Journal of Informetrics 8 (2014) 642–649

Contents lists available at ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

Visualization of ranking data: Geographical signatures in international collaboration, leadership and research impact

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ARTICLE INFO

Article history:
Received 31 January 2014
Received in revised form 21 April 2014
Accepted 20 May 2014
Available online 17 June 2014

Keywords:
Institutional rankings
International collaboration
Research impact

ABSTRACT

In this work we address the comprehensive Scimago Institutions Ranking 2012, proposing a data visualization of the listed bibliometric indicators for the 509 Higher Education Institutions among the 600 largest research institutions ranked according to their outputs. We focus on research impact, internationalization and leadership indicators, which became important benchmarks in a worldwide discussion about research quality and impact policies for universities. Our data visualization reveals a qualitative difference between the behavior of Northern American and Western European Higher Education Institutions concerning International collaboration levels. Chinese universities show still a systematic low international collaboration levels which are positively linked to the low research impact. The data suggests that research impact can be related directly to internationalization only to rather low values for both indicators. Above world average, other determinants may become relevant in fostering further impact. The leadership indicator provides further insights to the collaborative environment of universities in different geographical regions, as well as the optimized collaboration portfolio for enhancing research impact.

1. Introduction

Bibliometric data constitute a primary set of information on which academic research in scientometrics relies, but also provide an important supply for the growing issue of the assessment of the research and development system in different countries. This accountability interests a broader audience, encompassing other academic groups, as well as authorities and policy makers in higher education. The main bibliometric databases are primarily used by all academic circles for bibliographic research, but an increasing offer of search tools within the databases has widened the possibility of an easy gathering of indicators leading to publication and citation rankings often handled without the necessary rigor. Indeed, a widespread familiarity with bibliographic data collections seems to validate such efforts, but concerns were raised against a practice of "use and abuse" of citation based indicators, which progressively influence higher education policies, even without

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http://dx.doi.org/10.1016/j.joi.2014.05.005
1751-1577/

proper statistical treatment, as suggested, for instance, in the Citation Statistics report from the International Mathematical Union. The issue here is to contribute in providing frameworks to handle these indicators.

A collateral effect of this situation is well illustrated by the growing importance given to university rankings, still strongly relying on the number of high impact published papers and their citations, as pointed out in the Global University Rankings and their Impact – Report II. Within the context alluded so far, this Report mention an advice by Thomson Reuters (provider of the Web of Science platform) that bibliometric data "should be processed and interpreted competently. Misinterpretation of data may have particularly adverse consequences in cases of the uninformed use of citation impact data, for example, in reliance on average citation data that masks huge differences in numbers counted over several years, or on average journal citation counts that result from just one article collecting thousands of citations in a journal, while others have just a single citation or none whatsoever" (Rauhvargers, 2013). The European report also warns that university strategies may the driven rather than informed by rankings mentioning, as an example, the issue of internationalization with incentives to form international multidisciplinary research teams (Rauhvargers, 2013).

The present paper focuses on the impact, international collaboration and scientific leadership indicators for Higher Education Institutions, objects of a growing number of works, like an analysis of research collaboration effects on university excellence in four world regions, authored by researchers related to SCImago, like (Benavent-Pérez, Gorraiz, Gumpenberger, & de Moya-Anegón, 2012). Also based on SCImago ranking is an analysis of the effect of the research profile of the universities and research institutions on the ranking (Bornmann, de Moya-Anegón, & Mutz, 2013). Considering visualization of data, one of the points addressed here, interesting works based on SCImago institutional rankings, is an analysis of aggregated research impact data for research institutions of different countries (Bornmann & de Moya-Anegón, 2011) and a more recent worldwide mapping of research institutions and universities based on high-impact papers (Bornmann, Stefaner, de Moya-Anegón, & Mutz, 2014). The issue of internationalization of the rapidly growing Chinese science is the object of several investigations in the past few years, as can be appreciated in from the references in the work by Xianwen Wang and collaborators (Xianwen, Shenmeng, Zhi, Lian, & Chuanli, 2013). Other authors focus on intra and extra European Union co-authorship patterns, calling the attention that internationalization is assumed as to have impact on the quality of the scientific output (Mattsson, Laget, Nilsson, & Sundberg, 2008).

Hence, a positive link between research performance and degree of internationalization of research is apparently becoming a hegemonic idea, but this relation has been viewed in both ways: international collaboration as enhancing research impact, as mentioned above, but also the other way around: it is the research productivity (and quality) that foster the degree of international collaboration (Abramo, D'Angelo, & Solazzi, 2011). Considering scientific collaboration, a further issue has to be addressed, namely the effect of the research guarantor on the impact of the output of the collaboration (de Moya-Anegón, Bote, Bornmann, Moed, 2013; de Moya-Anegón, López-Illescas, Moed, 2013).

Mappings of scientific collaboration at different levels (individuals, institutions and countries) has been, therefore, of growing concern and have also been addressed to policy makers and administrators interested in the progression of scientific collaboration (Gazni, Sugimoto, & Didegah, 2012).

In this scenario, providing a common analysis framework for both, scientometricians and policy makers, administrators and the public, is of growing relevance. A bridge between inner academic circles devoted to scientometrics and a broader audience are given by open access data collections provided by the groups responsible for the bibliometric data bases. In some cases, only featured rankings are offered, revealing publication outputs and their impact measured by citations. As an example, one could mention the country profiles and national science rankings released in Sciencewatch from Thomson Reuters since the end of the last century, on which country research profiles can be obtained (Schulz & Manganote, 2012).

More recently, SCImago Journal and Country Rankings, "a portal that includes the journals and country scientific indicators developed from the information contained in the Scopus® database", offers an interesting and interactive indicators platform, which can be used to "assess and analyze scientific domains" (http://www.scimagojr.com/aboutus.php). Another product, also offered by Scimago since 2009, is the SCImago Institutions Ranking (SIR). SIR is a ranking of research institutions, primarily listed by number of outputs, which progressively included more indicators in the successive editions. This rich metadata (Scimago, 2011), in the 2012 edition, assembles 3290 research institutions, discriminated in five sectors – higher education, health, government, private and others – indicating their location (country and region), ranked according to the number of outputs (total number of documents published in scholarly journals indexed in Scopus) covering a period of 2006–2010. The indicators presented for each institution are: international collaboration, normalized impact, high quality publications, specialization index, excellence rate and scientific leadership, according to definitions and proxies to be discussed below. The country of each institution is also assigned and classified into eight geographical regions: Africa (AF), Asia (AS), Eastern Europe (EE), Latin America (LA), Middle East (ME), Northern America (NA), Oceania (OC) and Western Europe (WE).

The purpose of the present work, based on the metadata contained in the 2012 SIR report, is to discuss the limitations, as well as world regional differences, in the relation among proxies for research impact and quality, scientific leadership and international collaboration beyond simply ranking. We propose visualization maps of these indicators at the institutional level, providing benchmarks for institutional strategies, recalling that, as stated in the SIR report, their target audience is formed by policymakers, research managers, researchers, media and general public interested in research performance.

2. Methodology

In this work we propose an analysis of bibliometric data as released in the SCI world report 2012. This report lists, as mentioned above, 3290 institutions that published at least 100 scientific documents during 2010, collected by the Scopus database. The total number of outputs, however, covers a five year period, 2006–2010, ranking the institutions by the number of outputs. We extract manually from the report the data corresponding the 600 most productive institutions, 509 being Higher Education institutions, on which the results presented here are based on, as discussed below. Within this list, the top address scores over 200,000 outputs, while the last one averages an output of 1000 documents per year. This lower threshold ensures that, since we are dealing with average indicators at the institutional level, discrepancies due to biases that could be introduced by, for instance, a particular highly productive and influential group in a specific field in a smaller institution.

The chosen set of institutions permits the building of indicators maps in which the reader can easily locate a particular institution of interest from the SIR. The institutions in the report are divided in five sectors: Higher education (HE, mainly universities), Health System (HL), Government Agencies (GO), Private Corporations (PR) and others (OT). The great majority are HE institutions (66.2%), followed by HL (18.1%) and GO (12.2%) in the 3290 list. Taking the top 600 institutions, the HE set shows an even more representative share (84.7%, corresponding to 509 institutions)), followed by GO (8.7%) and then by HL (5.8%). Hence, the top 600 group in the ranking provides an adequate set of data for the purpose of focusing on Higher Education, with 509 hits in this category. A discussion about the other kinds of institutions is delivered by (de Moya-Anegón, Bote, et al., 2013; de Moya-Anegón, López-Illescas, et al., 2013). The group of 509 HE institutions shows also an interesting geographical distribution: 88% are located in WE (191), NA (143) and AS (117). Almost 50% of these Asian HE institutions are in China (57).

The output considered is the total number of documents published in journals indexed in Scopus, as stated in the SIR report. Our results and discussion focuses on 4 indicators whose definitions are reproduced below.

- International collaboration (IC): Institution' output ratio produced in collaboration with foreign institutions. The values are obtained from the number of documents whose affiliations include more than one country address divided by the total number of documents.
- Normalized impact (NI): relation between the average impact of the institution and the world average. This world average is 1 and a NI score of 0.8(1.3) means the institution is cited 20% (30%) below (above) average.
- High quality publications (Q1): the ratio of the publications of an institution appearing in the most influential journals, namely the first quartile in their categories, according to the Scimago Journal Rank.
- Leadership: as a proxy to scientific leadership of a given institution. This indicator for a given institution is the number of its outputs in which the address of the corresponding author (considered hence as the main contributor) is the institution in question. In the present work, we consider actually the ratio of these leadership papers to the total output.

These definitions have being used thoroughly in the literature, leading to a validation of these indicators. In what follows we reveal and discuss the possible correlations among these indicators, based on the values for the 509 most productive HE institutions in the world. Possible correlations between the indicators for different geographical regions are inspected by means of Spearman' correlation coefficients (Lehman, 2005) and validated by statistical power analysis using the Student' *t*-test (Cohen, 1988). The null hypothesis is that there is no correlation at all and we check if the null hypothesis is confirmed using a confidence level of 99.5%.

3. Results

A main underlying issue in analyzing indicators may be summarized as "how to impact the impact of research outputs" at the individual, institutional and country levels, with implications on rewarding/promotion, funding and research and development policies at different levels. Furthermore, research impact is also important for the sake of scientific body of knowledge itself: with the ever continuous growth of research outputs, the concern of how this knowledge stock could be properly used is also rising (Andras, 2011). Although a proxy for actual scientific influence flow, a widespread perception is that the higher the impact (number of citations) the higher the possibility that a given piece of information gathered from scientific research will not end in a drawer of a few unread papers (Wang, Ma, Chen, & Rao, 2012). Therefore, a natural question that follows is how impact may be raised and an also natural answer relies widely on fostering collaboration and improving publication quality (Didegah & Tehlwall, 2013). Hence, the indicators of IC and Leadership capture important trends related to collaboration in general. Furthermore, the higher the influence of the journal in which a work is published, the higher the possibility that this work will be noticed and developing an impact route.

Proper indicators when adequately compared could deliver a sound scenario for the interplay among them, revealing emerging patterns, determinants and providing roadmaps at the institutional level in pursuing of higher impact of their research outputs.

As a starting point we focus on a relation between the proxies of high publication quality (Q1) and normalized impact (NI). Fig. 1 reveals that Q1 and NI are positively linked. We recall that the dots in the figure represent scores of each HE, i.e., their Q1 and NI averages. The noticeable collapse of the dots on a curve with rather low dispersion suggests a consistency

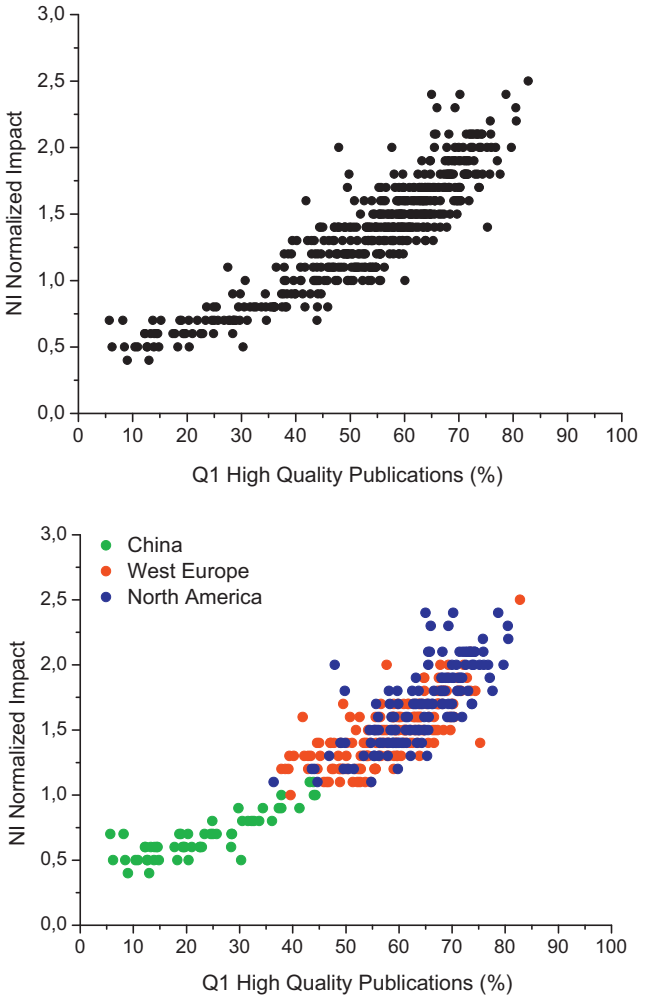

Fig. 1. Upper panel: Normalized impact (NI) as a function of High Quality publications (Q1) for the 509 HE institutions among the 600 highest output institutions in general in the Scimago Institutions Ranking 2012. Lower panel: NI as a function of Q1 only for 143 North American (blue), 191 Western European (red) and 57 Chinese institutions (green). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

between NI and Q1 indicators for averages over several thousand publications. A positive link between impact and the share of outputs published in influential journals is part of a common perception in the academic community. This positive link between NI and Q1 is validated by positive Spearman' correlation coefficients for Chinese, NA and WE HE institutions, $\rho = 0.853 \pm 0.085$, $\rho = 0.756 \pm 0.053$ and $\rho = 0.739 \pm 0.046$, respectively (The sign of the Spearman correlation indicates how the dependent variable, NI in this case, is associated to the independent one, Q1 in Fig. 1, are associated).

Fig. 1 indicates that normalized impact above average (NI = 1) is only attained for institutions with a Q1 share above 40%. Such threshold, a rather arbitrary index determined by the universe of papers taken into account, gains significance considering the regional scrutiny shown in the lower panel of Fig. 1. Here we consider only the WE, NA and Chinese HE institutions. Although constituting the backbone of the broader continuous curve of the upper panel, a clear regional clustering is revealed. All the NA and WE institutions within our set show Q1 share above 40% with NI higher than average, while all Chinese cases show low Q1 share and NI up to world average (actually, only Peking University shows NI = 1.1, slightly over average).

A positive link between publication quality and impact is frequently associated to a perception that the same occurs between international collaboration and impact. Such positive link would appear for both points of view found in the literature: on one hand, International collaboration is assumed to have impact on the quality of the scientific output (Mattsson et al., 2008) and, on the other hand, research productivity (and quality) would promote international collaboration (Abramo et al., 2011).

Taking the indicators for IC and NI for the 509 most productive HE from 2012 SIR edition, a more complex scenario emerges as can be seen in the upper panel of Fig. 2. In the limit of low NI and IC a positive link between both indeed suggest that the higher IC the higher NI. However, above 25% of IC such correspondence is not clearly seen anymore and a widely

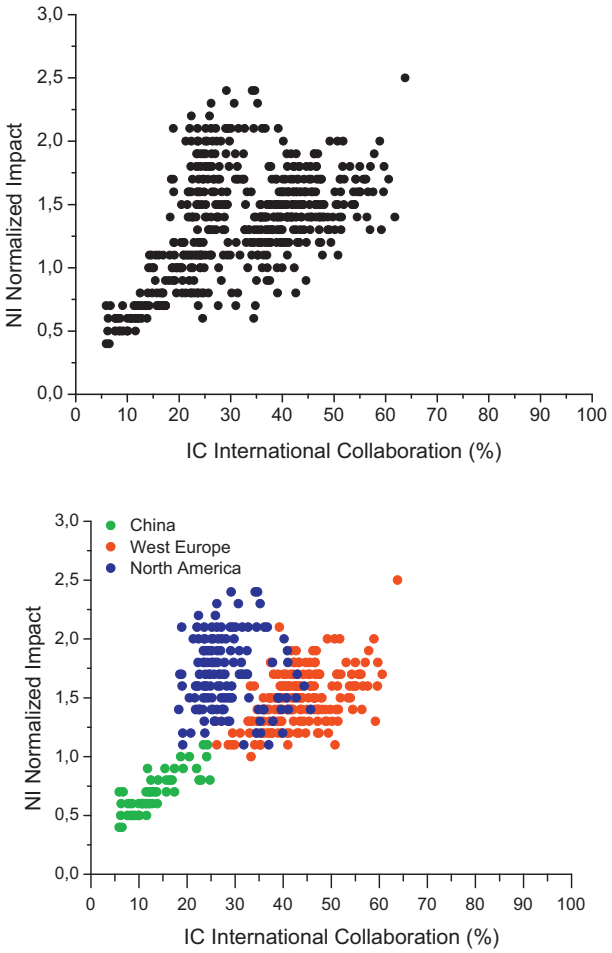

Fig. 2. Upper panel: Normalized impact (NI) as a function of International collaboration (IC) for the 509 HE institutions among the 600 highest output institutions in general in the Scimago Institutions Ranking 2012. Lower panel: NI as a function of IC only for 143 Northen American (blue), 191 Western European (red) and 57 Chinese institutions (green). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

disperse set of points reveal now evidence that further increasing IC would result in higher IC. An important insight is gained by discriminating the HE institutions in the selected geographical regions, WE, NA and China, lower panel in Fig. 2.

It is worth noting three distinct features. First, a clear positive relation between NI and IC for Chinese HE, all of them in the lower NI and IC limit, with a high positive Spearman' correlation coefficient of $\rho = 0.82 \pm 0.085$. Second, NA and WE HEs reveal quite different signatures regarding the relation between IC and NI. The NA institutions group around noticeable lower values of IC than the WE ones. Indeed, rather low IC (around 25%) may be related to high NI for NA HE institutions, which show no effective correlation between NI and IC as revealed by the Spearman' correlation coefficient for the NA institutions, $\rho = -0.021 \pm 0.053$ (no correlation is confirmed within a confidence level of 99.5%). On the other hand, WE HE institutions do show a correlation, between NI and IC, with $\rho = 0.504 \pm 0.046$. This leads to the last feature, namely that for a given degree of IC, a wide spectra of NI is found for both, WE and NA institutions. This dispersion suggests that, in spite of a correlation shown by WE institutions, the impact of research has to be related to an involved set of determinants above a certain threshold of IC, as will be discussed latter.

Regarding the relative low IC for NA institutions, we should keep in mind that the SIR captures only international collaborations with the IC indicator. One could hypothesize, that due to geopolitical aspects, higher degree of IC is expected for institutions in WE than in NA, where the weight of national collaboration supersedes international ones (Benavent-Pérez et al., 2012).

Considering that national collaboration is relevant and not captured by the IC indicator, further information given in SIR should be inspected, namely the leadership indicator of each HE institution. Recalling the definition, this indicator for a given institution is the number of its outputs in which the address of the corresponding author is the institution in question. Hence, if an institution presents a normalized leadership (leadership divided by total output) of 50%, which may be in collaboration or not, the other 50% of the output is necessarily in collaboration, including both, national and international ones. Fig. 3,

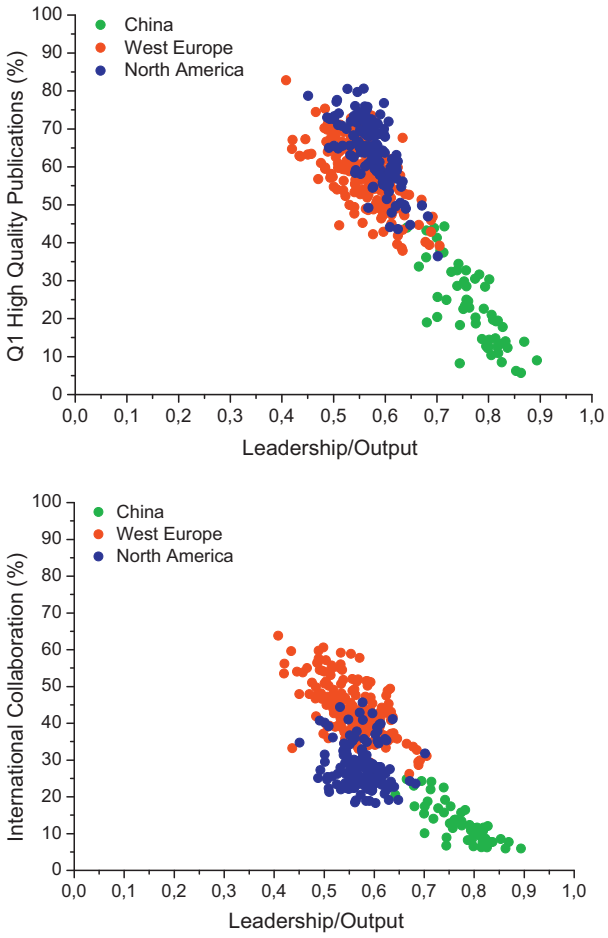

Fig. 3. Upper panel: High quality publication (Q1) as a function of leadership normalized by the total output for 143 North American (blue), 191 Western European (red) and 57 Chinese institutions (green) considered in the previous figures. Lower panel: International collaboration (IC) as a function of normalized leadership for the same institutions in the upper panel. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

upper panel shows Q1 as a function of normalized leadership for the WE, NA and Chinese institutions considered so far in this work. It is worth mentioning that NI (not shown here) shows qualitatively the same behavior as function of normalized leadership. For the sake of the present discussion, it is interesting to notice that IC, lower panel in Fig. 3, also shows the same behavior.

High quality publication are therefore negatively linked to normalized leadership, validated by negative Spearman' correlation coefficients for all three groups with a confidence level of 99.5%: $\rho = -0.553 \pm 0.085$ (China), $\rho = -0.696 \pm 0.053$ (NA) and $\rho = -0.504 \pm 0.046$ (WE). All NA and WE institutions show a leadership in the range between 50% and 65% and very few institutions in the set considered here show a leadership below 50%. Regarding IC as a function of normalized leadership, negative correlation is found by negative Spearman' coefficients for Chinese and WE institutions, $\rho = -0.39 \pm 0.085$ and $\rho = -0.615 \pm 0.046$, respectively. On the other hand, NA institutions show no correlation between IC and normalized output within a confidence level of 99.5%.

The effect of collaboration, national (not captured by the present data) and international on research impact has been addressed before (Benavent-Pérez et al., 2012) showing that NA and WE show higher levels of collaboration, while Asian ones show a noticeable higher degree of no collaboration. Hence, a high value of normalized leadership may be an indicator of research isolation with the consequences on quality and impact of the corresponding research.

4. Discussion and further work

The present work indicates that SIR is a strategic data source, giving subsidies and new insights to ongoing discussions on research impact and their determinants. Here we focus on the set of the largest HE, showing indicators derived from their outputs that reveal interesting features that might be useful for a wide range of readers and will be revised in the following.

The data shown here reinforces the common sense that impact of research output is related to publication quality, although this relation begins to be challenged by the growing availability of papers in the digital era not necessarily tied to journals (Lozano, Larivière, & Gingras, 2012). Nevertheless, Fig. 1 calls our attention to further aspects, namely the signature of Chinese contributions: it is remarkable that all Chinese HE institutions fall in a range up to NI = 1 (world average, exception is Peking University, but only slightly above average: NI = 1.1), while all larger HE institutions in NA and WE fall above. The coordinate relating the normalized impact world average with a given Q1 is influenced by the research profile dynamics and publication policies of the institutions that compose the ranking itself and possible evolves over time and may have no absolute significance, but the geographical grouping of the institutions according to the high quality publication profile cannot be neglected.

As already pointed out, international collaboration is held by many policy makers as a strategy for increasing research impact at different levels – individuals, institutions and countries – being a subject of intense study (Bote, Olmeda-Gómez, & de Moya-Aragón, 2013; Gazni et al., 2012). The results shown in Fig. 2 point out that international collaboration may show limitations as a strategy for increasing impact, as well as reveal an unexpected geographical grouping. Here one could think of a threshold at IC = 25%. Below that threshold we have all Chinese institutions that indeed resemble a linear relation between IC and NI. Some elite Chinese Universities – Zheijiang, Peking, Tsinghua – host over 50% of international collaboration of China (Xianwen et al., 2013) and are close to the world average impact and the threshold of IC beyond which NA and WE institutions depict a wide spectra of normalized impact not simply related to further increasing IC, with NA institutions showing no correlation between NI and IC and WE institutions with comparable IC showing a wide range of NI. A further insight can be gained by looking at the NI of HE institutions aggregated by countries based on the SIR report from 2010 (Bornmann and de Moya-Anegón, 2011). In this work the distribution of normalized impact of HE institutions of 50 different countries is depicted. The scenario shown in Fig. 2 of the present work is consistent with the distributions presented by (Bornmann & de Moya-Anegón, 2011). The discussion stimulated by these authors actually calls the attention to the correlation between a country performance and of the HE institutions of this country. Hence, determinants of research productivity and impact other than international collaboration have been of growing interest. In particular research context, teaching versus research positions, as well as department size, have been analyzed focusing a large WE University (Carayol and Matt, 2004). Although beyond the scope of the present work, these determinants should be further investigated in order to understand the wide spectra in research impact of major NA and WE HE institutions. Nevertheless, both groups show different patterns concerning international collaboration. In WE the geographical proximity apparently favors a more intense intra-European international collaboration (Mattsson et al., 2008). On the other hand, the role of collaboration among institutions within the same country is relativized by other authors, that call attention to other determinants, sometimes captured by bibliometric data, like publication quality, but also those that are not: extension of abstracts and adequate reference lists (Didegah & Tehlwall, 2013).

The limits of IC in fostering research impact of HE institutions with lower NI can be seen from the perspective that international collaboration involves different individuals in different institutions that have to agree on a standard that is recognized as being of "international quality" (Urbanovic & Wilkins, 2013). Hence, the NI can be affected by this agreement, given the wide spectra of publications considered in SIR. Interestingly in this context, the group of HE institutions (among the list of 509 considered here) located in Latin America, Eastern Europe, Middle East (with the exception of Israel) and Asia (excluding Japan and South Korea) show consistently low NI (below or near NI = 1), irrespective of IC, which may range from 10% to 50%. (not shown here)

The normalized leadership is an indirect measure of the effect of collaboration on the research impact, delivering a gross parameter of optimal leadership, around 50%, which is also roughly the lower limit, i.e., few HE institutions show a normalized leadership value below this threshold. In other words, apparently wealth HE institutions have a well-balanced leadership profile while highly centralized institutions present an accentuated drop in research impact. Again, a geographical pattern evolves here and Chinese institutions are the most centralized ones.

We believe that the results depicted in the present work deliver important hints for policy makers in research and development based on higher education institutions: international collaboration show limitations as a strategy for enhancing impact and policies to increase output could enhance solely leadership instead of collaboration, having a negative effect on research impact. Besides, the geographical grouping also indicates that other determinants than those considered by SIR are of relevance. The clear differences between WE and NA should be further investigated in order to possibly identify distinct strategy classes toward academic excellence. Possibly further aspects to be considered are a possible influence of the size of an institution on the productivity and possibly on the research impact, a subject that begins to be addressed (Horta & Lacy, 2011). So far, we found no clear dependence between output and NI in the set of data considered.

Finally, the examples of data visualization we present here suggest that linking the data contained in rankings like SIR is an effective way to bootstrapping the bare indicators.

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