XX Colóquio Internacional de Gestão Universitária - CIGU 2021
Universidade frente aos desafios da Pandemia:
Cenários Prospectivos para a Gestão Universitária

Evento virtual
24 e 25 de novembro de 2021
ISBN: 978-85-68618-08-0

Using the "U-Multirank" to Compare the Performances of Brazilian Universities with Latin American Countries in Academic and Industry Products

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ABSTRACT

The present research makes comparisons of the performances of Brazilian Universities in terms of academic and industry related production, based in the "U-Multirank", in the years 2017 to 2020. These comparisons are made with other Latin American countries listed in this ranking. Academic production is measured by indicators related to the number of papers published and citations received by Brazilian Universities, while Industry related products performance is based in the number of patents obtained and citations that Brazilian publications received in patents. This analysis is made for the average performances of all Brazilian universities listed in the "U-Multirank", which is an academic multidimensional ranking implemented in Europe in 2014. It is based in five Dimensions, which are composed by 35 Indicators, with some of them related to pure academic productions and some others related to researches that are applied to industry. The results show that the performances of Brazilian universities are better in terms of academic products and below average in industry related products, such as the number of patents. It is also noted improvements in those numbers, a tendency that needs to be verified in the future. In Latin America, Chile has the best performances in all the Indicators related to Industrial products.

Key Words: University-Industry relations, Patent production, Applied research, Academic rankings, Multidimensional academic evaluation.

1. INTRODUCTION

Of course, the main mission of a University is to provide good quality graduates that can help society to solve their problems, in all fields of knowledge. This is true since the appearance of the first Universities. It is also well known that another important contribution of the Universities is to make high level research, which is usually known as the second mission of the Universities. This mission increased in importance with the advance of the knowledge in all fields, because science becomes more specialized and a high level of specialization becomes mandatory for researches to be able to make further advances in science. This is how the "Research Universities" appeared, combining teaching and cutting edge level research.

Next, a third mission emerged, usually called "extension" (LAREDO, 2007), to connect the Universities more directly with society. It includes short and medium courses offered for non students of the University, cultural activities, divulgation of science, collaboration with industry, etc. Among those activities, one of the most important is related to the so called "University-Industry" links. This general term covers several aspects of those relations, like formal and informal consulting, co-production of research that is immediately applied to new products made in industry, etc. This is a strong form of collaboration with society, because it increases the capability of the national and/or regional industry, generating more financial revenue to industry and society, opening more high-skilled jobs and making better products for the society.

This is true in every region of the globe, but the level of these "University-Industry" collaborations vary very much from region to region and with the time frame analyzed. Countries that had an earlier industrialization usually have stronger and older University-Industry links, while later industrialized countries have a tendency to import technology from abroad and keep their research and development laboratories only for product adaptations and testing, with no larger technological advances. This part of the third mission was the reason for discussions everywhere when it appeared, even in the earlier industrialized countries. Those links generated many debates, with some academic personal afraid of losing the characteristics of the basic research done in Universities (ROSENBERG and NELSON, 1994).

Despite causing debates, those links proved to be very important and they did not harm activities of basic research developed in the Universities. For example, in the USA, in the beginning of the 1990s, 2/3 of the researches performed in the universities were defined as "basic research" (ROSENBERG and NELSON, 1994). This type of research is considered too expensive by the Industry and it is very hard to get possession of the results, which are usually in open access form, which do not give economical returns for those who pay the costs of development. These two facts reduce the interest of industries in basic research, leaving this task to governments.

Following the time line of more connectivity between Universities and Industries, many Universities were created already linked with local economic activities, like the exploration of petrol, agriculture, etc. Many courses in engineering were also created in the USA with a strong link between academy and industry in the second half of the 19th century (ROSENBERG and NELSON, 1994).

In Germany, where the "Research University" was created, the model of the "Entrepreneurial University" (CLARK, 1998) was more popular, in particular in some fields like chemistry, military applications, medicines and agriculture. It was common to have professors and scientists walking in universities and industry. Another fact that helped in creating "University-Industry" links was that "Technical Universities" started to appear in Germany and other European countries, so completing the three types of University that we know today: "Research University", also called "Classical University", "Technical Universities" and "Entrepreneurial University" (DE CAMPOS, 2010). Basic and applied researches were combined in the Universities and the number of graduates increased. Those were two important reasons for the success of German industries.

Looking at Asia, Japan increased a lot "University-Industry" relations after the Second World War, in particular in electronics, with more than one hundred Laboratories of research and development appearing in the period 1955-1963, with large support from universities (DE CAMPOS, 2010). This was done to make a strong industry to recover Japan from the Second World War and the results are well known for the successes achieved.

Looking for theoretical models for the "University-Industry" links, one of the most popular is the so called triple-helix (THUNE, 2010). This model is based in the collaboration between Universities, Industry and Government. The University is the "knowledge provider", offering experts, laboratories and infra-structure to perform research. The Industry is the "knowledge demander", bringing specific needs of results that allow them to improve existing products and/or to create new products. The government is responsible for organizing those links. Under this model, many graduate students are paid by Industry to develop research in topics of interest of industry and this research is usually performed in the University, under the supervision of a professor that is part of the team. Graduate students play a major rule in the process of creating and increasing the "University-Industry" links under this model.

This idea was further explored in the so called "Sabato Triangle" (SABATO and BOTANA, 1969; DE CAMPOS and DA COSTA, 2014), where the government, productive sector and the Scientific and Technological Infra-structure are positioned in the three vertex of a triangle that describe the scientific and technological system of a country. This model was later expanded by DAGNINO (2004), to include one more vertex, the one related to social demands.

The literature also defines the concept of "mode 2" of university research, where the research is motivated by practical problems and is mostly interdisciplinary. It is opposed to "model 1", where the main goal is to generate more knowledge, independent of its needs for practical problems (GIBBONS et al., 1994).

The literature also shows that there are basically three main forms of links between Universities and Industry (DE CAMPOS, 2010). The first and basic one is the formation of skilled professionals in technical areas that are used by industry after their graduation. It was the main form of collaboration between Universities and Industries in Latin America in the early 1960´s (DE CAMPOS, 2010). With the increase of technology in modern products, this point becomes fundamental to develop the economy of every country, since skilled labor was mandatory. After that, we have informal consulting, the second type of link, when university professors participate in industrial activities without a formal contract. This is usually a starting point for a better organized link that comes with the formalization of the joint work in a contractual form, which is the third form of link. It works very well, in particular in some specific areas like mining, agriculture and defense (DE CAMPOS, 2010).

In Latin American countries, in particular in Brazil, the first universities were created as "Classical Universities", with more focus on teaching and basic research. This model comes from the USA, where big universities using this model dominated the educational system. But it is important to mention that there is a big difference, when comparing Brazil with more developed countries, which is the lower demand of knowledge from Industry. In particular, the changing in the rules for importation of technology from more developed countries, which occurred in the 1990´s, facilitated the process of bringing foreign technology to Brazil, leaving just simple tasks to be made inside the country, like adaptation and quality control of products, which require just small technological steps. BERNASCONI (2008) calls attention that this low demand for "new knowledge" from Industry in Latin America will only change if there is an economic growth that is large enough to make the Industry to reach high levels of innovation. If this economic growth does not happen, the American model of "Research University" with strong links to Industry will not work in Latin America and the government will need to stay making most of the financial support to the public universities.

Another point showed by surveys is that the majority of the links "University-Industry" are made with larger industries, because they have more technological capabilities to absorb the research developed in universities (DE CAMPOS, 2010). Many of them are international companies, with a strong culture of using those links that come from their original countries

In general, the links centralized in educational activities remain the most important one in Brazil and Latin America. Besides this aspect, there were evidences that Latin America was already moving to the "triple helix" model in the last years of the 20th century (ETZKOWITZ and BRISOLLA, 1999) and that a growing number of patents in Brazilian Universities appeared in the early years of the 21st century (ETZKOWITZ et al., 2005). Surveys showed that these links have been forced by the reduction of financial resources given by the government to the universities, but the majority of professors were usually satisfied with those links, not only for the extra resources, but also for getting new ideas for research (DUTRENIT and ARZA, 2010). Later, it was shown that most of the production of patents was coming from incubation activities and spin-off companies appearing in the universities (ANPROTEC, 2020).

A good example of productive cooperation between academic and productive sectors can be found in São José dos Campos, Brazil, in the aerospace field (CINTRA, COSTA and DE CAMPOS, 2019; PELLEGRINI et al., 2017). The city has about a dozen of companies in the sector, as well as the "Instituto Nacional de Pesquisas Espaciais (INPE)", which includes technological researches and seven graduate courses in the space field, and the "Departamento de Ciência e Tecnologia Aeroespacial (DCTA)", a military organization that has several institutes for research and the "Instituto Técnológico da Aeronáutica (ITA)", an academic institution offering graduate and undergraduate courses. Campinas also has examples of this type of collaboration (DAGNINO and VELHO, 1998).

Motivated by those facts, we found that it is very important to verify the evolution of more Industry related production (patents), in particular compared to more academic production (papers in journals) of the Brazilian Universities. This comparison is important, because the university system is growing in Brazil in the last decades, even in the public system. It means that a growing number of patents may not reflect an increasing focus in applied research, but it may be just a consequence of an increase in the system. The type of measurement made in the present paper can show the evolution of the focus of the researches made in the Brazilian Academic Institutions.

There are many ways to study this problem. The present paper uses the data available in the "U-Multirank" (https://www.umultirank.org/; PRADO 2021a; PRADO, 2021b; PRADO, 2021c) to measure the "University-Industry" links. A comparison of the academic and industry related production of the Brazilian universities that are present in this ranking in the years 2017-2020 will be used. One reason to use this ranking is that it gives some indicators that can be used for this comparison against any other country and the world average.

Therefore, a comparison will be made between the average grades obtained by Brazilian Universities with the average grades obtained by all the universities listed in the ranking and for the countries Argentina, Chile, Colombia, Equator and Peru, which represent the South American countries that appear in this ranking, and Mexico and Costa Rica, to represent Latin American countries in the North and Central America.

2. THEORETICAL FOUNDATION

The studies performed here are based in the international multidimensional academic ranking "U-Multirank", so some basic explanations about academic rankings are required, as well as some more details about the "U-Multirank".

In the early years of the XXI century, several Academic International Rankings appeared to try to classify Academic Intuitions in single rankings (RIGHETTI, 2015). The first one was the "Academic Ranking of World Universities (ARWU) (http://www.shanghairanking.com/ARWU2020.html), known as "Shanghai Ranking". It appeared in 2003. After that, there is the appearance of "The Webometrics Ranking of World Universities" (http://www.webometrics.info/en) in 2004 and the "THE-QS", later divided into "Times Higher Education World University Rankings" (https://www.timeshighereducation.com/world-university-rankings) and "QS World University Rankings" (https://www.topuniversities.com/university-rankings).

The concept of a multidimensional ranking appeared in 2008 (VAN VUGHT and ZIEGELE, 2012), and it generated the "U-Multirank" (https://www.umultirank.org/). It uses five Dimensions to evaluate academic institutions: (1) Teaching and Learning, (2) Research, (3) Knowledge Transfer, (4) International Orientation and (5) Regional Engagement. The Dimensions are composed by a large number of Indicators, which give a broad view of the Institutions. This ranking is still not much popular in South America and, from the about 1800 Academic Institutions listed in the 2020 version of "U-Multirank", only 35 are from South America: 20 from Brazil, 6 from Chile, 3 from Argentina, 3 from Colombia, 2 from Ecuador and 1 from Peru.

3. METHODOLOGY

To make the analysis proposed here, we first look at the average performances of all the Brazilian Institutions listed in all the Indicators of each of the five Dimensions of the "U-Multirank", considering the years 2017 to 2020. There are 35 Indicators that were used in the four years considered by the present study. From those 35 Indicators, we see that 11 of them have more than 90% of data reported for Brazilian Institutions in at least two of the years studied. Considering those 11 Indicators, four of them can be considered as related to academic production: Citation rate, Research publications (absolute numbers), Research publications (size-normalized) and Top cited publications. There are also four Indicators that can be used to measure the output of "University-Industry" relations: Co-publications with industrial partners, Patents awarded (absolute numbers), Patents awarded (size-normalized), Publications cited in patents. The present study concentrates in these eight Indicators. Next, we define those indicators, taking the information from https://www.umultirank.org/export/sites/default/press-media/documents/Indicator-Book-2019.pdf.

> Citation rate is "the average number of times the university's research publications are cited in other research in a period of four years before the evaluation; normalized at the global level to take into account differences in publication years and to allow for differences in citation customs across academic fields."
>
> Research publications (absolute numbers) is "the number of university's research publications (indexed in the Web of Science Core Collections database), where at least one author is affiliated to the source university or higher education institution."
>
> Research publications (size-normalized) is "the number of research publications (indexed in the Web of Science database), where at least one author is affiliated to the university (relative to the number of students)."
>
> Top cited publications is "the proportion of the university's research publications that, compared to other publications in the same field and in the same year, belong to the top 10% most frequently cited worldwide."
>
> Co-publications with industrial partners is "the percentage of the university's research publications that list an author affiliate with an address referring to a for-profit business enterprises or private sector R&D unit (excludes for-profit hospitals and education organizations)."
>
> Patents awarded (absolute numbers) is "the number of patents assigned to (inventors working in) the university (over the period 2008-2017)." Those years are valid for the 2020 version of the ranking.
>
> Patents awarded (size-normalized) is "the number of patents assigned to (inventors working in) the university over the period 2008-2017 (per 1,000 students)." Those years are valid for the 2020 version of the ranking.
>
> Publications cited in patents is "the percentage of the university's research publications that were mentioned in the reference list of at least one international patent (as included in the PATSTAT database).

For items related to patents, only granted patents are used, obtained from the database of the "European Patent Office" (https://data.epo.org/access-control/patstatsubscription.jsp). Longer periods of time are used for the patents, because the process of getting them is quite long. As an example, the 2020 version of the rank uses data from 2008-2017. Those eight Indicators will be used to compare the evolution of academic and industry related products. Since "U-Multirank" gives letter grades from A (highest) to E, we use the correspondences A = 5, B = 4, C = 3, D = 2 and E = 1 to make the numerical averages. A grade zero was attributed in case of missing data and "Not Applicable" data were excluded from the averages.

4. RESULTS

The first observation to be made when looking at the "U-Multirank" site is that missing data is an important problem in this ranking when looking for comparisons. It happens due to the large number of Indicators and the fact that a high percentage of the data comes from questionnaires answered by the Universities, and many of them do not report data properly. As an example, Brazilian Institutions have 44.71% of available data in the years 2019 and 2020, an increase when compared to a minimum of 38.48% in 2018, but still below world average, which reached 54.46% in 2020. It means that we have to improve data report to get better positions in this ranking, since Brazilian Institutions are still about 10% below world average in terms of data available, despite of the increases observed in the last two years. To have a comparative view of the percentage of data reported for the countries in South America, we build Figure 1. It shows the percentage of data reported for each South American country that appear in the U-Multirank for the four years considered. It is observed that Brazil oscillates between 40% and 45% of data available, with a small increase in the last two years considered (2019 and 2020), which is an indication of improvements in the numbers.

In terms of comparisons, Brazil has better numbers only when compared to Argentina, which oscillates between 35% and 40% of data reported. Colombia is on the top, with an average of 70%. Ecuador made a large increase, from less than 40% in 2018 to near 60% in 2020, a second place in this year. Peru is third in 2020, with a little more than 50%, a strong decrease from the near 70% reached in 2017 and 2018 and the 60% obtained in 2019. Chile started near 55% in 2017, oscillated positively in 2018 to more than 60%, but decreased to a little less than 50% in 2020. Those comparisons give some information about data reported, but needs to be examined carefully. The numbers of Academic Institutions in the countries are very different and they vary from year to year. Table 1 shows the number of Institutions for each South American country in the period analyzed, showing a predominance of Brazilian Institutions.

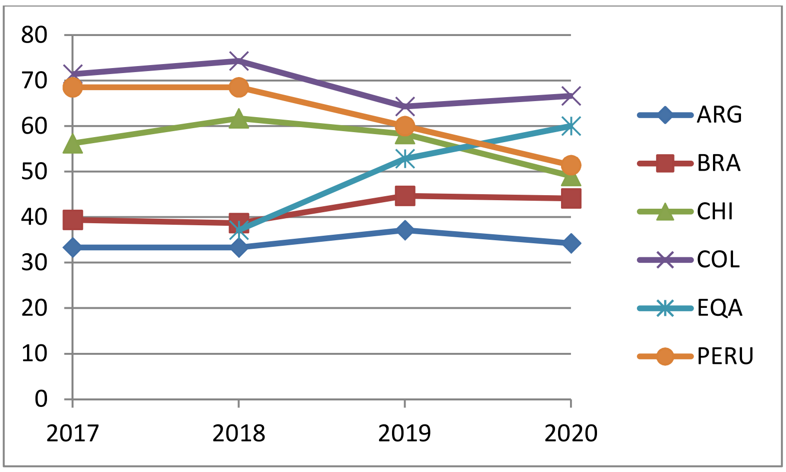

Figure 1 - Percentage of data reported by the South American countries in the U-Multirank for the period 2017-2020.

Table 1 – Number of Academic Institutions from South America in the U-Multirank for the period 2017-2020.

	2017	2018	2019	2020
Argentina	3	3	2	3
Brazil	15	15	17	20
Chile	3	5	5	6
Colombia	1	1	2	3
Ecuador	0	1	2	2
Peru	1	1	1	1

Table 2 shows in detail the performance of the Brazilian Universities considering those eight Indicators. BR represents the average of the Brazilian Universities, AR represents Argentina, CH Chile, CO Colombia, EC Ecuador, PE Peru, CR Costa Rica, MEX Mexico and WR the average of all Universities in the world that are listed each year. Regarding the two countries outside South America, added to extend the comparisons, Costa Rica has only one University listed in the years 2017 to 2020 and Mexico has seven Universities from 2018 to 2020 and eight in 2017.

Table 2 Average Performances of the Universities in the Latin American countries in the Indicators selected for the comparisons.

Indicator	**2017**	**2018**	**2019**	**2020**
Citation rate	AR 2.00 **BR 2.20** CH 2.67 CO 2.00 EC ----- PE 3.00 CR 0.00 MX 2.14 ***WR 3.60***	AR 2.00 **BR 2.27** CH 2.80 CO 2.00 EC 0.00 PE 2.00 CR 0.00 MX 2.17 ***WR 3.63***	AR 2.00 **BR 2.24** CH 3.40 CO 2.00 EC 3.00 PE 2.00 CR ---- MX 2.17 ***WR 3.53***	AR 2.00 **BR 2.26** CH 3.14 CO 2.33 EC 3.00 PE 2.00 CR ---- MX 2.17 ***WR 3.48***
Research publications absolute numbers	AR 4.00 **BR 4.00** CH 3.67 CO 3.00 EC ----- PE 3.00 CR 0.00 MX 3.12 ***WR 3.41***	AR 4.00 **BR 3.93** CH 3.40 CO 3.00 EC 0.00 PE 3.00 CR 0.00 MX 3.29 ***WR 3.45***	AR 3.00 **BR 4.12** CH 3.00 CO 3.50 EC 2.00 PE 4.00 CR 0.00 MX 3.29 ***WR 3.24***	AR 3.33 **BR 4.00** CH 3.83 CO 3.00 EC 2.50 PE 3.00 CR 1.00 MX 3.57 ***WR 3.34***
Research publications size-normalized	AR 2.00 **BR 3.67** CH 3.33 CO 2.00 EC ----- PE 2.00 CR 0.00	AR 2.00 **BR 3.73** CH 3.00 CO 2.00 EC 0.00 PE 2.00 CR 0.00	AR 4.00 **BR 4.00** CH 4.00 CO 2.50 EC 2.00 PE 3.00 CR 0.00	AR 4.00 **BR 4.20** CH 4.17 CO 2.38 EC 3.00 PE 2.00 CR 1.00

	MX 2.50 ***WR 3.61***	MX 2.57 ***WR 3.65***	MX 2.00 ***WR 3.49***	MX 3.43 ***WR 3.49***
Top cited publications	AR 2.00 ***BR 2.00*** CH 2.00 CO 3.00 EC ----- PE 2.00 CR 0.00 MX 2.14 **WR 3.61**	AR 2.00 ***BR 2.13*** CH 2.60 CO 2.00 EC 0.00 PE 2.00 CR 0.00 MX 2.00 **WR 3.63**	AR 2.00 ***BR 2.12*** CH 3.20 CO 2.00 EC 2.50 PE 2.00 CR ----- MX 2.17 **WR 3.53**	AR 2.00 ***BR 2.00*** CH 3.00 CO 2.00 EC 2.00 PE 2.00 CR ----- MX 2.17 **WR 3.52**
Co-publications with industrial partners	AR 2.33 **BR 2.60** CH 2.67 CO 3.00 EC ----- PE 2.00 CR 0.00 MX 3.00 ***WR 3.74***	AR 2.00 **BR -----** CH 2.20 CO 3.00 EC 0.00 PE 2.00 CR 0.00 MX 2.33 ***WR 3.58***	AR 2.00 **BR 2.06** CH 2.80 CO 3.50 EC 4.00 PE 2.00 CR ---- MX 2.33 ***WR 3.54***	AR 2.00 **BR -----** CH 3.50 CO 2.67 EC 4.50 PE 2.00 CR ---- MX 2.17 ***WR 3.51***
Patents awarded absolute numbers	AR 1.67 **BR 1.87** CH 3.00 CO 1.00 EC ----- PE 2.00 CR 0.00 MX 1.62 ***WR 2.58***	AR 1.67 **BR 1.93** CH 2.40 CO 2.00 EC 0.00 PE 2.00 CR 0.00 MX 1.71 ***WR 2.54***	AR 2.00 **BR 1.82** CH 3.40 CO 1.50 EC 1.00 PE 2.00 CR 0.00 MX 1.71 ***WR 2.51***	AR 1.67 **BR 1.65** CH 2.83 CO 1.00 EC 1.00 PE 2.00 CR 0.00 MX 1.57 ***WR 2.41***
Patents awarded size-normalized	AR 1.67 **BR 2.13** CH 3.00 CO 1.00 EC ----- PE 2.00 CR 0.00 MX 1.37 ***WR 2.60***	AR 1.67 **BR 2.13** CH 2.40 CO 2.00 EC 0.00 PE 2.00 CR 0.00 MX 1.43 ***WR 2.57***	AR 2.00 **BR 2.00** CH 3.40 CO 1.50 EC 1.00 PE 2.00 CR 0.00 MX 1.43 ***WR 2.53***	AR 2.00 **BR 2.45** CH 3.00 CO 1.00 EC 1.00 PE 2.00 CR 0.00 MX 1.71 ***WR 2.42***
Publications cited in patents	AR 2.00 **BR 2.07** CH 2.33 CO 1.00 EC ----- PE 2.00 CR 0.00	AR 2.33 **BR 2.20** CH 2.40 CO 3.00 EC 0.00 PE 2.00 CR 0.00	AR 2.50 **BR 2.29** CH 3.20 CO 2.50 EC 1.00 PE 2.00 CR ----	AR 1.67 **BR 2.11** CH 3.17 CO 2.67 EC 1.50 PE 2.00 CR ----

	MX 2.00 ***WR 3.22***	MX 2.17 ***WR 3.43***	MX 2.00 ***WR 3.45***	MX 2.33 ***WR 3.34***

Table 2 shows that the average performances of the Brazilian Universities are not bad in the Indicators used here for the comparisons. It is important to remember that Brazil has around 20 Universities listed every year, so comparisons with countries that have just a few Universities are not so good, since the other countries may be represented only by good performance Universities. In that sense, the comparisons with the world average make more sense, and the present paper will focus more on this point, although it does not neglect neighbor countries. To make a summary of the comparisons with the world averages, Table 3 is made. It shows the relative grades of Brazilian Institutions with respect to the world averages (grades of Brazil divided by the world averages) in the four years studied.

Table 3 - Average of the relative grades of Brazilian Institutions in the period 2017-2020.

Indicator	**2017**	**2018**	**2019**	**2020**
Citation rate	**0.61**	**0.63**	**0.63**	**0.65**
Research publications absolute numbers	**1.17**	**1.14**	**1.27**	**1.20**
Research publications size-normalized	**1.02**	**1.02**	**1.15**	**1.20**
Top cited publications	**0.55**	**0.59**	**0.60**	**0.57**
Co publications with industrial partners	**0.70**	**-----**	**0.58**	**-----**
Patents awarded absolute numbers	**0.65**	**0.76**	**0.73**	**0.68**
Patents awarded size-normalized	**0.82**	**0.83**	**0.79**	**1.01**
Publications cited in patents	**0.64**	**0.64**	**0.66**	**0.63**

In terms of "Citation rate", Brazil is behind the averages of Chile and the world and ahead of Mexico every year. In fact, all the countries used for comparisons are behind the world average in all the years and usually by a large amount. Chile is in first place in the interval 2018-2020, with Peru first in 2017, but with only one university listed in the ranking. It is important to mention the existence of the "Very Large Telescope (VLT)" array, which is a telescope facility operated by the European Southern Observatory on Cerro Paranal, in the Atacama Desert, in northern Chile. It generates a large number of publications that have many citations and they increase the Chilean numbers in this Indicator. In terms of results relative to the world average, Brazil has small but consistent increases, going from 0.61 in 2017 to 0.65 in 2020. This continuous increase is in agreement with CROSS, THOMSON and SINCLAIR (2017), which studied this point in the interval 2011-2016, using a different methodology and data from all the Academic and Research Institutes in Brazil, not only a few of them listed in this ranking, and also verified a constant increase from year to year.

In terms of “Research publications (absolute numbers)”, the Brazilian Universities are in first place compared to the other selected countries and ahead of world averages, except in 2018, where Argentina is ahead by 0.07 points. Looking at the relative evolution of the Brazilian Universities compared to the world average, which is a better comparison, it is clear that Brazil has between 17% and 27% more publications than world average, depending on the year considered, which are large amounts.

The same occurs for “Research publications (size-normalized)”, with Brazilian grades ahead of world averages and all the other countries studied in all the years. Chile is always in the second place, with Argentina strongly increasing its numbers in the last two years, making even a triple tie with Brazil and Chile in 2019 and remaining very close to them in 2020. The results relative to the world averages show an important increase in the last two years, going from 1.02 in 2017-2018 to 1.15 in 2019 and 1.20 in 2020. It is also interesting to note that those numbers are smaller than the ones for “Research publications (absolute numbers)”, except for 2020, when those numbers are identical (1.20), 20% above world average, a very significant result.

The results are not so good in terms of the Indicator “Top-cited publications”, with Brazilian Universities far behind world average. Chile leads in the period 2018-2020 and Colombia in 2017. Brazil is very close to all the other countries studied with scores close to 2.00, against a world average above 3.5 in this Indicator every year. The relative results shown in Table 3 make it very clear, with Brazilian numbers in the range from 0.55 to 0.60 with oscillations, without a general tendency. It shows that the overall production of publications of Brazilian Universities is large, but a smaller percentage of them, compared to world averages, are listed as “Top-cited” publications. Those results are in agreement with CROSS, THOMSON and SINCLAIR (2017), which shows that the number of Brazilian publications had a much better position, in 13th in the world, but the papers listed in the 1% and 10% more cited papers were below world average, in the period going from 2011 to 2016. This fact needs to be better studied, but one of the possible explanations given by CROSS, THOMSON and SINCLAIR (2017) is the recent appearance of additional 87 Brazilian journals in the Web of Science. This is itself a good sign of the importance of Brazilian science, but those journals are not so well known internationally and usually focused in local problems, so the papers that appear in those journals have lower citation rates. Since the majority of the papers published in those journals are from Brazil, this fact decreases the average citation rate of Brazilian papers. Therefore, this fact is not necessarily bad for Brazilian sciences. It may indicate a focus in solving local problems and strong regional links with society. Of course this point deserves deeper studies, to separate local important science from science that is just not good enough to have good impact. CROSS, THOMSON and SINCLAIR (2017) also shows that Brazilian papers were increasing fast and in a consistent form in terms of citations in the period 2011-2016.

Regarding “Co-publications with industrial partners”, the first observation is that it is necessary to improve data report. There are data available for 2017 and 2019; both of them much below world average, but these data are missing in 2018 and 2020. In this Indicator, Ecuador has a large leadership in the period 2019-2020, even ahead of the world averages, but the results are based in only two institutions. Brazil is always behind Chile and Colombia. It is also noted a significant decrease in the results relative to the world averages in the two years reported, from 0.70 in 2017 to 0.58 in 2020.

Coming now to the production of patents, one of the main focuses of the present research, it is clear that this is a weak point in Brazil. The Indicator “Patents awarded (absolute numbers)” has Chile in the first place every year and ahead of the world averages, except in 2018. All the other countries have results below world average, which may indicate that the links “University-Industry” are deficient in Latin American countries. Brazil is consistently ahead of Mexico by small amounts. When looking at the relative results shown in Table 3, this weak point is very clear, since the numbers are in the interval from 0.65 to 0.76, with decreasing numbers in the last three years. Of course the present study uses only few institutions, but it gives indications of aspects that need to be better studied.

Moving now to the Indicator “Patents awarded (size-normalized)”, Brazilian numbers improved. The differences with the world average are reduced and, in 2020, we have reached results above world average. Chile is still the first every year and beats world average in 2017, 2019 and 2020, but Brazil is now in second place every year. The relative results confirm this improvement, with numbers in the interval from 0.82 in 2017 to 1.01 in 2020. It means that our rate of conversion of publications in patents is improving. This Indicator is better when compared to “Patents awarded (absolute numbers)”, because it considers the sizes of the Institutions.

For “Publications cited in patents”, Brazil is behind world averages every year by more than one point. Chile is in the first place in 2017, 2019 and 2020, with Colombia first in 2017. Colombia is in the second place in 2019 and 2020. Brazil has results very similar to Mexico. The numbers relative to the world averages are very similar each year, with small variations in the range 0.63 to 0.66. An interesting fact to be observed is the rate between the relative grades obtained in “Publications cited in patents” and “Citation Rate”. The results are: 1.05 in 2017, 1.02 in 2018, 1.05 in 2019 and 0.97 in 2020. It indicates that Brazilian citations in academic and industry related products are very similar, with all numbers close to 1.0. It is an indication that the importance of Brazilian Science is about the same in the two types of products.

5. CONCLUSIONS

The combination of results obtained here gives indications that Brazilian Universities need to improve data reported to get better positions in the “U-Multirank”, because we still have a large amount of missing data, around 10% below the world averages in 2020.

Regarding quantity and quality of academic research, Brazilian Institutions seem to be focusing in quantity of publications, generating numbers above world averages, but they are not so good in quality of publications, and the results in “Citation Rate” and “Top-cited” publications are below world averages. The positive point in that the numbers regarding “Citation Rate” are increasing every year, which may lead to increases in “Top Cited” publications later. From the countries analyzed, Chile has the best results regarding the number of citations in both Indicators.

The results in the Indicators related to “University-Industry” products show a weak point in data reported for “Co-publications with Industrial Partners”, with grades available only in 2017 and 2019, and both of them below world averages. In terms of number of patents, Brazilian numbers are behind world averages in both Indicators (absolute and size-normalized numbers), but the differences are much smaller in the size-normalized Indicator, that has more meaning for comparisons because it takes into account the sizes of the Universities. This Indicator also showed an important increase in 2020, when it is just above world average, which is a tendency that needs to be better observed in future results. The

Indicator "Publications cited in patents" has numbers that are steady and below world averages, but about the same results obtained in the Indicator "Citation Rate", which means that the importance of Brazilian science regarding academic and industry related products are similar. Chile is also the best performer in all the Indicators regarding Industry related products.

Of course these points need further studies and the present research aims only to give some first observations on this problem, but the results obtained are generally in agreement with the literature and constitute one more view of looking at the University-Industry production.

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