Journal of Scientometric Res. 2022; 11(3):358-370
http://www.jscires.org

Research Article

The Influence of International Scientific Collaboration with English-speaking Countries on the Research Performance of Brazilian Academic Institutions

Samile Andréa de Souza Vanz[1,*], Domingo Docampo[2]

Universidade Federal do Rio Grande do Sul. Programa de Pós-graduação em Comunicação, Programa de Pós-graduação em Ciência da Informação, Porto Alegre, BRAZIL.
Universidade de Vigo, atlanTTic Research Center for Communication Technologies, Vigo, SPAIN.

ABSTRACT
Scientific collaboration, a practice that traces its roots back to the birth of modern science, has spread through the research community, expanding the ties between institutions and countries and becoming a strategy to improve research productivity. Collaboration with institutions from countries of renowned scientific leadership thus constitutes a clear opportunity for the scientific advancement of academics as well as institutions worldwide. This work focuses on the set of Brazilian papers indexed by InCites between 2010-2019 to analyze the advantages, measured in terms of the citation impact and percentage of publications in Q1 journals, as well as (just for the papers published between 2014 and 2018) the position in the ARWU Global Ranking of Academic Subjects, derived from the sustained scientific collaboration with institutions from Australia, Canada, United Kingdom, and the United States. Our results show that collaboration with these four countries presents clear advantages for Brazilian institutions in all areas of knowledge. In particular, our study shows that the percentage of publications in Q1 journals doubles, and the citation impact increases markedly for the set of papers in collaboration with the aforementioned countries. Our study also shows that, by and large, Brazilian academic institutions benefit from these international collaborations to improve their positions in the current edition of the ARWU Global Ranking of Academic Subjects.
Keywords: Scientific collaboration, Citation analysis, Corresponding author, Brazilian universities, ARWUGRAS ranking

Correspondence
Samile Andréa de Souza Vanz
Universidade Federal do Rio Grande do Sul. Programa de Pós-graduação em Comunicação, Programa de Pós-graduação em Ciência da Informação, Porto Alegre, BRAZIL.
Email id: samile.vanz@ufrgs.br
ORCID ID: 0000-0003-0549-4567

Received: 03-06-2022
Revised: 08-08-2022
Accepted: 20-08-2022
DOI: 10.5530/jscires.11.3.39

INTRODUCTION

Scientific collaboration has its roots in the birth of modern science, during the 17th century, in France, as an answer to the professionalization of science the country was experiencing at the time.[1] Nowadays, international collaboration has become a reflection of scientific quality,[2] and its practice has grown into a strategy for scientists to improve their research productivity and the level of their research endeavors.

A countries' scientific capacity can be measured through several indicators that put nations such as the United States, the United Kingdom, and Canada in the top positions, followed by continental European countries such as Sweden, Finland, Switzerland, France, and Germany, as well as Japan, Israel, and Australia, while Brazil appears to belong to the group of lagging countries.[3] The growth in the world's scientific capacity is one of the factors that, together with the easier access to communication technologies and the decrease in travel prices, are behind the growing influence of networks. The relevance of international collaboration with researchers from Australia, Canada, the United Kingdom, and the United States has already been highlighted in previous studies.[4–7] According to McManus[8] USA and UK are the first and second major scientific partners, Canada and Australia being between the 10 major partners.

Objectives and Scope of the Study

This paper presents results related to the production and impact data of Brazilian universities in the years of 2010–2019, analyzed by area of knowledge. The goal of this study is to identify Brazilian universities and areas that benefit from international scientific collaboration for increasing their scientific impact as measured by the number of citations received and to assess whether that collaboration influences the performance of Brazilian institutions in the Shanghai Ranking's Global Ranking of Academic Subjects.

The following hypotheses were delineated:

a) Brazilian universities' scientific impact, as measured by the number of citations to their published papers, benefits from the international collaboration with institutions from Australia, Canada, the United Kingdom, and the United States.

b) Brazilian universities' share of publications in higher impact journals increases through international collaboration with institutions from Australia, Canada, the United Kingdom, and the United States.

c) Brazilian universities' positions in the Shanghai Global Ranking of Academic Subjects improve through collaboration with institutions from Australia, Canada, the United Kingdom, and the United States.

Along with these hypotheses, we also want to elucidate the following questions:

1) Is there an area of Brazilian science that benefits the most from international collaboration with institutions from Australia, Canada, the United Kingdom, and the United States?

2) Is there an area in which the Brazilian authors who take on the position of the corresponding author get more recognition?

Literature Review

In a study conducted under a historical and sociological perspective,[1] Beaver and Rosen identified several examples of scientific collaboration in the 17th century: Kepler and Brahe, Hooke and Boyle, Lavoisier and Laplace, Dulong and Petit, Gauss and Weber. It is said that the expression "invisible colleges" was first used by Comenius in a meeting with British experimentalists around 1641. Boyle, who was in the meeting, used the expression in a letter to his advisor in 1645 to describe the interactions of a small group of natural philosophers.[3]

The level of co-authorship in Science has raised steadily in the past 40 years. In a recent analysis of co-authorship,[9] Zhigang *et al*. showed that the collaboration between individuals has been growing, from an average of 2.2 authors per paper in 1980 to 7 in 2019. The number of institutions involved in each paper has also grown, from an average of 1.59 in 1980 to 2.66 in 2019. However, international collaboration between countries has grown at a much slower rate, with averages of 1.14 countries in 1980 and 1.48 in 2019.

The correlation between collaboration and impact, measured through citation numbers, has already been reported in the literature.[2,10-12] Leta and Chaimovich[13] reported significant gains (up to 40%) in impact derived from international collaboration. Papers written in collaboration are more cited for several reasons, such as the wide dissemination of the work and the possibility of citations proportional to the number of authors[14] and the involvement of international leaders in the organization and supervision of several groups that often come from different areas.[15] Collaboration also influences the acceptance of the submitted papers, due to the degree of technical competence exposed in the multi-authorship.[16] Bordons *et al*.[6] identified differences in the impact related to the country of origin of the team leading the research effort. Studies led by scientists from countries of global scientific leadership, such as Australia, Canada, the United Kingdom, and the United States, usually attract a high number of citations. Partnering with institutions from those countries becomes then very attractive for other researchers. Together with the type of collaboration – national or international – and the scientific performance of the collaborating country, the order of authorship is an important detail that has not been overlooked in the literature. Chinchilla Rodriguez *et al*.[17] noted that Brazilian papers indexed on Clarivate Analytics from 2000 to 2016 follow a pattern that falls short of the world impact averages. Domestic papers (published among Brazilian authors) and those published in international collaboration in which Brazil takes the position of the corresponding author, fall short of the world average.

University rankings gather indicators that should reflect several aspects of academic excellence.[18] Bibliometric indicators of scientific output and citation are present in every international university ranking and receive weights ranging from 20 to 100% of the final score. Kaycheng[19] observed a strong correlation between the various criteria considered individually; some criteria contributed very little and would be masking, in fact, the relevant dimensions measured in the ranking. Robinson-Garcia *et al*.[20] showed that, despite the differences in methodology, as well as the weights attributed to publication and citation data, all rankings tend to measure a combination of the number of articles produced by the university and their relative citation impact. Therefore, bibliometric indicators that combine the volume of publications and the volume of citations, as well as the average number of citations per publication, can offer an image of research universities that is very similar to the scenario shown by international rankings.

It is in that context that co-authorship and the credits given to each author – and, as a result, to each university and country of affiliation – gain some spotlight in current discussions. Authors' contributions in published papers fall roughly into three categories: those who sign as the first author, those who sign either as the corresponding and/or the last author, and those who contribute with no specific role.[21] The corresponding author has gained status as the most important author among analytical approaches.[22] Corresponding authors are usually among the senior components of the group, the ones who most contribute to guarantee the research funding;[23] they are responsible for the research project, for bringing together the co-authors, and for the preparation of the paper. Several studies about scientific collaboration[6,17] take the role of the corresponding author into account. Being a corresponding author has become a symbol of leadership and responsibility. In this study, we will use the set of papers with at least a corresponding author belonging to an institution as one of the baselines to make comparisons with the papers derived from specific international collaborations of the researchers from that institution.

METHODOLOGY

The data used in this paper derive from InCites, a database created by Clarivate Analytics. Data of papers (article type) published between 2010 and 2019 by the 230 most productive and most cited Brazilian institutions were collected in June 2020 and March 2021. The analyses were carried out for data in the six areas of the GIPP InCites' schema: Engineering and Technology (ENG), Clinical, Pre-Clinical and Health (MED), Life Sciences (LIFE), Physical Sciences (NAT), Social Sciences (SSCI), Arts and Humanities (HUM).

First, we carried out a descriptive analysis of the number of papers produced by the selected Brazilian universities, including the number and percentage of citations, Category Normalized Citation Impact, and the number and percentage of papers published in journals of the First Quartile. We will use the "ALL" label for this set of papers. Then, we identified all papers where an author from a Brazilian university took the role of the corresponding author. In the Tables that follow, results associated with this set of papers will lie under the "CORR AUTHOR" label.

Considering the relevance of international collaboration with Australia, Canada, the United Kingdom, and the United States,[4-7] our study then identified the papers co-authored by Brazilian researchers and at least one researcher from any of those four countries. Results associated with this set of papers will lie under the "ACKS COLL" label. As we want to compare the impact of international collaboration when it involves or not those four countries, the "NO ACKS COLL" label will refer to the set of papers (co-authored by Brazilian researchers) not included in the "ACKS COLL" collection.

For better readability, we have used acronyms for all the universities included in the tables that follow. Table 1 shows the correspondence of the chosen acronyms to the universities' names. Table 2 presents the list of subjects and acronyms.

In Tables 3 to 10, we will include the following indicators associated with different sets of papers from an institution:

Table 1: List of acronyms for the Brazilian universities mentioned in the paper.

Institution	Acronym
Universidade Federal de Minas Gerais	UFMG
Universidade Federal Paraná	UFPR
Universidade Federal do Rio Grande Sul	UFRGS
Universidade Federal do Rio Janeiro	UFRJ
Universidade Federal de Santa Catarina	UFSC
Universidade de Brasília	UNB
Universidade Estadual Paulista	UNESP
Universidade Estadual de Campinas	UNICAMP
Universidade de São Paulo	USP

- PUB: Total number of papers (article type) between 2010 and 2019.
- PPUBC: percentage of papers (over PUB) in CORR AUTHOR.
- PPUBA: percentage of papers (over PUB) in ACKS COLL.
- PPUBN: percentage of papers (over PUB) in NO ACKS COLL.
- CNCI: Category Normalized Citation Impact, calculated by dividing the citation count by the expected citation rate (baseline) for publications sharing the same type of document, same year of publication, and same area.
- CNCIA: Category Normalized Citation Impact for papers in ACKS COLL.
- CNCIC: Category Normalized Citation Impact for papers in CORR AUTHOR.
- CNCIN: Category Normalized Citation Impact for papers in NO ACKS COLL.
- CIT: Total number of citations.
- PCITC: percentage of citations (over the total number of citations) to papers in CORR AUTHOR.
- PCITA: percentage of citations (over the total number of citations) to papers in ACKS COLL.
- PQ1: Percentage of publications in the first quartile by Journal Impact Factor.
- PQ1C: Percentage of publications in the first quartile by Journal Impact Factor of papers in CORR AUTHOR.
- PQ1A: Percentage of publications in the first quartile by Journal Impact Factor of papers in ACKS COLL
- PQ1N: Percentage of publications in the first quartile by Journal Impact Factor of papers in NO ACKS COLL.

Data Analysis

Analysis of data was carried out using the Statistical Package for Social Sciences (SPSS 23.0), with Pearson's product moment analysis of correlation for values of the normalized citation impact and percentage of Q1 publications in ACKS COLL and the groups ALL and CORR AUTHOR to check the validity of the hypotheses a) and b) outlined in the introductory section of the paper. Partial Correlation analyses were used to check whether those correlations held when controlling for four relevant covariates (Total number of papers, and percentage of papers in ACKS COLL, CORR AUTHOR, and NO ACKS COLL).

ARWUGRAS Analysis

The Academic Ranking of World Universities (ARWU), a.k.a. the Shanghai Ranking, produces an annual classification by subjects –Shanghai Ranking's Global Ranking of Academic Subjects (ARWUGRAS)– that brings visibility to many Brazilian universities listed in subject rankings close to their fields of specialization. ARWUGRAS comprises 54 subjects split into large areas, namely, Natural Sciences, Engineering, Life Sciences, Medical Sciences, and Social Sciences. Those areas roughly correspond to five of the Clarivate's GIPP areas. The 2020 rankings rely on bibliometric results from the period 2014–2018, aggregated through a weighted combination of the following indicators:

- Q1: Number of publications (article type) in the first quartile of the Journal Citation Impact.
- CNCI: Average number of citations per article normalized by the *Web of Science* category and publication year.
- IC: Percentage of international collaborations.
- TOP: Number of publications (article type) in a list of key journals.
- AWARD: For some subjects ARWU makes use of an additional indicator that refers to the "total number of an institution's staff that has won a significant award in an Academic Subject since 1981. The awards were identified through the ShanghaiRanking's Academic Excellence Survey" (ARWUGRAS 2020).

In the 2020 edition of ARWUGRAS, all the bibliometric indicators relied on raw measures of research parameters for publications (article type only) between 2014 and 2018. As stated in the ARWUGRAS Methodology (ARWUGRAS 2020), for all the indicators except CNCI final scores "are computed from raw measures as the square root of the percentage of the top-scored institution". As of CNCI, "The maximum value of the indicator in a subject is set as the lower value of: (1) the twice of the average CNCI for all institutions in this subject; (2) the maximum of the CNCI for all institutions in this subject". Institutions' scores on CNCI are then "calculated as the proportion of their CNCI to the maximum value. If an institution's CNCI is higher than the maximum value, its score on CNCI will be assigned as 100".[24]

Table 2: List of subjects chosen for the present study from the Shanghai Ranking's Global Ranking of Academic Subjects (ARWUGRAS) 2020.

Area	Subject	acronym	N BRAZIL	N TOTAL
ENG	Food sciences and engineering	FOO	19	300
ENG	Chemical engineering	CHM	11	500
ENG	Biotechnology	BIT	10	500
ENG	Energy science and engineering	ENE	5	400
ENG	Mechanical engineering	MEC	5	400
ENG	Material science and engineering	MSE	2	500
LIFE	Veterinary sciences	VET	23	300
LIFE	Ecology	ECL	20	500
LIFE	Agricultural sciences	AGR	6	500
LIFE	Human biology	HBI	3	500
LIFE	Biology	BIO	2	500
MED	Dentistry and oral sciences	DEN	29	300
MED	Pharmacy and pharma sciences	PHA	8	500
MED	Public health	PUH	8	500
MED	Clinical medicine	CLI	6	500
NAT	Physics	PHY	10	500
NAT	Mathematics	MAT	6	500
NAT	Chemistry	CHE	2	500
SOC	Management	MAN	4	500
SOC	Economics	ECO	2	500
SOC	Political sciences	POL	2	400

For each subject, N TOTAL (N BRAZIL) is the total number of universities (Brazilian universities) included in the ARWUGRAS 2020 official list.

For this study, we have chosen all the subjects that include at least five Brazilian universities in the corresponding ARWUGRAS Ranking. We have also selected the three subjects in the Social Sciences showing the largest presence of Brazilian universities. Finally, we have included in the list of 21 subjects four additional topics that cover a substantial share of the scientific production of Brazilian universities, namely Biology, Chemistry, Human Biology, and Materials Science and Engineering.

To perform the simulations needed for the study we extracted from InCites the raw measures of all Brazilian universities ranked in the chosen subjects. The data for these simulations correspond to the period 2014–2018, as stated by the 2020 edition of ARWUGRAS. It constitutes, therefore, a subset of the complete set of data used in the other part of the study. To cancel the effect of international collaboration we recomputed the scores as follows: for every institution and subject, we assigned the average raw values of the indicators (Q1, CNCI, and TOP) obtained for the CORR AUTHOR collection of papers to the set of papers ACKS COLL.

Computation of the Modified Scores

To compute final scores, we follow ARWUGRAS's methodology.

Let X be a Brazilian institution with a raw value of r_x for a particular indicator. Let r_{max} be the top raw score for that particular indicator among all the institutions ranked.

Hence, applying ARWU's methodology, the score of the institution X, s_x, in that indicator is computed as follows:

$$s_x = 100\sqrt{\frac{r_x}{r_{max}}}$$

Now, after recalculating for the effect of the papers in ACKS COLL, both the raw score of X and the maximum raw score in the table may change. Let then r'_x be the new raw score of X, and r'_{max} the new maximum score. The new final score on the indicator, s'_x, will then be computed in the same fashion.

We use UNESP as an example to calculate the score in the indicator Q1 for the Agricultural Sciences. According to InCites, UNESP shows a raw value on Q1 (i.e. number of publications in the first quartile in the period 2014-2018), r_x, of 768. The top raw value among the institutions worldwide in Agricultural Science corresponds to Wageningen University and Research, 2531. UNESP score, s_x, would then be

$$s_x = 100\sqrt{\frac{768}{2531}} = 55.08$$

ARWU rounds the value to the first decimal digit, 55.1, as the ARWUGRAS webpage for the Agricultural Sciences shows.[1]

We then calculated the new scores after canceling the effect of the international collaboration. Researchers from UNESP published 3354 papers in the Agricultural Sciences between 2014 and 2018, 768 of them in Q1 journals. The percentage of Q1 papers in that period (taking into account only papers with at least a corresponding author affiliated with UNESP) was 22.2 for that subject. Out of the 768 Q1 contributions from UNESP in the period, 212 papers were included in the ACKS COLL set. Now, the total number of papers of UNESP in ACKS COLL was 451. Hence, assuming that those papers were from the "CORR AUTHOR" set, the expected number of Q1 papers would have been 100 (22.2% of 451). Therefore, the new raw score for UNESP in Q1 would be 768-212+100=656.

1 http://www.shanghairanking.com/Shanghairanking-Subject-Rankings/agricultural-sciences.html

Carrying out the same computation for Wageningen University and Research produces a new Q1 raw score for that institution, 2487, which again reaches the maximum value of all the modified scores of universities in the ARWUGRAS list.

The new score for UNESP in the indicator would then be

$$s'_x = 100\sqrt{\frac{656}{2487}} = 51.4$$

In the next section, we present the results of the complete simulations.

RESULTS

To investigate the extent to which scientific collaboration benefits the research performance of Brazilian universities in terms of bibliometric impact, we have identified the total number of papers indexed in InCites for each university and the number of papers in which an author affiliated with a Brazilian university assumed the position of the corresponding author.

Table 3 presents some results for the 25 Brazilian institutions with the largest number of papers published between 2010 and 2019, indexed in the InCites database.

On average, researchers from those 25 universities occupy the corresponding author position in 49.3% of their publications. Those universities show, except in a few cases, a share of papers signed as the corresponding author larger than the average share of all Brazilian institutions (43.6%). Table 3 shows several disparities, starting with the great difference (an order of magnitude) between the institutions with the highest and lowest scientific production in the period analyzed (column PUB). Although less noticeable, differences in institutional profiles can also be seen in CIT, PQ1, and CNCI.

The percentage of papers with a corresponding author from the institution (PPUBC) varies from 38% to 59.7% and shows no significant correlation with the total number of papers ($r=-0.125$, $p=.55$). Nor does the percentage of citations to papers with a corresponding author from the institution (PCITC), ranging from 19.3% to 59.7%, ($r=-0.061$, $p=.77$). The percentage of Q1 contributions decreases in the set of papers CORR AUTHOR; the gap ranges from 0.9% to 20.8%, with an average of 8.5%. This means that the association with other institutions (in or outside Brazil) in which the other institution takes the lead of the investigation helps but does not radically improve the ability of Brazilian universities to publish in the first quartile. We will check later whether accounting only for the collaboration with institutions from the four English-speaking countries selected for our analysis does have a substantial impact on %Q1 Figures.

When comparing the Category Normalized Citation Impact of all papers published by Brazilian institutions included in

Table 3: Publication and citation figures, and percentage of Q1 contributions of large Brazilian universities in all the categories of the Web of Science (2010-2019): ALL and CORR AUTHOR papers.

	All				Corr author			
2010-2019	PUB	CIT	CNCI	PQ1	PPUBC	PCITC	CNCIC	PQ1C
USP	90560	1054740	1.00	37.5	47.4	35.0	0.74	35.1
UNESP	35204	321101	0.82	31.4	53.1	40.9	0.65	27.8
UNICAMP	29964	340039	0.99	40.5	49.0	37.9	0.75	38.0
UFRJ	26590	328974	0.95	39.0	46.4	30.9	0.66	33.7
UFRGS	24132	265181	0.95	33.5	51.0	39.9	0.71	30.4
UFMG	22579	240091	0.94	33.3	53.6	40.6	0.69	32.1
UNIFESP	16868	203557	0.96	31.9	39.2	26.0	0.63	28.8
UFPR	15257	121917	0.74	29.8	50.8	39.3	0.57	28.9
UFSC	13772	151401	1.02	36.2	52.8	41.7	0.74	35.7
FIOCRUZ	13607	159935	0.99	35.1	43.3	32.3	0.76	32.9
UFPE	10890	93338	0.75	29.9	51.3	46.0	0.66	29.6
UERJ	10813	145872	1.04	41.5	38.0	19.3	0.58	32.9
UFV	10787	75879	0.69	26.8	55.3	50.2	0.63	26.5
UFSCAR	10748	96726	0.77	36.6	48.7	43.2	0.69	35.0
UNB	10747	100486	0.87	30.8	47.9	30.9	0.60	27.6
UFSM	10281	76607	0.73	25.9	59.7	56.2	0.68	23.5
UFC	9741	88452	0.77	30.9	49.2	42.4	0.66	29.3
UFF	8968	73026	0.74	32.8	45.4	34.4	0.61	29.8
UFG	7646	63643	0.75	28.2	47.9	36.6	0.61	25.6
UFBA	7364	68895	0.86	30.9	44.4	31.3	0.64	28.2
UFRN	7360	70852	0.96	34.4	51.3	36.4	0.67	30.8
UFMS	7213	46928	0.64	22.1	46.2	35.6	0.52	18.3
UEM	6972	54899	0.72	24.5	56.7	51.5	0.63	22.7
UFPEL	6860	75249	1.10	31.2	48.1	31.9	0.76	25.5
UFLA	6831	43523	0.63	21.0	56.9	54.7	0.60	19.1
average	**16870**	**174452**	**0.86**	**31.8**	**49.3**	38.6	0.66	29.1

Table 3 we found a statistically significant difference in the scores for CNCI (M=0.86, SD=0.13) and CNCIC (M=0.66, SD=0.06), t(24)=8.78, *p*<.001. CNCI and CNCIC are positively correlated (r= 0.65, *p*<.001). The CNCI indicator ranges from 0.63 to 1.1, with only four universities above 1. The impact of papers whose corresponding author is affiliated with a Brazilian university, CNCIC, shows a thinner range, reaching from 0.76, to 0.52.

Table 4 presents results about the collaboration profile of the 25 Brazilian institutions with the largest scientific production between 2010 and 2019.

On average, papers in ACKS COLL represent around 16% of all the papers associated with Brazilian institutions but manage to attract in excess of 33% of the total citations, whereas papers in NO ACKS COLL represent around 14% and attract around 18% of the total citations. Normalizing PCITA and PCITN (by dividing them among the corresponding PPUB) we found a statistically significant difference, t (24)=10.32, *p*<.001,

Brazilian institutions show a Category Normalized Citation impact substantially higher for ACKS COLL papers (CNCIA) than for CORR AUTHOR papers (CNCIC). There was a statistically significant difference in the scores for CNCIA (M=1.86, SD=0.50) and CNCIC (M=0.66, SD=0.06), t(24)=12.70, *p*<.001. As of the collaboration excluding those four countries, the association also holds: CNCIN and CNCIC differ in the scores, CNCIN (M=0.93, SD=0.05) and CNCIC (M=0.66, SD=0.06), t(25)=24.7, *p*<.001. However,

Table 4: Publication and citation figures, and percentage of Q1 contributions of large Brazilian universities in all the categories of the Web of Science (2010-2019): ACKS COLL and NO ACKS COLL.

	ACKS COLL				NO ACKS COLL			
2010-2019	PPUBA	CNCIA	PCITA	PQ1A	PPUBN	CNCIN	PCITN	PQ1N
USP	22.5	2.01	43.9	58.3	15.8	0.94	17	45.1
UNESP	16.3	1.75	35.8	57.5	13.4	0.96	17.6	44.4
UNICAMP	19.2	1.92	35.8	61.6	14.6	1.02	16.1	45.9
UFRJ	21.7	1.97	46.9	62.4	17.2	0.89	17.3	45
UFRGS	17.2	2.23	35.6	55.7	15.8	0.94	18	42.9
UFMG	18.1	2.17	39.2	51.5	13.3	0.96	17.3	44.8
UNIFESP	22.3	2.12	47.6	51.5	9.2	0.9	9.6	40.1
UFPR	14.8	1.53	30.3	45.6	13.6	0.89	19.5	41.8
UFSC	14.2	2.81	33.8	52	19.9	0.93	22.2	44.3
FIOCRUZ	21.1	2.14	44.3	56.1	12	0.9	12.4	44.7
UFPE	13.2	1.43	22.2	45.4	18.3	0.88	25.7	36
UERJ	23.8	2.34	55.9	69.1	16.6	0.86	14.5	47.8
UFV	11.1	1.43	22	53.4	11.2	1.01	17.9	41.4
UFSCAR	13	1.13	16.8	50.1	17.2	0.97	25.8	48.3
UNB	18.1	1.95	39.3	47.3	17.6	0.87	20.7	43.6
UFSM	8.7	1.28	13	50	12.7	0.98	20.3	39.6
UFC	13.2	1.5	24	48.7	16.7	0.97	24.9	45.5
UFF	13.5	1.39	26.4	50.2	17.3	0.88	23.2	43.2
UFG	13.2	1.7	32.2	51.1	11.6	0.87	14.9	41.9
UFBA	17.7	1.89	38.7	48.8	14.2	0.87	17.4	41.6
UFRN	14.4	2.67	35	58	19	0.99	24.4	46.4
UFMS	12.4	1.28	24.3	46.7	9.2	0.85	14.2	33.8
UEM	9.6	1.68	20.5	45.8	10.8	0.95	15.9	40.7
UFPEL	18.4	3.04	48.1	62.6	9.3	0.97	10.6	42.4
UFLA	9.7	1.25	16.7	49.1	10.8	0.92	18.4	35
average	**15.9**	**1.86**	**33.1**	**53.1**	**14.3**	**0.93**	**18.2**	**42.6**

the difference in mean between CNCIA and CNCIC is about 4.5 times larger than the one between CNCIN and CNCIC.

It is worth pointing out that the dispersion of CNCIC is very low, ranging from .52 to .76 with a standard deviation of 0.05. On the other hand, CNCIA shows a far larger range (1.13, 3.04) and standard deviation (0.50). This indicates that a sizable share of the differences in impact among Brazilian institutions may be attributed to the collaboration with the four English-speaking countries. Indeed, CNCI (Table 3) and CNCIA (Table 4) are positively correlated, and the association is statistically significant (r= 0.89, p<.001).

To check whether this effect was associated with the size of the institutions we carried out the same analysis for the sample of 230 institutions in Brazil with at least 200 papers between 2010 and 2019. We found CNCI and CNCIA positively correlated and the association statistically significant (r=0.79, p<.001). We also investigated (for the sample of 230 institutions) the effects of the variables related to the total number of publications (PUB) and to the proportion of publications in ACKS COLL (PPUBA), NOT ACKS COLL (PPUBN), and CORR AUTHOR (PPUBC) in the relationship between CNCI and CNCIA through partial correlation analyses. We found a positive partial correlation relationship between CNCI and CNCIA, controlling for: PUB (r=0.79, p<.001), PPUBA (r=0.87, p<.001), PPUBC (r=0.79, p<.001), and PPUBN (r=0.81, p<.001). The comparison with the zero-order correlation (r=0.79) suggest that controlling for all those covariates had little effect in the relationship between CNCI and CNCIA.

On average, the share of Q1 papers by Brazilian institutions in ACKS COLL is larger than the share of Q1 papers in CORR PAPER. We found a significant difference in the scores for PQ1A (M=53.1, SD=6.2) and PQ1C (M=42.6, SD=3.7), t(24)=7.27, p <.001. Extending the analysis to the sample of 230 institutions with at least 200 papers between 2010 and 2019 we found PQ1 and PQ1A positively correlated and the association very statistically significant (r=0.68, p<.001). We also found a positive partial correlation relationship between PQ1 and PQ1A, controlling for: PUB (r=0.67, p<.001), PPUBA (r=0.57, p<.001), PPUBC (r=0.67, p<.001), and PPUBN (r=0.64, p<.001). The comparison with the zero-order correlation (r=0.68) suggest that controlling for all those covariates had little effect in the relationship between PQ1 and PQ1A.

The advantage of collaborating with researchers from these four countries is also clear in the analysis of specific areas. Table 5 shows the results of the collaboration with the four English-speaking countries in the six areas of the GIPP schema. We will contrast the results of the ACSK COLL set of papers with two baselines: the CORR AUTHOR and the NO ACSK COLL sets of papers.

The percentage of papers in ACKS COLL fluctuates around 20%, except in the case of Engineering and Technology and, most dramatically, the Arts and Humanities. The gains from the collaboration in terms of normalized impact are apparent for both baselines, particularly in the Health Sciences. In the case of the Arts and Humanities, in spite of the low number of papers in ACKS COLL and NO ACKS COLL there are substantial gains associated with international collaboration. However, one of the areas, Engineering and Technology, does not appear to improve from the collaboration to the same extent.

Analysis by GIPP Areas

In Table 6 we summarize the average effects of the ACKS collaboration in the CNCI and percentage of Q1 publications for the 20 institutions with more publications in the period 2010-2019 on the six GIPP areas.

A short analysis of each GIPP area using a larger sample of Brazilian universities follows. We found a positive correlation relationship between CNCI and CNCIA, as well as between PQ1 and PQ1A, in all the areas. A positive correlation was also found between CNCI and CNCIN; however, the differences in mean between CNCIN and CNCIA are also statistically significant, with CNCIA consistently much higher than CNCIN in all the areas. Results of the corresponding t-tests are shown in Tables 7 and 8.

We also found a positive partial correlation relationship between CNCI and CNCIA, as well as between PQ1 and PQ1A, controlling for covariates related to the number of publications (PUB), as well as the percentage of papers in

Table 5: Percentage of papers, Category Normalized Citation Impact, and %Q1 publications for the six GIPP areas: ACKS COLL and CORR AUTHOR sets of papers.

	ALL	ACKS COLL			CORR AUTHOR			NO ACKS COLL		
GIPP AREA	PUB	PPUBA	CNCIA	PQ1A	PPUBC	CNCIC	PQ1C	PPUBN	CNCIN	PQ1N
OVERALL	429528	17.9	1.83	53.9	82.8	0.60	27.6	15.8	0.94	43.5
LIFE	215532	17.1	1.57	53.2	85.1	0.60	24.7	13.4	0.84	40.9
HEALTH	122892	20.7	2.23	50.7	83.4	0.61	22.7	10.4	0.91	38.9
NAT	106940	19.3	1.69	65.1	76.4	0.70	40.0	24.3	0.84	49.9
ENG	72202	14.2	1.17	56.3	82.5	0.74	44.5	22.6	0.94	54.2
SOC	19322	22.8	1.70	46.9	77.4	0.50	24.2	14.4	1.09	35.1
HUM	5767	5.8	2.71	38.3	91.5	0.24	21.0	5.6	1.86	26.2

Table 6: Number of papers, Normalized Impact, and %Q1 publications. Averages of largest Brazilian institutions across the 6 GIPP areas and the four different sets of papers (ALL, CORR AUTHOR, ACKS COLL, and NO ACKS COLL).

	ALL			CORR AUTHOR			ACKS COLL			NO ACKS COLL		
GIPP	PUB	CNCI	PQ1	PPUBC	CNCIC	PQ1C	PPUBA	CNCIA	PQ1A	PPUBN	CNCIN	PQ1N
LIFE	7716	0.87	31	47.4	0.66	28	16.2	2.03	52.5	12.8	0.92	41.5
MED	5885	1.01	28.1	41.6	0.67	26	18.8	2.52	48.3	10	0.9	38.6
NAT	5000	0.98	45.2	50.2	0.71	40	18.7	1.91	64.4	21.4	0.9	49.3
ENG	3093	0.85	46.7	54.9	0.76	45.1	13.2	1.27	55.5	21	0.98	54.1
SSCI	740	0.75	29.9	52.2	0.49	24.9	23	1.65	45.9	13.4	0.86	37.8
HUM	300	0.37	24.8	78.7	0.28	22.6	8.6	1.12	38.6	5.3	0.93	36.5

Table 7: Results of the t-tests on the differences in scores (CNCIA vs CNCIC and CNCIN vs CNCIC) for the different GIPP areas. N is the number of institutions analyzed. M represents the Mean, and SD the Standard Deviation. T provides the values of the t statistic, and p measures the statistical significance of the tests.

				t-tests on the differences in scores							
		CNCIC		CNCIA		t-test		CNCIN		t-test	
GIPP	N	M	ST	M	ST	t	p	M	ST	*t*	*p*
LIFE	219	0.53	0.20	1.86	2.53	31.0	<.001	0.83	0.29	15.3	<.001
MED	181	0.58	0.21	2.18	2.74	7.4	<.001	0.83	0.33	10.7	<.001
NAT	145	0.63	0.19	1.43	0.92	10.6	<.001	0.85	0.21	12.9	<.001
ENG	122	0.80	0.22	1.23	0.57	10.7	<.001	0.76	45.12	7.1	<.001
SSCI	76	0.50	0.21	1.40	0.89	10.3	<.001	0.95	0.32	8.1	<.001
HUM	36	0.21	0.12	1.13	1.50	3.7	<.001	0.74	1.10	3.1	4.E-03

Table 8: Results of the t-tests on the differences in scores (PQ1A vs PQ1C) for the different GIPP areas.

		t-tests on the difference in scores					
		PQ1C		PQ1A		t-test	
GIPP	N	M	ST	M	ST	*t*	*p*
LIFE	219	19.9	10.40	47.0	12.7	32.0	<.001
MED	181	21.5	11.70	42.3	15.6	18.7	<.001
NAT	145	35.3	10.70	57.3	17.8	15.7	<.001
ENG	122	40.4	9.30	53.2	15.8	9.1	<.001
SSCI	76	27.5	10.50	45.8	17.1	11.9	<.001
HUM	36	19.1	18.90	27.8	32.3	1.5	>.05

CORR AUTHOR (PPUBC), ACKS COLL (PPUBC), and NO ACKS COLL (PPUBN). Details are shown in Table 9. Complete datasets used in the analysis are available upon request.

As we shall show, the specific results of the different GIPP areas follow the same pattern observed in the previous analysis of all the scientific production of Brazilian institutions.

Life Sciences

Large Brazilian institutions show CNCI data substantially higher for ACKS COLL papers (CNCIA) than for CORR AUTHOR papers (CNCIC). On average, Brazilian institutions with a sizable scientific production in the Life Sciences (in excess of 1,000 papers between 2020 and 2019) multiply the citation impact by 3, and all of them see their CNCI increase at least two-fold.

We extended the analysis to the 219 institutions in Brazil with at least 100 papers in the Life Sciences between 2010 and 2019. We found CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.90 p<.001, r=0.61 *p*<.001, respectively).

Pre-Clinical and Health Sciences

On average, Large Brazilian institutions (with at least 1,800 papers in the Health Sciences between 2010 and 2019) multiply the citation impact by 3.5. The Health Sciences present the highest volume of citations and CNCIs in Brazilian institutions when compared with the other GIPP areas.

We extended the analysis to the 182 institutions in Brazil with at least 75 papers in the Health Sciences between 2010 and 2019. We found CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.91 *p*<.001, r=0.61 *p*<.001, respectively).

Physical Sciences

On average, institutions with at least 1,800 papers in the Physical Sciences between 2010 and 2019 multiply the citation impact by 2.7. In this area, a decrease in the percentage of papers as corresponding author is observed, on average, when the institutions show larger percentages of papers in collaboration with English-speaking countries; the relationship is statistically significant: PPUBI is negatively correlated with PPUBC (r=-0.84, *p*<.001). The association holds for the Health and Life Sciences as well, but it is not statistically significant (*p*>0.01).

We extended the analysis to the sample of 145 institutions in Brazil with at least 75 papers in the Physical Sciences between 2010 and 2019. We found CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.78 *p*<.001, r=0.66 *p*<.001, respectively).

Social Sciences

On average, institutions with at least 300 papers in the Social Sciences between 2010 and 2019 multiply the citation impact by 3.5.

We extended the analysis to the sample of 76 institutions in Brazil with at least 50 papers in the Social Sciences between 2010 and 2019. We found again CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.78 *p*<.001, r=0.62 *p*<.001, respectively).

Table 9: Partial Correlation between CNCI and CNCIA, as well as between PQ1 and PQ1A, for the the different GIPP areas. The control variables are related to the number of publications (PUB), as well as the percentage of papers in CORR AUTHOR (PPUBC), ACKS COLL (PPUBC), and NO ACKS COLL (PPUBN).

Control	Pearson Correlation CNCI vs CNCIA						Pearson Correlation PQ1 vs PQ1A					
Variable	LIFE	MED	NAT	ENG	SSCI	HUM	LIFE	MED	NAT	ENG	SSCI	HUM
None	0.90	0.91	0.79	0.69	0.75	0.74	0.62	0.65	0.66	0.50	0.62	0.58
PUB	0.90	0.91	0.77	0.69	0.74	0.75	0.61	0.64	0.64	0.50	0.62	0.57
PPUBA	0.92	0.93	0.73	0.68	0.77	0.71	0.57	0.52	0.59	0.48	0.63	0.57
PPUBC	0.90	0.91	0.79	0.69	0.76	0.68	0.52	0.65	0.66	0.50	0.61	0.57
PPUBN	0.92	0.92	0.79	0.68	0.76	0.76	0.60	0.62	0.64	0.47	0.61	0.58

All the correlations statistically significant at $p<.001$

Arts and Humanities

This is an area not well represented in the Web of Science; however, the analysis carried out for the 36 institutions in Brazil with at least 40 papers in the Arts and Humanities between 2010 and 2019 shows that papers in this area also benefit from the ACKS collaboration in terms of citation impact.

We found CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.78 $p<.001$, r=0.58 $p<.001$, respectively).

Engineering and Technology

Papers in the area of Engineering benefit from the collaboration with researchers from English-speaking countries in terms of citation impact, although not to the same extent as the other five areas of knowledge. That difference being acknowledged, it is worth highlighting that on average institutions with at least 1,000 papers in Engineering and Technology between 2010 and 2019 multiply the citation impact by 1.75.

We extended the analysis to the sample of 122 institutions in Brazil with at least 75 papers in the Engineering and Technology between 2010 and 2019. We found CNCI and CNCIA, as well as PQ1 and PQ1A, positively correlated. The association is statistically significant (r=0.69 $p<.001$, r=0.50 $p<.001$, respectively).

ARWUGRAS RESULTS

Since major academic classifications rely on bibliometric data, it is clear that the kind of international collaborations analyzed in the present study are bound to have a positive impact on the ranking positions of Brazilian universities. In particular, the analysis of the Shanghai Ranking by Subjects will enable us to identify the areas in which the positions in the ranking of Brazilian universities most benefit from the collaboration with the four English-speaking countries.

As stated in the section devoted to discussing the methodology, we recalculated the score of all the universities in the ARWUGRAS classifications when bibliometric Figures for papers in collaboration with those four countries were replaced by averages over papers in which the corresponding author belongs to the institution under analysis.

The fact that we used the same procedure for all the institutions on the ARWUGRAS list, not only to Brazilian universities, helps in ensuring a fair comparison.

For each Brazilian university we computed the variation in the position in the ranking, as well as the ratio using the position in ARWUGRAS 2020 as baseline. We summarize the results of all the subjects analyzed in the paper in Table 10, which shows a general overview of all the subjects, including the average of all Brazilian universities listed in the corresponding ARWUGRAS subjects, along with the results of the universities listed in at least five subjects. Complete datasets used in the analyses of the different subjects are available upon request.

DISCUSSION AND CONCLUSION

Results from this paper show that when a Brazilian university takes on the role of the corresponding author, the impact on the research decreases in most fields. Between 2010 and 2019, on average Brazilian institutions had a CNCI for papers in which a corresponding author was associated with them of 0.66, in contrast with the total CNCI of 0.86. These results are in line with the ones obtained by Moya Anegón *et al*.[7] Those authors observed that there is a tendency for the impact to decrease for all countries with respect to the papers in which the corresponding author belongs to the country (except for the USA) when that impact is calculated in relation to the all the papers published by researchers from that country. The results presented in Table 3 and 4 show that Brazil is not an exception to that rule.

The impact gains of papers in which the corresponding author is not affiliated with a Brazilian institution was also observed by Grácio *et al*.[25,26] (2019; 2020) for papers indexed by SCOPUS between 2003 and 2015. The authors-showed that the impact increased by 68.1% when the Brazilian author was not the corresponding author. For the institutions in Table 3,

Table 10: Average ranking ratios (diff/rank) of all Brazilian universities in each subject (column BRAZIL). Ratios of the universities listed in at least five ARWUGRAS subjects, rest of the columns. Acronyms taken from Table 1.

Subject	BRAZIL	USP	UNICAMP	UFRJ	UNESP	UFRGS	UFMG	UFSC	UFPR	UNB
CLI	-195%	-204%				-180%	-191%	-523%		
PUH	**-68%**	-36%				-78%	-96%	-194%		-124%
PHY	**-64%**	-30%	-69%	-98%	-41%					
HBI	**-30%**	-49%		-47%			7%			
BIO	**-25%**	-24%		-26%						
POL	**-17%**	-31%								-3%
MSE	**-12%**	-3%	-21%							
ECO	**-11%**	-12%		-11%						
CHE	**-5%**	-2%	-8%							
BIT	**-4%**	-36%	1%	5%	1%	-1%	3%		2%	2%
ECL	**-4%**	-19%	-2%	-1%	11%	-11%	12%	-8%	5%	-28%
VET	**-3%**	-7%	1%	2%	-15%	-9%	3%	1%	2%	-5%
MEC	**-1%**	2%	2%	-5%	4%	0%	-1%	-6%		
DEN	**-1%**	0%	-65%	11%	5%	1%	10%	-12%	-1%	22%
FOO	**-1%**	0%	0%	1%	4%	12%	-1%	1%	-1%	
AGR	**0%**	4%	1%		-3%	-7%		4%		
ENE	**1%**	-2%	2%	1%	0%	-1%	2%	3%	7%	
CHM	**4%**	7%	12%	4%		6%	4%	3%	3%	
MAT	**6%**	11%	11%	-21%	19%					
PHA	**10%**	24%	9%	6%	10%	14%	5%	10%		
MAN	**11%**	16%			6%					

the increased impact corresponding to the period 2010–2019 was 57.7%, very much in agreement with Grácio *et al.* findings. Whether these findings indicate that researchers led by the Brazilian university teams have a lower impact because they usually deal with topics of local interest is a question that we leave for further work, as it needs more research to be adequately addressed.

The study's initial hypotheses – namely, international collaboration with Australia, Canada, the United Kingdom and the USA benefits Brazilian universities'

a) number of citations received,

b) share of publications in higher impact journals,

c) Brazilian universities' positions in the Shanghai Ranking, were proven right based on the presented data.

The analyses of the number of citations and category normalized citation impact CNCI show large gains for Brazilian universities derived from the association with institutions from Australia, Canada, the United Kingdom, or the United States. As Tables 7, 9 show, Brazilian universities multiply their normalized impact in all the major research areas according to the GIPP classifications (on average, the factor ranges from 1.75 in Engineering and Technology to 3.5 in the Social and Health Sciences). This results support the validity of hypotheses a).

The quartile analysis of the journals in which the papers were published also reveals the positive influence of collaborating with major English-speaking countries, and supports the validity of hypotheses b). On average, 51.5% of the papers in collaboration with these countries were published in journals of the first quartile, almost twice the percentage found for the papers whose corresponding author is affiliated with a Brazilian institution – which represent the 27.5% of the total number of papers.

As shown in Table 10, the areas that concentrate the largest share of the scientific throughput of Brazilian universities clearly highlight the impact of the collaboration with Australia, Canada, The United Kingdom, and the USA in the ARWUGRAS rankings. In particular, two subjects in the Health Sciences, Clinical Medicine (CLI) and Public Health (PUH), account for more than 75% of the scientific production of Brazilian institutions in that area. The large negative ratios point to the great impact in the respective AWUGRAS rankings of the international cooperation with researchers from major English-speaking countries. The two largest areas in the Life Sciences, Biology, and Human Biology, also show large negative ratios. The results in those four subjects are consistent with the large impact of the international ACKS collaboration in CNCI and the proportion of Q1 publications analyzed before in the paper. In the Natural Sciences, Physics is the subject in which the benefits of the cooperation are more noticeable. In the Social Sciences, the benefits are also clear in Economics and Political Sciences. The results in the Engineering subjects show that Brazilian universities, when all the institutions see the effect of the ACKS collaboration removed, keep up with their positions in the ARWUGRAS rankings. Three cases are worth highlighting: Mathematics, Pharmaceutical Sciences, and Management. In those three areas, the quality of the scientific production having a corresponding author affiliated with the Brazilian institutions helps in advancing through the ranking.

Our findings point to a general advantage gained by Brazilian universities in collaboration with Australia, Canada, the United Kingdom, or the United States, thus supporting the validity of hypotheses c) formulated in the Introduction.

The results also help in shedding light over one of the leading questions of this study posed in section 1: "Is there an area of Brazilian science that benefits the most from collaboration?" For a number of subjects, there would be a loss of positions if the collaborations with English-speaking countries were canceled; that would happen, notoriously, for Clinical Medicine, Public Health, Physics, Biology, and Human Biology, subjects that account for more than 40% of the scientific production of Brazilian universities. To a lesser extent, the effect is also noticeable in the areas of Materials Science and Engineering, and Chemistry, subjects that account for more than 10% of the scientific production of Brazilian universities. In the Social Sciences, the benefits are apparent in Economics and Political Sciences.

The second question posed in section 1, "Is there an area in which the Brazilian authors who take on the position of the corresponding author get more recognition?" can also be partially answered using the results from Table 10. Mathematics, Pharmacy, and Management emerge as the areas in which the extra help from international collaboration is not needed to advance in the respective rankings.

Corroborating Bordons *et al*.[6] and Wagner,[3] our results for some of the analyzed subjects show that researchers and institutions with unique knowledge can be found in Brazil. Those scientists can become strategic partners not only for their geographical, biological, or social conditions but also for their expertise in specific disciplines. According to the report on scientific collaboration published by the Royal Society (2011), science is becoming increasingly global, and the participation of all countries is necessary to face problems that affect all countries.

Prompted by an analysis of highly cited scientists in Latin America, Martinez and Sá[27] stated that while yet a regional leader, as far as scientific production is concerned, Brazil is still relatively peripheral to global science. Mc Manus *et al*.[8] argue that their findings point in a different direction, one in which "Brazilian researchers are seen to be effectively collaborating to world prominent themes of high impact and to advance the innovative science". Our results corroborate Mc. Manus *et al*.[8] findings in what concerns the advancement of innovative science in Brazil through international scientific collaboration. However, we have also shown that the gap between the impact of the science produced in Brazil with or without international collaboration with major English-speaking countries is still noticeable, particularly in Physics and the Health and Life Sciences.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1. Beaver DB, Rosen R. Studies in scientific collaboration: Part I – the professional origins of scientific co-authorship. Scientometrics. 1978;1(1):65-84.
2. Schmoch U, Schubert T. Are international co-publications an indicator for quality of scientific research? Scientometrics. 2008;74(3):361-77.
3. Wagner C. The New Invisible College. 2008, Washington: Brookings Institution Press.
4. González Alcaide G, Park J, Huamani C, Ramos JM. Dominance and leadership in research activities: Collaboration between countries of differing human development is reflected through authorship order and designation as corresponding authors in scientific publications. Plos One. 2017. https://doi.org/10.1371/journal.pone.0182513
5. Van Leeuwen TN. Strength and weakness of national science systems: A bibliometric analysis through cooperation patterns. Scientometrics. 2009;79(2):389-408.
6. Bordons M, González-Albo B, Aparicio J, Moreno L. The influence of R&D intensity of countries on the impact of international collaborative research: Evidence from Spain. Scientometrics. 2015;102:1385-400.
7. Moya Anegón F, Guerrero Bote VP, Bornmann L, Moed HF. The research guarantors of scientific papers and the output counting: A promising new approach. Scientometrics. 2013;97: 421-34.
8. McManus C, Baeta Neves AA, Maranhão AQ, Souza Filho AG, Santana JM. International collaboration in Brazilian science: Financing and impact. Scientometrics. 2020;125:2745-72.
9. Hu Z, Tian W, Guo J, Wang X. Mapping research collaborations in different countries and regions: 1980-2019. Scientometrics. 2020;124:729-45.
10. Glänzel W. National characteristics in international scientific co-authorship relations. Scientometrics. 2001;51(1):69-115.
11. Persson O, Glänzel W, Danell R. Inflationary bibliometric values: The role of scientific collaboration and the need for relative indicators in evaluative studies. Scientometrics. 2004, 60;(3):421-32.
12. Jones B, Wuchty S, Uzzi B. Multi-university research team: Shifting impact, geography, and stratification in science. Science. 2008;322:1259-62.
13. Leta J, Chaimovich H. Recognition and international collaboration: The Brazilian case. Scientometrics. 2002;53(3):325-35.
14. Vanz SA, Stumpf IR. Colaboração científica: Uma revisão teórico conceitual. Perspectivas em Ciência da Informação. 2010;15(2):42-55.
15. Hsiehchen D, Espinoza, Hsieh A. Multinational teams and diseconomies of scale in collaborative research. Science Advances. 2015;1(8):e1500211.
16. Katz JS, Martin BR. What is research collaboration? Research Policy. 1997;26:1-18.
17. Chinchilla-Rodríguez Z, Larivière V, Costas Comesaña R, Robinson-García N, Sugimoto CR. Building ties across countries: International collaboration, field specialization, and global leadership. Proceedings of the 23rd International Conference on Science and Technology Indicators. 2018;1509-18.

18. Hazelkorn E. How Rankings are Reshaping Higher Education. in Climent, V., Michavila, F. and Ripolles, M. (eds) Los Rankings Universitarios. Mitos y Realidades. 2013.
19. Kaycheng S. Multicolinearity and indicator redundancy problem in world university rankings: An example using Times Higher Education World University Ranking 2013-2014 data. Higher Education Quarterly. 2015;69(2):158-74.
20. Robinson-Garcia, N, Torres-Salinas, D, Herrera-Viedma, E, Docampo, D. Mining university rankings: Publication output and citation impact as their basis. Research Evaluation, 2019;28(3):232-40.
21. Xiaojun H, Rousseau R, Jin C. In those fields where multiple authorship is the rule, the *h*-index should be supplemented by role-based *h*-indices. Journal of Information Science. 2010;36(1):73-85.
22. Wouters P, Thelwall M, Kousha K, Waltman L, de Rijcke S, Rushforth A, Franssen T. The Metric Tide: Literature Review (Supplementary Report I to the Independent Review of the Role of Metrics in Research Assessment and Management). 2015, HEFCE.
23. Man JP, Weinkauf JG, Tsang M, Sin D. Why do some countries publish mores than others? An international comparison of research funding, English proficiency and publication output in highly ranked general medical journals. European Journal of Epidemiology. 2004;19:811-7.
24. ARWUGRAS (2020). Methodology for ShanghaiRanking's Global Ranking of Academic Subjects 2020. http://www.shanghairanking.com/Shanghairanking-Subject-Rankings/Methodology-for-ShanghaiRanking-Global-Ranking-of-Academic-Subjects-2020.html#5. Accessed 13 July, 2020.
25. Cabrini Grácio MC, Tannuri de Oliveira EF, Chinchilla-Rodríguez Z, Moed HF. The influence of corresponding authorship on the impact of collaborative publications: A study on Brazilian institutions (2003-2015). Proceedings of the 17th International Conference on Scientometrics and Informetrics, 2019;511-22.
26. Cabrini Grácio MC, Tannuri de Oliveira EF, Chinchilla-Rodríguez Z, Moed HF. Does corresponding authorship influence scientific impact in collaboration: Brazilian institutions as a case of study. Scientometrics. 2020;125:1349-69.
27. Martinez M, Sá C. Highly Cited in the South: International Collaboration and Research Recognition among Brazil's Highly Cited Researchers. Journal of Studies in International Education. 2020;24(1):39-58.