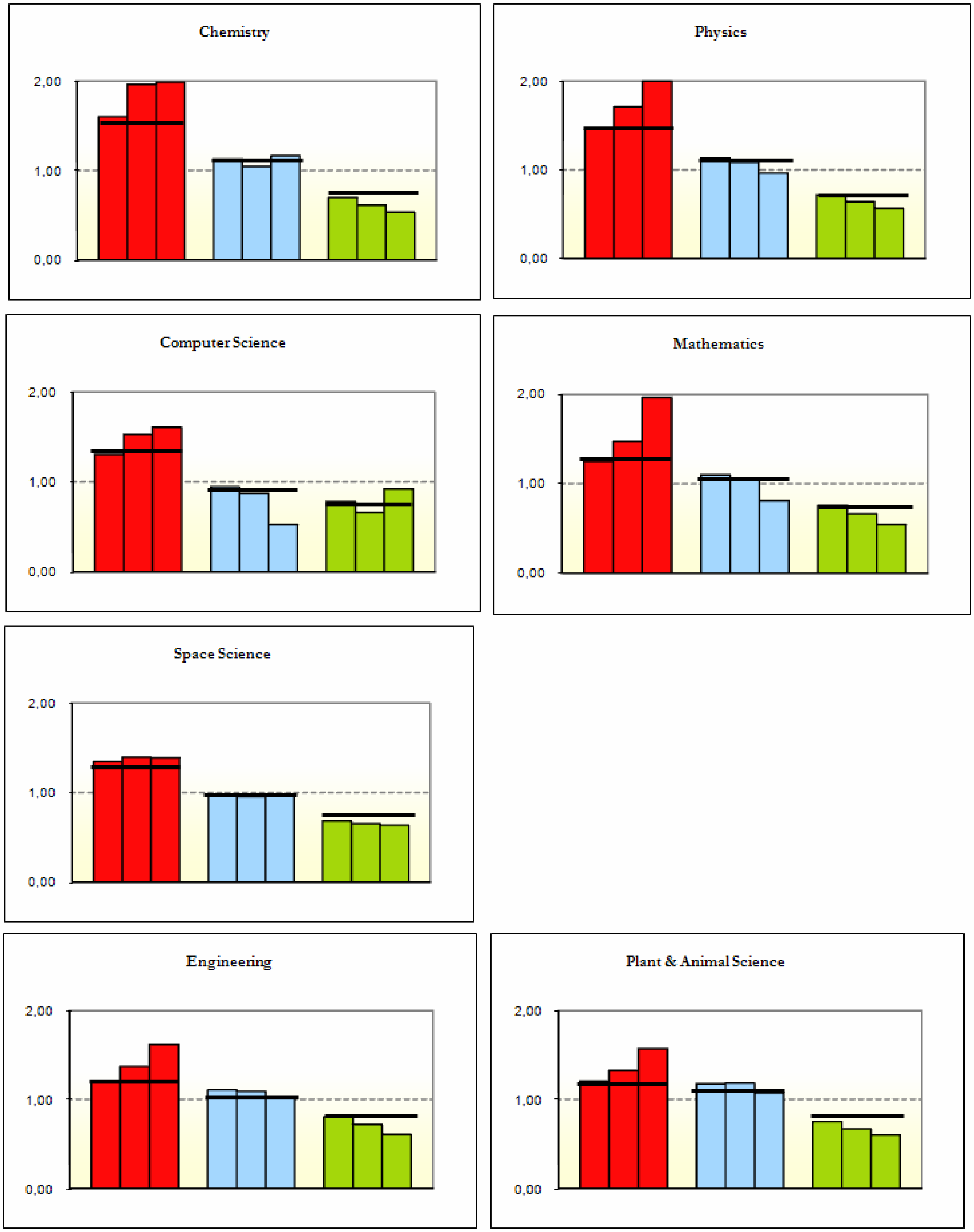

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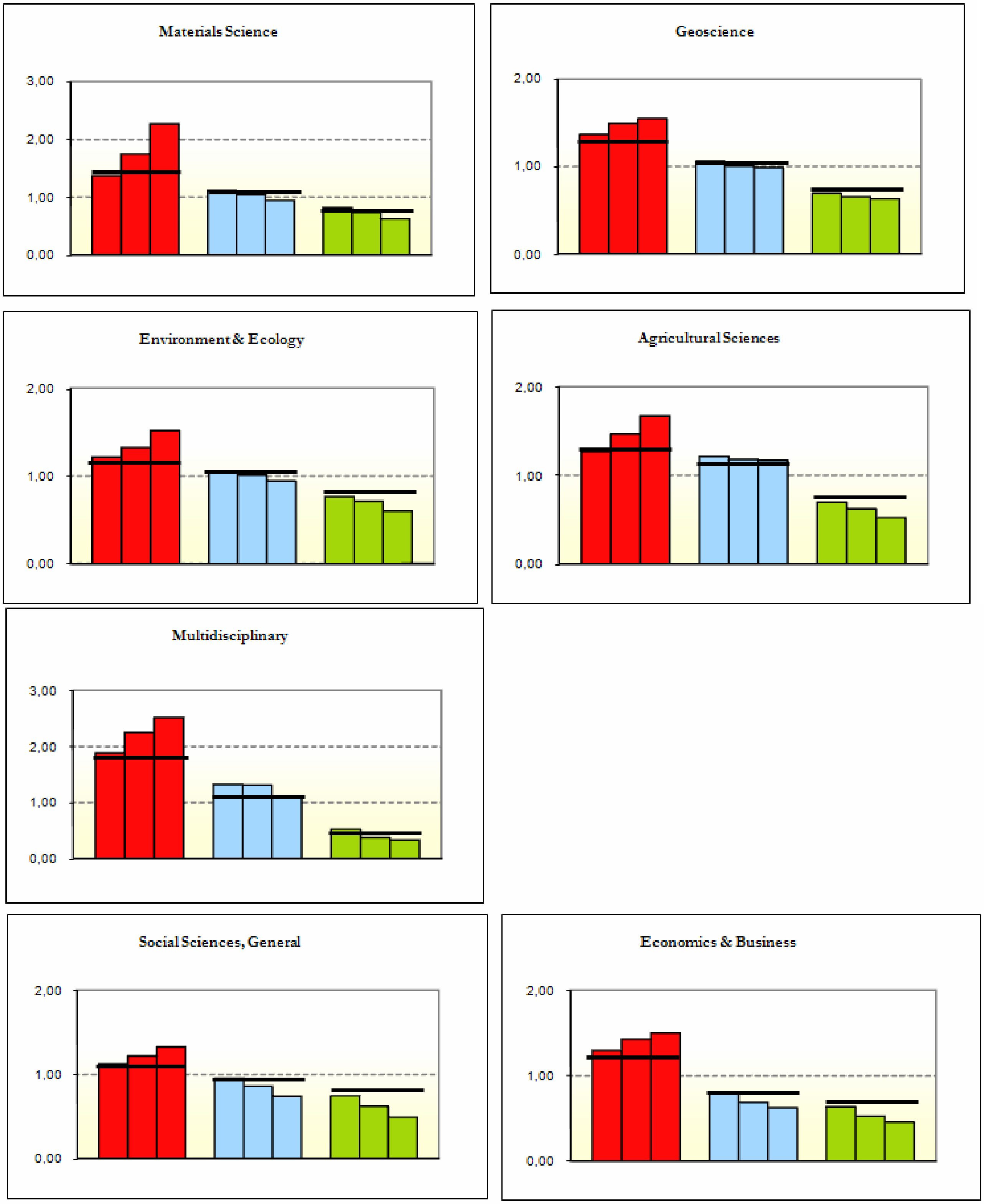

Figure 2. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the β = 2 Member of the FGT Family of High-impact Indicators. Shares of the Top 5% Appear As Black Horizontal Lines

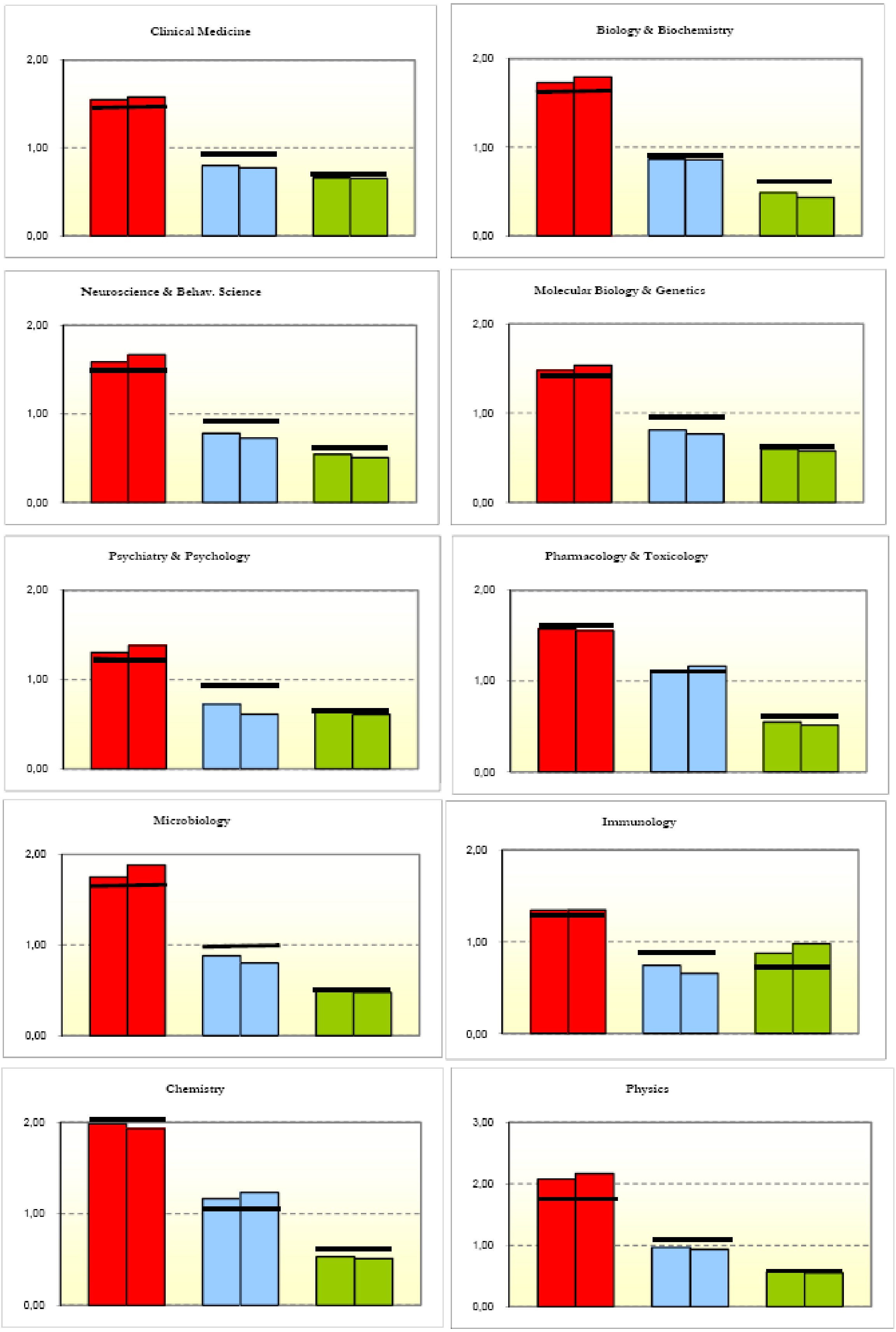

Figure 2. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the β = 2 Member of the FGT Family of High-impact Indicators. Shares of the Top 5% Appear As Black Horizontal Lines

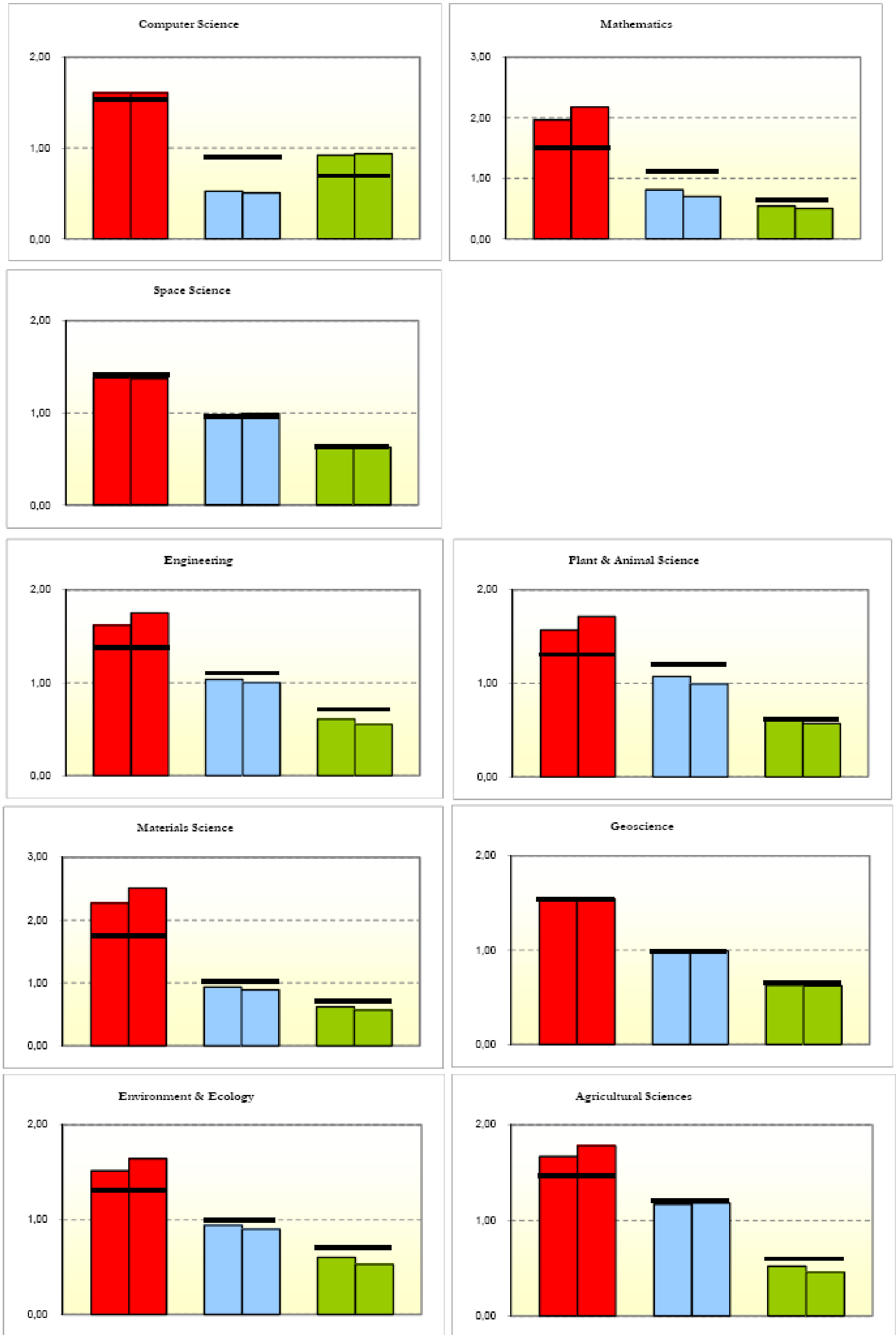

Figure 2. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the b = 2 Member of the FGT Family of High-impact Indicators. Shares of the Top 5% Appear As Black Horizontal Lines

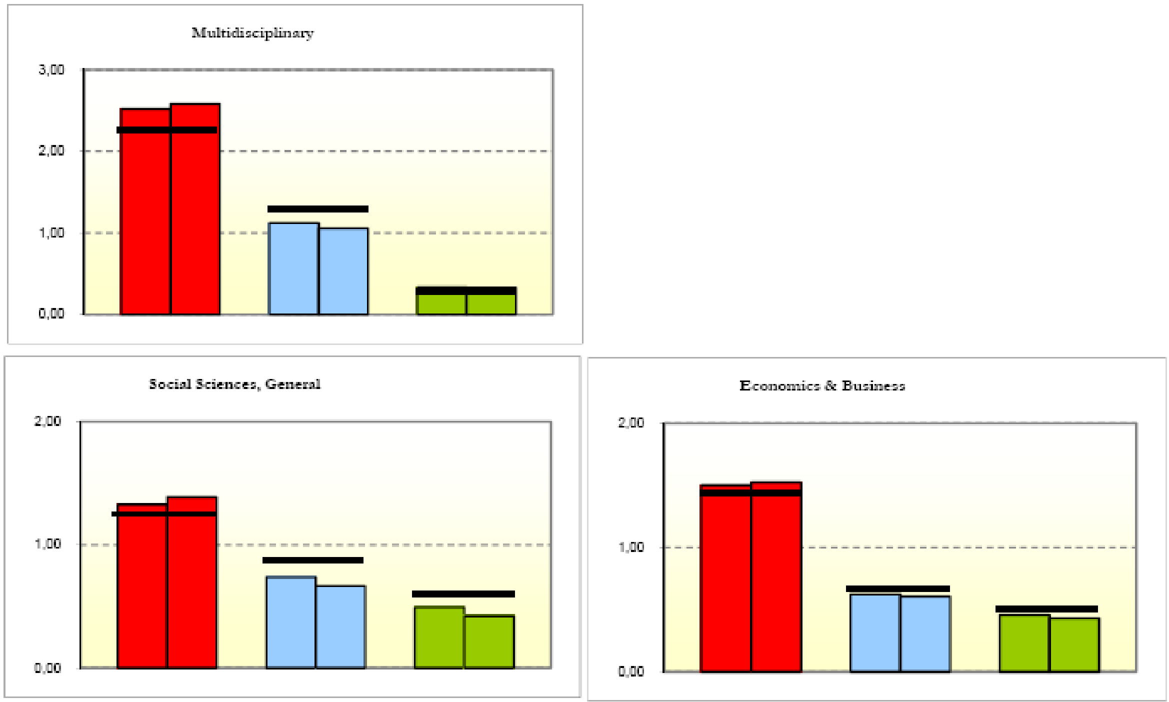

Figure 3. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the β = 2 Member of the FGT Family of High-impact Indicators. Shares of Uncited Articles Appear As Black Horizontal Lines

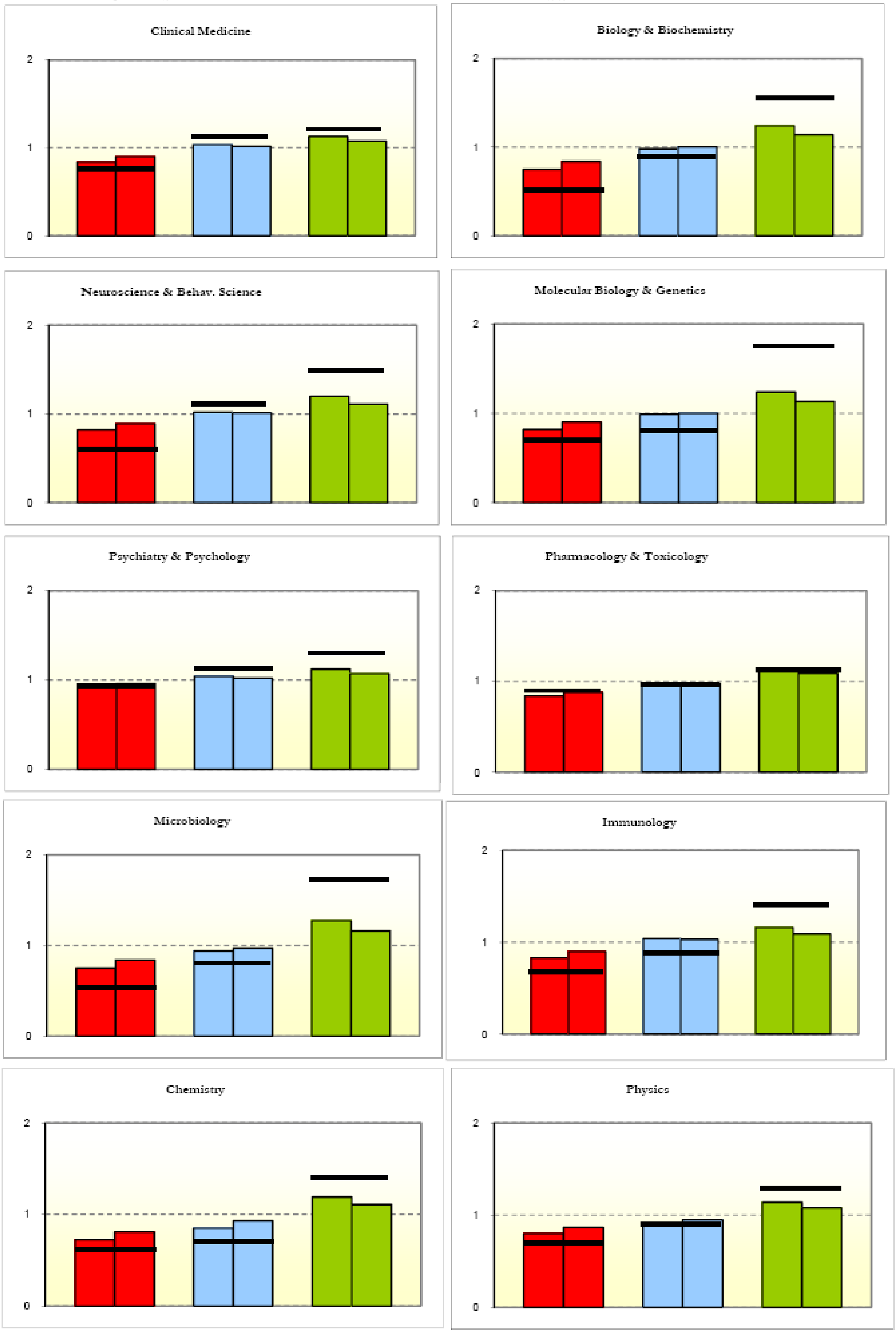

Figure 3. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the b = 2 Member of the FGT Family of High-impact Indicators. Shares of Uncited Articles Appear As Black Horizontal Lines

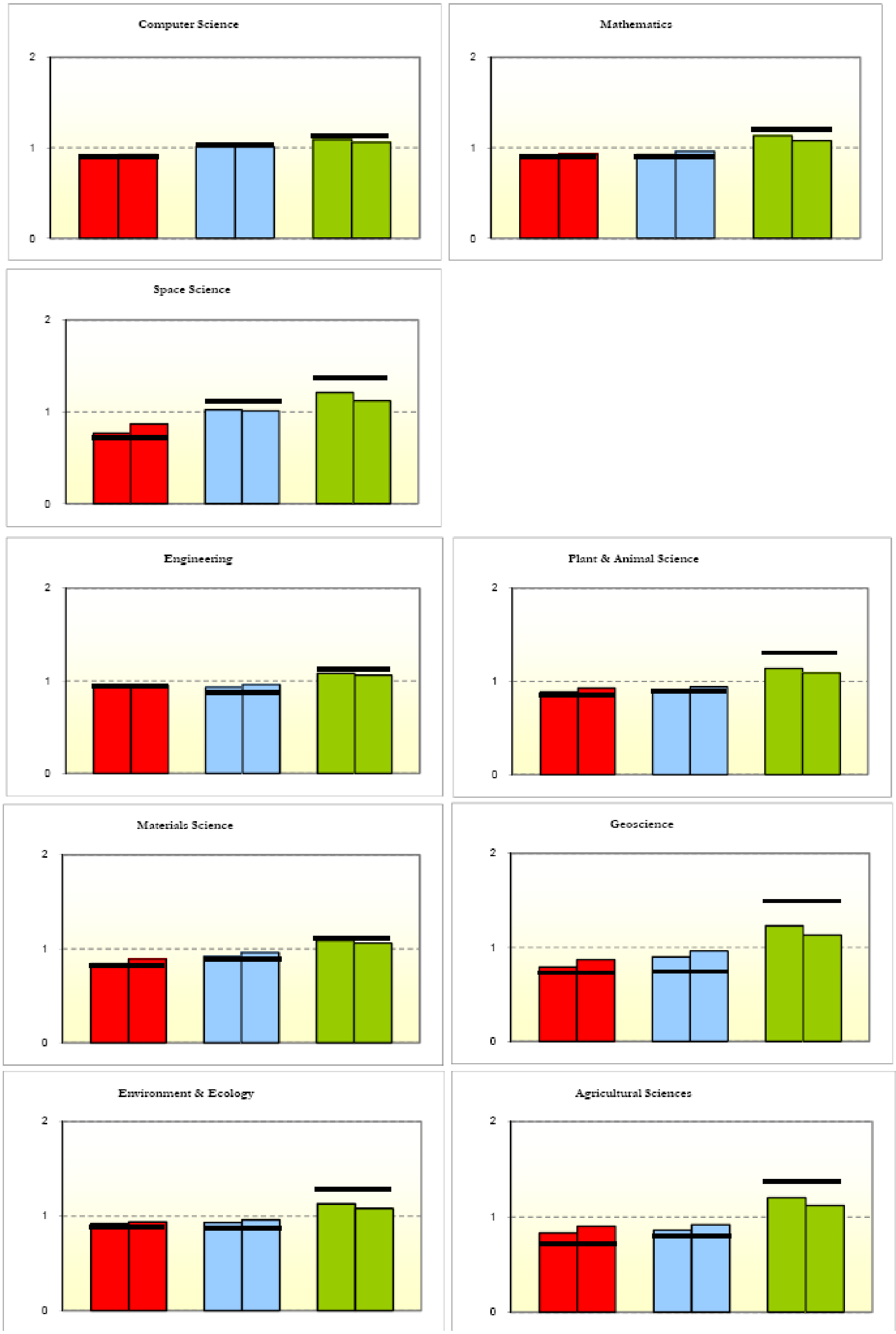

Figure 3. The Relative Contribution to World High-impact Levels By the U.S. (red), the EU (blue), and the RW (green) When the CCL Is Equal to the 80th and 95th Percentiles, According to the b = 2 Member of the FGT Family of High-impact Indicators. Shares of Uncited Articles Appear As Black Horizontal Lines