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COMMENTARY – Professional Development

Southern Promises: A snapshot of the microbiology research landscape in South America based on bibliometric data

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Abstract

Scientists have a single currency for productivity and impact: published articles. In an effort to map the global research landscape in microbiology, and to obviate the current lack of bibliometric analysis in the field, FEMS – the Federation of European Microbiological Societies generated a dataset encompassing an exhaustive, worldwide list of microbiology studies for 2013-4, which further includes information as author affiliation, funding agency and number of citation. The manually-curated database is useful in assessing impact and regional productivity of microbiology research at different levels. Here, the data for microbiology research in South America are presented and discussed in detail. Based on the analysis, it emerged that despite great degrees of variation between number of published articles among the countries, a more levelled research productivity was observed when considering further dimensions like population size or number of research Institutes. Normalized productivity and impact increase in countries with a "central research hub," i.e. an Institute or University producing a substantial portion of the national output (15 % or more). From these observations, a possible strategy to increase impact and productivity in (microbiology) research for emerging countries is outlined.

Introduction

Academic publishing is in turmoil, as testified by the recurrent criticisms of the infamous journal impact factor (Casadevall *et al.* 2016), the emergence of alternative metrics as a proxy for the reach of scientific studies, the increasing popularity of the open-access model or, as recently, the occasional arm wrestling between publishers and university libraries (Schiermeier and Rodríguez Mega 2017) – and yet academic literature remains the principal vehicle for scientific knowledge. Scientific papers are arguably the only recognised currency of researchers, influencing PhD graduation, increasing grant acceptance and promoting academic tenure. It is safe to assume that the number of publications in a scientific discipline correlates, not only on a personal but also on a global level, with the efforts and productivity of scientists, and might indirectly indicate the impact of a research field or discipline on society. In the field of microbiology, however, bibliographic studies on the global relevance of scientific publications are still scant (Vergidis *et al.* 2005) despite the fact that microbiology research permeates areas as diverse as medicine, agriculture, biotechnology and industry.

Database generation

In occasion of the 40th anniversary of *FEMS Microbiology Letters*, we conducted an effort to map the global research landscape by geolocating recent scientific publications in the field of microbiology (research articles, reviews and others like editorials and book chapters). We compiled a dataset of ca. 42'000 articles (further referred as DOI for **d**igital **o**bject **i**dentifier) by listing all publications on the Web of Science (Thomson Reuters) for journals in the category Microbiology from the years 2013-4 (generalist journals or megajournals as *Nature*, *Science* or *PLoS ONE* were not included; the entries in our database are thus slightly underestimated). The data were arranged in tables amended with among others Institute affiliation/localization for the first author, article keywords and, if known, the Funding Agency supporting the research. The database was manually normalised to achieve consistency of entries, especially regarding different naming of Countries (e.g. "People's Republic of China" vs. "China") and Institute ("ETH Zurich" vs. "Eidgenössische Technische Hochschule Zürich"). The DOI are subdivided in 6 geographic regions, i.e. Europe (Western and Eastern combined), South America, North America, Asia, Africa, and Oceania. Importantly, the database includes citations for each article for the years 2013 to 2015. In this way, a "virtual" article-specific impact factor (AVIF for **a**rticle **v**irtual **i**mpact **f**actor) was calculated; such article-based metric is arguably more indicative of the significance of a specific study rather than the controversial and widely-used journal impact factor, which is based on an average journal-wide calculation. Here, the subset of data for South America was investigated in term of regional productivity and impact.

Microbiology landscape mapping for South America

A total of 1'805 DOI has been retrieved and curated in the South America database (without Central America and the Caribbean Area) for 2013-4, as compared to 16'072 DOI for Europe, corresponding to ca. 11 % of the European productivity. The database analysis for Europe (manuscript in preparation) confirmed previous data by Vergidis *et al.* (2005) that (Western) Europe dominates the microbiological landscape in term of research productivity. For South America, interesting observations can be drawn (summarised in **Figure 1** and **Table 1**). In the analysis, although these data are intrinsically relevant and are available in our database, we deliberately decided not to focus on where microbiology research topics are concentrated ("research hotspot"). This is because the scientist profession has a nomadic character and researchers frequently change their place of work, and research hotspots might have an arbitrary trait (e.g. research on Malaria is done also in Malaria-free countries).

The bulk of productivity in South America is localized in Brazil and Argentina, where almost two-thirds and one-quarter of DOI are produced (1'149 DOI or 64 % and 423 DOI or 23 %, respectively), followed by Chile (88 DOI or 5 %), Colombia (72 DOI or 4 %) and Uruguay (32 DOI or 2 %). The other countries (Venezuela, Peru, Ecuador, Bolivia, The Guianas and Paraguay) produced less than 1 % of the output and were not further considered to minimize the effect of small sample size on the analysis. Among the top five Latin American countries, a more even distribution of research productivity was observed when considering further dimensions as GDP (gross domestic product), national population and number of Research Institutes or Universities (≈ normalised productivity; see **Table 1**). Argentina and Uruguay produced around 9-10 DOI per million persons, Brazil and Chile around 5, Colombia around 1,5. A GDP share between 1,3-5,2 million US$ were calculated for the publication of one DOI in the countries (please note that these values are purely arithmetical, and could be considered as proportional to the cost of DOI or inversely correlated with the country's efficiency). A correlation seems to emerge between the number of Institutes and DOI/Institute for Brazil (133 Institutes and ca. 8,6 DOI/Inst.), Argentina (73 Inst. and ca. 5,8 DOI/Inst.) and Colombia (29 Inst. and 2,5 DOI/Inst.), although this does not apply for neither Chile (21 Inst. and ca. 4,2 DOI/Inst.) nor Uruguay (5 Inst. and ca. 6,4 DOI/Inst.).

When analysing the productivity of the Institutes within a country, 5 Brazilian Institutes, none in Colombia and 1 in each of the remaining countries reached the arbitrarily-set benchmark of more than 50 DOI or 20 % of total national productivity. Whereas for Brazil and Argentina the highly-productive Institutes produced around 4-15 % of the nation's DOI, the *Universidad de Chile* in Santiago (Chile) and the *Universidad de la República* in Montevideo (Uruguay) achieved around 25 % and 65 % of the national productivity, respectively. Highly-productive Institutes are located in the capital (for Argentina: *Universidad de Buenos Aires*, 15 % of national DOI) except for Brazil (i.e. *Universidade de São Paulo* and *Universidade Estadual Paulista* in São Paulo with ca. 14 % and 6 % of national DOI, respectively; *Universidade do Estado* in Rio de Janeiro, 9 % of national DOI; *Universidade Federal de Minas Gerais* in Belo Horizonte, 8 % of national DOI; *Universidade Federal do Rio Grande do Sul* in Porto Alegre, 4 % of national DOI). The countries' average AVIF show similar values with Chile and Uruguay scoring highest (ca. 3,4) and continent mean AVIF at ca. 2,9 (AVIF average without top 5 countries ca. 2,3). Interestingly, no Institute in Uruguay reached the Top 300 in the considered University rankings, i.e. the last available rankings from *Quacquarelli Symonds*, *Times*

Higher Education and *Center for World University Rankings*, while for the other countries 1-5 Institutes were consistently in the list (although one must consider university rankings, especially in this case, with some scepticism since they also include unrelated research areas).

Contextualisation of data and conclusions

The analysis shows a general trend set by the countries with highest productivity (Brazil and Argentina) that seems not to be followed, in particular, by Uruguay and Colombia (see infographic in **Figure 1**). Uruguay reaches similar (normalised) productivity and efficiency (DOI/mil. persons, DOI/Inst. and GDP/DOI) as Brazil and Argentina with only 5 Institutes. Although Colombia and Chile have a comparable number of DOI and Institutes, the first scored worst in both normalised productivity and efficiency. Interestingly, when considering intra-national productivity, Colombia is the only country without a highly productive Institute whereas Chile and Uruguay have one single Institute producing around 25 % and 65 % of the country's DOI, respectively. These two countries also showed highest AVIF scores. These observations suggest that a general strategy to increase productivity, reduce costs and possibly increase impact could be to have a "central" research centre acting as a high-productivity hub in a positive reinforcement scenario. The proximity among researchers would reduce scattering of resources, foster collaboration within an Institute, allow sharing of equipment and core facilities thus reducing costs, and increase (inter)national visibility and access to funds. Interestingly, Argentina has one Institute producing ca. 15 % of DOI as opposed to Brazil (5 Institutes producing 4-14 % DOI), which could explain why the first scores slightly better in term of productivity (DOI/mil. persons) and efficiency (GDP/DOI). The exhaustiveness of our database made it impossible to collect data on the infrastructural assets of each single Institute, although some of these are indicative of high funds and prestige (e.g. biosafety containment facilities BSL-3 and BSL-4; Cyranoski 2017). For obvious reasons, our database could not include the affiliations for all co-authors of a study, thus intra- and international collaborations among scientists are overlooked although this are crucial for science (Rodrigues *et al.* 2016). (It is assumed that multiple affiliations are rather rare for first authors.) It is safe to postulate that an increase in (inter)national visibility results in more collaborations, more DOI, more funds and, in turn, even increased visibility.

The impact of the published studies shows comparable AVIF among countries. The average AVIF values indicate, rather unsurprisingly, that quantity (i.e. high productivity) does not necessarily entail high quality (i.e. impact). The fact that countries with < 1% DOI have a below-average mean AVIF indicates that nations with low productivity struggle in generating high-impact studies. As for the "regular" journal impact factor, our AVIF data should be regarded with some prudence (e.g. the known tendency for reviews to harvest more citations also applies here). Crucially, our database compiles citations for every single article and might thus be more representative of the relevance of a publication rather than a journal-dependent prestige "tag."

As previously noted by Vergidis *et al.* (2005), areas showing the steepest increase in productivity in the years 1995-2003 were Asia, Eastern Europe and Latin America. This last region (encompassing South and Central America as well as the Caribbean) produced around 2 % of all microbiology studies or around 5 % of the articles from Western Europe. Although the DOI in our database were retrieved using a different approach, our analysis for 2013-4 further consolidates this trend, with South America alone producing around 4 % of all articles and 13 % of the Western European output, indicating how the region is growing its share in global research productivity in microbiology. Altogether, our data suggests that professionals in microbiology should be increasingly looking at South America as emerging, promising area when seeking for collaborations in their research field or – although national-specific contexts like the political situation or the existing infrastructures as well as personal decisions and family situations play a major role in the mobility of a scientist (Rodrigues *et al.* 2016) – even as a place to live and work. It has been previously reported that South American studies tend to have a lesser impact than those from developed countries (Meneghini *et al.* 2008) due to yet unknown reasons. Further analyses will be necessary to investigate if this is due to a psyco-social bias toward developing countries, and the FEMS-bibliometric database will prove helpful to address this point.

The analysis of the data over a longer time period could give a more accurate snapshot on productivity and impact, and account for the long breath of scientific research (i.e. the delay between conception of research, fund acquisition, conduction of research, publication, harvest of citation and acquisition of further funds and prestige). It would be of great interest to see, in the case that the trends observed here hold true, if the *Universidad de la República* in Uruguay will be soon listed in the Top 300 list and if the remaining South American countries, i.e. Bolivia, Ecuador, The Guianas, Paraguay, Peru and Venezuela, will be able to reach higher productivity, efficiency and impact in (microbiological) research by a "central hub" strategy.

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Conflict of interests

The author declares no conflict of interests.

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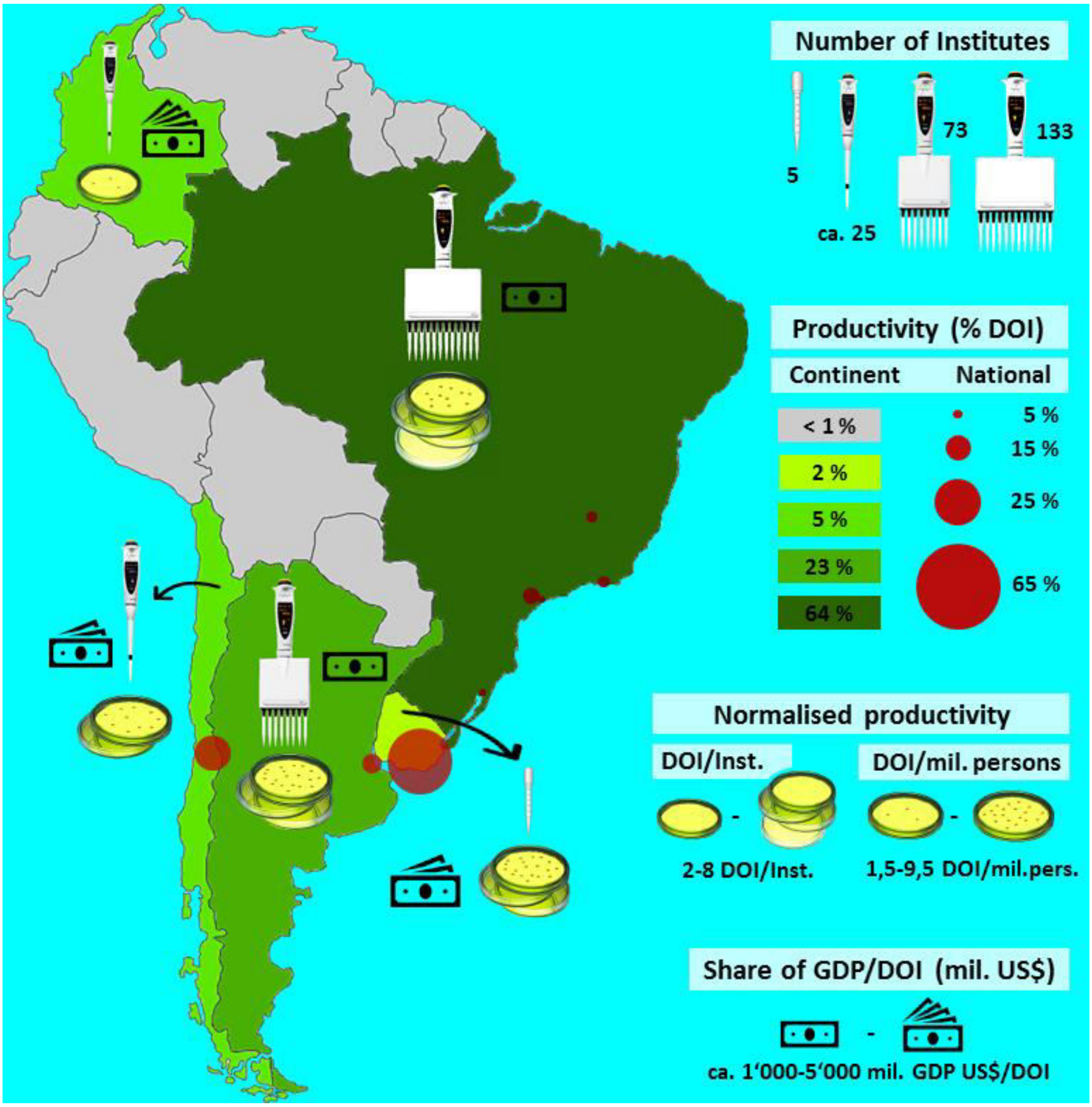

Figure 1. Snapshot of the microbiology research landscape in South America in 2013-2014. The productivity of the single countries producing more than 1 % of the continent's total DOI (Brazil, Argentina, Chile, Colombia and Uruguay, represented by shades of green) is levelled when considering further dimensions as national population and number of Research Institutes (i.e. "normalised productivity" in DOI/Institute, represented by stacked Petri dishes, or in DOI/million persons, represented by colony growth on Petri dishes) or gross domestic product (i.e. "share of GDP/DOI" in US$, represented by banknotes). Some countries, in particular Uruguay and Chile, have national hotspots for microbiology research (red circles), which seem to boost national productivity, efficiency and impact. For details see text. The exact data are reported in Table 1. GDP: gross domestic product, DOI: digital object identifier; Inst.: Institutes; mil.: million.

Table 1. Overview of productivity and virtual impact in microbiology research in South America in 2013-4.

Country	# DOI	% DOI	DOI/mil. persons	# Institutes	DOI/Inst.	GDP/DOI (mil. US$)	AVIF
Brazil	1’149	63,7 %	5,44	133	8,64	1’543	2,93
Argentina	423	23,4 %	9,56	73	5,79	1’285	2,73
Chile	88	4,9 %	4,81	21	4,19	2‘933	3,41
Colombia	72	4,0 %	1,47	29	2,48	5‘246	3,01
Uruguay	32	1,8 %	9,26	5	6,40	1‘796	3,41

A total of 1’805 DOI were retrieved, with Bolivia, Ecuador, The Guianas, Paraguay, Peru and Venezuela producing less than 1 % of the continent’s DOI (data not shown/further considered). DOI: digital object identifier (primarily research/review article in microbiology journal); GDP: gross domestic product; mil.: million; AVIF: article virtual impact factor.