Networks of international cooperation of the BRICS bloc: evaluation of strategic areas and potential partnerships in STI

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Abstract

Since the BRICS Declaration in Cape Town in 2013, its five member countries have committed to cooperation programs in science, technology and innovation (STI), based on the five strategic thematic areas assigned to each signatory: climate change and mitigation of catastrophes (Brazil); water resources and pollution treatment (Russia); geospatial technology and its applications (India); new and renewable energy, and energy efficiency (China); and astronomy (South Africa). Five years after the Declaration and almost a decade after the First BRICS Summit, the evaluation of the strengthening of international cooperation among countries remains a challenge, due to their low presence in the large index databases commonly used for the collection of scientific data, such as Web of Science and Scopus. The proposal of this research is to carry out a study on international cooperation among the countries in the last five years through the Dimensions platform, based on the incidence of international co-authoring and co-financing of research agencies from the five countries, seeking to highlight the following points: the networks that consolidate themselves from the international cooperation among the BRICS countries, areas emerging in research with incidences of co-authorship, and how the research networks have been developed around the five strategic areas defined in the BRICS Cape Town Declaration. It aims to evaluate how the international

cooperation of the BRICS bloc in strategic thematic areas has been growing, pointing to possible areas of strengthening of international partnerships that can be deployed through this study.

Introduction

We stress the paramount importance of science, technology and innovation for human development. Indeed, while recognizing the role and significance of competitiveness in the rapid technologically changing global environment, we agree that people-centered and public-good driven science, technology and innovation, supporting equitable growth and sustainable development, shall form the basis of our cooperation within the framework of BRICS.

[First BRICS Science, Technology and Innovation Ministerial Meeting: Cape Town Declaration]

Based on the premise that Science, Technology and Innovation are core elements for the social and economic development of countries in the geopolitical sphere, BRICS members have signed a multilateral cooperation agreement in areas considered scientifically strategic. Thus, Brazil has been appointed to lead research in the field of climate change and catastrophe mitigation. Research on water resources and pollution treatment was the main responsibility of Russia. Geospatial technology and its applications was assigned to India. In turn, China would lead research on new and renewable energy and energy efficiency, while South Africa would lead research in astronomy.

Notwithstanding, the enormous amount of commitments made by the BRICS may obscure the development of formal plans that allow their effective feasibility and implementation (Kirton, Larinova, 2018). That is to say, to what extent have the cooperation commitments established by the Cape Town Declaration been incorporated into the scientific policies of the countries of the bloc? Further, what was its impact on the co-authoring networks of researchers from Brazil, Russia, India, China, and South Africa? Finally, what is the weight of these agreed areas in the research agendas of each of the group's countries?

The new millennium brought with it new geopolitical dynamics. Thus, if by the end of the 20th century, the production of scientific and technological knowledge was concentrated in three regions of the world – Japan, the United States, and part of Europe – the emergence of the so-called emerging countries changed the flow of investment and production in science, technology, and innovation (Cassiolato, Vitorino, 2009). This is the case of the BRICS

countries, which, since the consolidation of the bloc, have taken up a new role based, above all, on mutual development commitments. In this sense, and in understanding the importance of science and technology for the development of countries, international scientific collaboration occupies a strategic place.

According to Michael Kahn (2015, p.194), “the BRICS bloc’s cement comes from a shared desire to rebalance the relations of global political power and institutions, just as global market forces have rebalanced economic power.” Coupled with the economic development achieved in the first decade of the 21st century, the five countries have shown a strong concern for investment in Science, Technology, and Innovation (Carnoy et al., 2013), reinforced by the BRICS International Summits, such as the Cape Town Declaration (2013), which envisaged the intensification of multilateral agreements and engaged the five signatories in a cooperation program in science, technology, and innovation (STI).

Although they are still considered emerging powers, the impacts of the last global economic crisis caused a weakening of investments in Science, Technology, and Innovation. These wears bring the need for planning that promotes the reallocation of resources in fields considered strategic. Consequently, periods of economic instability such as the current one make evident not only the need to assess the impact of the investments, in order to enable these applications to focus on promising initiatives, but also strengthen international research and cooperation networks to maintain the same degree of competitiveness with the countries that dominate the market circuits of scientific production.

Previous research has sought to investigate the scientific production (Wagner, Wong, 2012; Finardi, 2015) or patent production (Ueno, 2013) among the BRIC countries. Nevertheless, understanding that Science, Technology and Innovation are part of a panorama that involves different economic, political and financial stakeholders, a holistic vision of the complex scientific ecosystem becomes necessary. Thus, our purpose in this article is to offer a complete panorama, not only involving the scientific or technological production, but also contemplating the different stakeholders of a chain of complex and interdependent systems, based on a set of data extracted from the Dimensions platform. Based on the international collaborative networks that have been formed following the signing of the Cape Town Declaration, we aim to provide, from a look at strategic decisions and research agendas, a dimension on the current state of production and investment in Science, Technology, and Innovation. Thus, we aim to investigate the formation of the co-authorship networks of the countries that compose the bloc based on the thematic areas defined in 2013, looking at the areas that received investment from the development agencies in the last five years.

Dimensions as a panoramic tool of the global scientific ecosystem

According to UNESCO's 2010 Science Report, since the beginning of the 21st century, developing countries have expanded their activities in scientific production due to high investments in scientific policies, measured mainly by services-based metrics indexing. For example, the Science Citation Index Expanded (SCIE), issued by the publisher Thomson-Reuters, is acknowledged as the authoritative source for high-quality scientific publications used for researcher-quality bibliometric analyses, journal citations, and the comparison of the quality and productivity of national results. Studies (Wagner, Wong, 2011) point out that, based on the SCIE data, there has been an increase in the scientific production of the BRICS countries, which have experienced a considerable increase in their indicators. Despite the growth, their representativeness in SCIE reaches only 3% of the scientific production of the base. Within SCIE, over 60% of journals are attributed to three countries only: United States (34%); United Kingdom (19%), and the Netherlands (8%), reflecting an English-language bias, which had already been documented in previous studies (Moller, 1990; Luukonen, 1990). Nevertheless, SCIE and Web of Science focus mostly on natural sciences and engineering, with little performance in Science and Humanities, and accounts for only 40% of the world's scientific output.

Given this panorama of low representativeness of countries outside the hegemonic axis, especially due to distorted proportions (Nwagwu, 2010), it becomes necessary to seek other ways of measuring scientific data beyond the bases traditionally used for extracting data from the scientific production of semi-peripheral and peripheral countries. It is in this sense that the Dimensions¹ platform, in addition to others such as 1Science², has become an important alternative to platforms such as Web of Science and Scopus (Thelwall, 2018).

Nevertheless, with the understanding that the scientific ecosystem is not limited to the practice of production and consumption of scientific productions, such as publication and quotation, but rather to a complex integrated system, it becomes necessary to integrate other elements in order to promote a holistic view on an interdependent set of scientific stakeholders. The ecosystem analogy used here concerns the recognition of mutual interdependencies between different stakeholders involved in the production of knowledge. The knowledge production chain is not only limited to a set of researchers who publish their work, but also a

¹ Platform developed by the Digital Science group.

² Platform developed by the Science-Metrix group.

network of economic, political and social groups that directly affect scientific and technological production, such as funding from development agencies, research agendas, the relationship between researchers and national and international research groups, and the very building of reputation in renowned systems that support academic work, among others. As discussed by Mazlounian, et al (2013), the synergistic effects on knowledge creation are composed of a series of agendas that form a “global scientific food chain,” as the production of new knowledge is nourished by previous existence of relevant knowledge sets and their adaptation to new changes in the environment related to the research activity.

To understand the complex scientific ecosystem, it does not suffice to look only at citations, publication scores, career movements, academic awards or other generic measures (Clauset, Larremore & Sinatra, 2017) that account for merely one sphere of the set of stakeholders that compose an environment of dispute and survival. It is necessary to look at scientific and technological production, it being understood as resulting from interactions between research institutions and, mainly, from investment by national or international financial agencies, which directly affect the scientific production process. Therefore, in order to address a complex scientific ecosystem, it is necessary to look at the set of stakeholders that make up the academic environment: researchers, research institutions and their dynamics of interactions between different stakeholders, development agencies and their respective research agendas as political decisions, in addition to peer consumption based on bibliometric data, as well as circulation in spaces beyond those considered traditional by science.

Recognizing the global scientific food chain (Mazlounian et al., 2013) and the scientific oligopoly that has dominated the complex publishing market for some time (Larivière, Haustein & Mongeon, 2015) and understanding the limited space reserved for emerging countries in these domains, as discussed previously, it was necessary to seek a more robust platform. We sought platforms that could provide an offer beyond a broad spectrum of data, not limited only to editorial trademarks traditionally used for the evaluation of science, such as Web of Science or Scopus, which do not account for a more complex dimension of scientific production in peripheral or semi-peripheral countries. To that end, we chose to use the Dimensions platform as an effective tool for measuring and evaluating a complex scientific ecosystem on a global scale.

In addition to a coverage that does not remain limited to the data extracted from WoS and Scopus, Dimensions uses the Digital Object Identifier (DOI), collected through Crossref, providing more data for a larger overview of domestic production. Alongside scientific production, the platform allows the integration of other relevant data relating to the scientific

ecosystem: patent production, subsidies and altmetric data comprise other aggregated information that allows us to have a broader dimension on the scientific circulation of countries and institutions.

Methodology

Understanding Dimensions as an important alternative tool that provides a broad spectrum of data, information on technological, scientific and development production in the topics considered strategic for BRICS countries, as defined in the Cape Town Declaration (2013)³, was extracted. To do this, the scientific and patent production was collected between the years 2014 to 2018, using the following keywords in the titles and abstracts: “climate change,” for Brazil; “Water resources” or “pollution treatment,” for Russia; “Geospatial technology,” for India; “Renewable energy,” for China; and “Astronomy,” for South Africa. It should be noted that, despite a broad picture of the scientific production in these countries, it is only possible to treat the data only up to 50,000 titles.

After extracting the data in CSV, the next step was to extract total information about the scientific production, identifying scientific production numbers in open access and closed access and patent production. Although it is understood that, for the treatment of data for the understanding of national scientific production in a comparative way, which is not our purpose in this research, it is necessary to take into account indicators of affinity, such as the Jaccard coefficient of similarity (1912) and the Salton index (Salton & Bergmark, 1979), the choice in this paper was to present only the total gross data for a panoramic dimension on the investment and production in science, technology, and innovation. For this purpose, the following information was used: a) total production; b) open access production; c) country of origin of the researchers; d) fields of knowledge covered in production; e) production amount in the areas identified over five years; f) number of patents; g) amount in development subsidies invested; h) relationship of the development agencies that invested in the subject in each signatory; (i) investment by area of the countries’ development agencies in the last 5 years.

After the collection and extraction of the raw data, the research networks were generated based on the worksheet generated by the Dimensions platform. It was decided to verify which networks are formed from the co-authorship survey, as well as their relation with the investment offered by agencies in each country.

³ This collection was carried out between April 20 and May 10, 2018.

The categorization of the data for the formation of the co-author networks required processing through the R language, using IDE RStudio. Each article in the database contained information on the countries of their authors, who were reorganized in order to create relations between their respective countries, so that all the countries of the co-authors had connections between them.

The Gephi software, widely used in the field of social network analysis, was used to visualize the co-authorship networks, in which each node represents a country and the edge is the link between these two nodes (countries). In a second moment, by applying a modularity algorithm, the data was divided into groups of interest, as explained by Ruediger (2017):

The modularity allows the mapping of the different groups of a network. A cluster / community / cluster of nodes will be classified if the connection between nodes is greater than its connection to other nodes in the network. The algorithm used by the program is based on the Louvain method (Blondel et al, 2008).

At the end of the process, the algorithm separates the network into groups (Newman, Girvan, 2004) called clusters, which will be analyzed here as representations of online collective subjectivities in interactions.

Results

For the presentation of the results, the data were divided into three blocks:

- 1) Total data of each of the countries in their respective subjects, as defined in the Cap Town Declaration, from three datasets:
 - a) Scientific production in open and closed access;
 - b) Patent production⁴;
 - c) Time line of the five main areas that emerge on the scientific production of the countries in the respective themes.
- 2) Investment data provided to the countries in each of the previously defined subjects based on the following information:
 - a) Areas invested, seeking to establish a correlation with the areas that emerge from the scientific production on the subject;
 - b) Main development agencies that have invested in the subjects in question.

⁴ Due to the low expressiveness of patent production in some countries, we chose to carry out the search in the platform based on general data, as opposed to titles and abstracts, for patent production.

- 3) Co-authorship networks formed based on the scientific production of these countries and their relationship with the previously identified development agencies.

Total data

Country	Total scientific production	Total scientific production in Open Access	% OA	Total patents generated
Brazil	1,991	732	36.77%	34
Russia	843	134	15.90%	170
India	151	36	23.84%	23
China	4,907	782	15.94%	665
South Africa	90	34	37.78%	09

Table 01: Total scientific production and patents registered in each of the themes defined in the period 2014 to 2018 in each of the respective signatories

Although the total dimensions of countries are not taken into account, it is important to emphasize the relevance of the raw data for an overall presentation of the scientific production of the countries in the defined subjects. It is also important to point out the proportion of production in Open Access, taking into account its relevance in balancing inequalities on the visibility of scientific production on a global scale (Alperín, Rozemblum, 2017). Brazil – as well as other Latin American countries, such as Mexico and Chile – have invested in Open Access, seeking a deeper insight into the country's scientific production, as shown by the report produced by the Science-Metrix group (2017), which points to a high degree of Brazilian production, as well as initiatives such as Scielo, which have enabled a broad participation of researchers in open-access scientific production.

In addition to Brazil, as can be seen from the data collected, South Africa stands out – despite the low production in the defined subject – thanks to its adhesion to Open Access (37.78% of the South African production collected in Astronomy is in open access). According to UNESCO⁵, South Africa is a leading African country in terms of open-access policies at the governmental level and grassroots initiatives at universities and research organizations. The

⁵ Available at: <http://www.unesco.org/new/en/communication-and-information/portals-and-platforms/goap/access-by-region/africa/south-africa>

main South African signatories of the Open Access 2020 international campaign, launched in 2016, include the National Library of South Africa and the South African National Library and Information Consortium (SANLIC). It is also worth mentioning that, since 2009, South African journals have been incorporated into Scielo, since the creation of the regional collection Scielo SA, a project supported by the Academy of Science of South Africa.

Based on the scientific production of the countries, a timeline on national scientific production was generated on the Dimensions platform itself. It should be noted, however, that there are many factors that affect the total value of the collection performed on the platform, such as the increase in the adhesion of titles in the database and the validation of post-publication DOIs.

Brazil

Russia

India

China

South Africa

Figures 1-5: Images generated from the Dimensions platform, collected on May 20, 2018.

While Brazil, Russia and China have increased production in the thematic axes defined in Cape Town, India experienced a fluctuation in production on geospatial technology in 2015, recovering in the following years, while South Africa has been showing declining production in astronomy since the year of the signing of the declaration, although it presented a growth on the subject in the years before the 5th BRICS Summit.

Emerging areas

Based on the data collected, it was possible to map areas emerging from the timeline of the five main sub-areas within each signatory's subject. This data was generated by the Dimensions platform itself on May 20, 2018.

Figure 6: Images generated from the Dimensions platform, collected on May 20, 2018.

In Brazil, three areas emerge on the subject of climate change: *Earth Sciences*, in the sub-areas of geosciences [purple line] and atmospheric sciences [pink line], which showed an increased production in the last year, *Biological Sciences*, with high production in ecology [blue line], and *Environmental Sciences* [green line].

Figure 7: Images generated from the Dimensions platform, collected on May 20, 2018.

The areas of applied and earth sciences and engineering stand out in the Russian scientific production in Aquatic Resources and Pollution Treatment. Consequently, a very significant increase can be seen in the Physical-Chemical [blue line] production, with a predominance of the engineering area, which is divided into Environmental Engineering [purple line], Chemical Engineering [yellow line], and Materials Engineering [green line]. The number of articles produced in Interdisciplinary Engineering [pink line], however, has remained relatively constant over the last five years.

Figure 8: Images generated from the Dimensions platform, collected on May 20, 2018.

The areas emerging from the geospatial technology in India are, first, Geomatic Engineering [blue line]. Following that, a less systematic growth in Physical Geography and Environmental Geoscience [purple line] can be observed, followed by Artificial Intelligence and Image Processing [pink line], Information Systems [yellow line], and Environmental Sciences and Management [green line]. It should be noted that, with the exception of the last area – Environmental Sciences and Management – all others underwent a very significant drop in the number of publications in the year 2015, followed by peak growth in the following period.

Figure 9: Images generated from the Dimensions platform, collected on May 20, 2018.

The areas emerging from the Chinese scientific production are Physical-Chemical [blue], Electronic and Electrical Engineering [green], Materials Engineering [purple], Environmental Engineering [yellow], and Interdisciplinary Engineering [pink], with a clear predominance of engineering in the subject delegated to China.

Figure 10: Images generated from the Dimensions platform, collected on May 20, 2018.

In South Africa, emerging areas on astronomy are Astronomical and Space Sciences, with a significant increase in 2013; Physical Sciences, Plasma, Particle, Nuclear, Molecular and Atomic Physics; Communication Technologies and Artificial Intelligence; and Image Processing.

Investment and research agenda

Public institutions for the development of Science and Technology (STIs) were established to meet specific demands aimed at the socioeconomic development of the countries and are considered important stakeholders in the process of implementing public policies (Bassi, 2012). These policies aim to foster the development of research considered strategic by the countries, through the investing role of the state, aiming to meet the demands of both society and the government itself in the medium and long term (Salles-Filho, Bonacelli, 2007). This strategic definition on the investments in STI is referred to as a research agenda, i.e., “the network of social institutions that shape the institutional, intellectual and material framework on which scientific knowledge is to be produced” (Silva, 2015). The research agenda can thus be defined as an organized set of intellectual tools materialized in official prospective documents in which, directly or not, political-institutional positions are established to govern and enable the scientific and technological production for a given period in a specific historical and cultural context (Frickel et al., 2010; Hilgartner et al., 2015). According to Renan Silva (2017), the research agenda is an eminently political phenomenon, as it is sustained by values disseminated mainly in the professional routine of the research community, despite often incorporating (in greater or lesser intensity) the interests of other social groups, capable to shape the social and political environment on which more knowledge is to be produced.

In the conception of Hess (2014), the produced knowledge itself acts as a stakeholder in the research agenda, being even able to change the strategic planning of interests and lead to the production of a new research agenda based on it. Thus, in order to understand the research agenda, it is necessary to look at the diverse set of stakeholders involved and their networks of interactions from a holistic view that enables the understanding of a set of factors that determine decisive interests in STI. In order to do so, this research sought to carry out a survey of development investments in the BRICS bloc, acknowledging development institutions as important stakeholders in this network of strategic economic and social interests regarding the production of knowledge and technology.

Based on the data collected on the Dimensions platform, it was possible to evaluate the investment intended to each subject in the signatory countries. In total, 376 subsidies were

identified, mainly from the following development agencies: National Council for Scientific and Technological Development (CNPq), Research Support Foundation of the State of São Paulo (FAPESP), both from Brazil, Natural Environment Research Council NERC), from the United Kingdom, and the United States Department of the Navy (DoN).

As can be seen in the graph generated below, regarding the subject of climate change, resources were mostly allocated to the area of Health. The areas that emerged on the subject based on the production collected in the platform were Earth Sciences, Biological Sciences and Environmental Sciences, with a small representation by the development agencies, and may indicate a disconnection between resources invested and scientific production. Although these data are dependent on the information provided by the national development agencies, they allow us to evaluate whether the resources invested could be directed mainly to the areas that emerge in the production of knowledge regarding a subject, serving as an important tool for decision making on the allocation of resources.

Brazil

Figure 11: Images generated from the Dimensions platform, collected on May 20, 2018.

Taking into account that the areas emerging in the subject of “climate change” in Brazil include *Earth Sciences*, in the sub-areas of geosciences and atmospheric sciences, *Biological Sciences*, with high production in ecology, and *Environmental Sciences*, here is little distribution in the representation between development investments and emerging areas of national production. Investments in Earth Sciences and Environmental Sciences are below the 200K mark for the entire country, while Biological Sciences are among the five areas with the most investments in climate change in the last five years. It is also observed that the areas that had the most investment did not appear as emerging areas in climate change in the last five years, such as Health Sciences, Engineering, and Chemistry.

Figure 12: Images generated from the Dimensions platform, collected on May 20, 2018.

In Russia, the two areas that emerge in the discussion on Water Resources and Pollution Treatment are Engineering and Chemistry. These areas have received significant investments, even though they are not among the three areas with the largest allocation of resources in the last five years. The areas with the most investments on the subject are Humanities, Health Sciences, and Environmental Sciences.

India

Figure 13: Images generated from the Dimensions platform, collected on May 20, 2018.

Environmental and Engineering Sciences, the two emerging areas of India's geospatial technology research, are among the top five investments in the country, which indicates a good alignment between the definitions of the agenda and strategic decisions defined in the multilateral agreement of the BRICS bloc for investments in science, technology, and innovation.

China

Figure 14: Images generated from the Dimensions platform, collected on May 20, 2018.

The two areas emerging from research on New Energy and Renewable Energies in China are among the top three investments on the subject in the country, which, as is the case with India, shows a correlation between the national research agenda and the interests expressed and agreed at the 5th BRICS Summit.

South Africa

Figure 15: Images generated from the Dimensions platform, collected on May 20, 2018.

Among the areas emerging in South Africa on the subject Astronomy, only physical sciences, a field of significant growth in the timeframe proposed for this analysis, is contemplated by the investments in the country, according to what is presented by Dimensions platform.

Although the data point to relevant information on the research agendas, it is important again to point out that the data obtained in the platform do not represent the total production of the countries. A deeper study is required, respecting the differences between fields and their dynamics of production.

As pointed out previously, to understand the research agendas means to explore a set of data produced by different dynamic stakeholders that interact in the circuit of production, consumption and circulation of Science, Technology, and Innovation. With the understanding that the need for an outlook that is capable of capturing the interaction flows between the agents involved in the process of knowledge production, it is necessary to use methodologies that are capable of understanding the dynamics established among the different stakeholders, such as the analysis of social networks.

Co-authorship networks

When studying research collaborations, it becomes necessary to discuss the methods for counting and treatment of data in this research. Before discussing the results obtained, it should be noted that there are different ways of processing data for the understanding and analysis of collaboration networks. For example, collaborative scientific products can be fully credited to each partner or, instead, fractionally credited to employees according to specific rules. A comprehensive analysis of the various methods and possible biases they introduce has previously been conducted by Gauffriau et al. (2007). Notwithstanding, more than solidifying numbers for the application of statistical counts and metrics, this paper acknowledges the importance of standardizing social bonds in which stakeholders involved have important consequences for other stakeholders with whom an interaction is established (Freeman, 2004; Otte, Rousseau, 2002). In this sense, the analysis of social networks provides an approach that goes beyond statistical numbers in order to help determine the conditions under which interactional patterns have been established, in order to understand their consequences.

There are a number of ways of processing data to perform the analysis of co-authorship networks (Barabasi, et al, 2002; Finardi, 2015). It is possible to assign equal measures to each country or fractionate them as regards measures on international cooperation, based on a set of co-authorships. Nevertheless, as the present study seeks to discuss the data based on bilateral scientific collaborations, it preferred, as in Finardi & Buratti (2016), to use a “total-count” method to distribute scientific products among the partners, assigning the same weight for each of the nodes.

Regardless of whether the nodes represent individuals, organizations or even countries, and whether the links refer to communication, cooperation, friendship or commerce, said links can be differentiated in most environments. These differences can be analyzed by defining a weighted network in which the links are not only present or absent but have some form of weight associated with them. In a social network, the weight of a link is usually a function of duration, emotional intensity, intimacy, and service exchange (Granovetter, 1983).

In the analysis performed, a network was chosen in which the size⁶ of the node is given by the degree of weighted input, which enables the verification of a diversity of connections, and the size of the edge by the sum of the relationship between the nodes. This, it is possible to interpret the graph in order to understand relations at the geopolitical level. In other words,

⁶ In social network analysis, node size is known as weight and regulates the size of the node in the network. This size is generated depending on the metric and algorithm used.

the larger the node in the network, the greater its diversity of connections and the greater the edge, the stronger will be the connection between these nodes.

Based on that, it is possible to make inferences regarding some understandings of the co-authorship network in each thematic area defined at the Cape Town Summit for the BRICS countries.

Figure 16: Graph generated in Gephi from the data obtained in the Dimensions platform.

In the graph generated from the set of 1,991 Brazilian productions on climate change, it is possible to observe a centrality of the United States over the co-authorship network in Brazil. One of the possibilities of analyzing network graphs of co-authorship is to draw inferences on the contexts behind the visualization generated. In the Brazilian case, it is important to emphasize a process of Americanization of science following World War II (Haney, 2008), particularly during the Brazilian military regime (Moreira, 2014), especially in the fields of Sociology, Political Science, and Economic Sciences (Pinto, 2001; Coats 1997; Engelmann, 2013). As pointed out by Afonso de Albuquerque and Diógenes Lycarião (2018), a globalized neoliberal agenda was imposed by the United States, known as the Washington

Consensus, which refers to a set of economic policies imposed on debtor countries by U.S. financial institutions, which (Lima, Maranhão, 2009), through the importation of ideas and researchers from hegemonic countries such as the United States and the United Kingdom.

It is before this scenario that we can understand the centrality of the United States in the graph generated, mainly by its re-colonizing role in Brazil and Latin America (Dutta, Rastogi, 2016), through different economic policies in different spheres, as well as a strong interaction with the United Kingdom, both members of an oligopoly of scientific publishers that has been dominating the science market for more than a century (Larivière, Haustein, & Mongeon, 2015), directly affecting the spaces of visibility in scientific circulation (Sousa, Oliveira, 2018).

It should be noted that a direct relationship cannot be observed in all analyses of the graphs of co-authorship networks, with the international investment in research in the BRICS country. For example, the four development institutions that made the most investment in climate change research in Brazil include the National Council for Scientific and Technological Development (Brazil), the Research Support Foundation of the State of São Paulo (Brazil), and the United States Department of the Navy (United States), Brazil and the United States being the two countries with the greatest diversity of relationships in the network.

Figure 17: Graph generated in Gephi from the data obtained in the Dimensions platform.

As in Brazil, the countries that have been stood out by the frequency of co-authorship on water resources in Russia are those that have had investment through de development subsidies, such as China and the United States, as well as Russia itself, although the highest intensity is in the relationship with Germany. The agencies that most invested in research on water resources in Russia were the Russian Science Foundation (Russia), the National Aeronautics and Space Administration (NASA, United States), and the National Nature Science Foundation of China (China), among the 62 grants collected.

This network is in line with the findings of Glänzel (2001) on national characteristics in national co-authorship relations in several countries. According to his study, Glänzel noted that Germany proved to be a very important partner for most countries, especially for Austria, Hungary, Poland, and Russia, while Russia presents itself as an important partner for several Eastern and Western European countries. Although the findings of Glänzel date from more than a decade ago, the network with Russia, based on a specific timeframe and in the subject of water resources, shows that this is a country of great diversity of articulation and interaction, becoming an important stakeholder both with Eastern Europe, with which it nurtures a

relationship of centrality in the network, and in countries in Western Europe, Asia, and North America, showing its potential of scientific influence and international articulation. This diversity observed in the network refers to what Neumann (2013) considers as part of the identity formation of Russia, which is divided between the attraction of being economically, politically and socially part of a developed Europe while playing a European-style imperial role in relation to the Asian countries.

Figure 18: Graph generated in Gephi from data obtained in the Dimensions platform.

Unlike the other networks investigated in the BRICS countries, India has a less diverse, self-centered network, thus showing little international co-authorship. It should be noted that the Dimensions platform uses the Crossref database, extracting information from the scientific

production whose Digital Object Identifier has been validated. Because the collection has returned a low production number, a more in-depth study is required to understand the ways of preserving digital data from persistent addresses in India.

The data obtained from the development subsidies also reflect this return, which does not match with the scientific production of India, in particular in the field of space geotechnology (Ramachandran, Jayakumar, 2007; Dar, Dar 2009; Kumar, Pandey, 2011; and Singh, Thakur, 2011, among others), since the country is considered one of the world's major powers in the production and development of information technology, with strong political, social and administrative investments, defining it as a priority sector in the past 10 years (Gupta, Dhawan 2003) . In spite of the self-centered production from the obtained data and the incongruence of the data collection for a national coverage, it is possible to notice its good interaction and strengthening of relations with the BRICS countries as relevant for the formation of the network, thus making it a key agent for the articulation between the other countries of the bloc.

It should also be noted that the Dimensions platform does not have a source of data regarding India's development agencies, and the collection for a closer measurement of the country's size requires investments and opening of data to feed the platform. Therefore, it is impossible to draw inferences on scientific production contexts and the understanding of the scientific ecosystem in a broad way without a more refined collection, deeper investigation on the ways of producing and preserving digital scientific data, and an opening for the provision of data from Indian institutions.

China

in grants to attract back scientists who carried out training in other countries, particularly in the United States (King, 2004), a phenomenon known as brain drain (Giannetti, Liao, Yu, 2015; Saxenian, 2005), sustaining the world's fastest economic growth.

In addition to a strategic investment in areas considered priority, in line with the thematic areas agreed for China in the Cape Town Declaration, China's investments in the renewable energy and new energy sectors appear from two central stakeholders emerging in the graph: China, through the agencies University Grants Committee (UGC), National Natural Science Foundation of China (NSFC), and Innovation and Technology Commission (ITC); and the United States, through the Advanced Research Projects Agency-Energy (ARPA-E).

South Africa

Figure 20: Graph generated in Gephi from the data obtained in the Dimensions platform.

As in Brazil, there is a high degree of co-authorship with the United States and the United Kingdom, reflecting a process imposed by that British colonization, affecting not only not only language (Philipson, 1996), but also the dynamics of scientific production, as well as in the process of recolonization and Americanization of knowledge, as experienced in Latin America (Kuhn, 2015). Like India, the low return on data collection may indicate a lack of investment in persistent data preservation and archiving policies, such as DOI, which requires a more thorough examination of the cultural and social dynamics of scientific publication in the country.

Despite the high percentage of open-access publications (37.78%), this is a recent movement, with few national public policies aimed at encouraging the production and dissemination of knowledge (Czerniewicz and Goodier, 2014; Goodier, Czerniewicz, 2014), which makes it important to highlight important initiatives in South Africa that already point to the quantity of open-access productions in the country. One of them is SciELO-SA, an initiative funded by the Department of Science and Technology (DST) and the Department of Higher Education and Training (DHET), which currently features 75 South African journals⁷. The second initiative worth mentioning is the recent launch of Africarxiv, a preprint repository developed by the Open Science Center (COS), which will promote scientific knowledge in African countries in various scientific fields.

These two initiatives already point to a significant cultural change in terms of dissemination of knowledge in the country. A study published in 2013 (Czerniewicz, Weinz, 2013) showed an invisibility through a Google query for research in South Africa in an area where it is known that much research has been carried out, such as Astronomy, the subject chosen by the signatory country, despite the understanding of the complexity involved in this type of production, in particular because of its technological and innovative character, and the strong tension between the socialization and privatization of knowledge.

Discussion

The agreements signed at the international cooperation meetings include strategic planning, which enables its viability and the design of a methodology that follows up its evolution over time. Kirton and Larinova (2017) show that 400 international cooperation

⁷ http://www.scielo.org.za/scielo.php?script=sci_alphabetic&lng=en&nrm=iso

agreements for the future have been signed within the framework of the BRICS bloc in 6 years (2009-2015). According to Diego Vieira de Jesus (2013, p. 35), the preference for a lower degree of commitment is related to “the preference structure of the members for greater agility in the implementation of commitments, greater flexibility to make political choices, and greater independence in relation to third parties.”

Nevertheless, this paper questions the consequences of the establishment of imprecise obligations, which may generate a gap between the commitments established in the formal meetings of the group’s countries and the means to implement them. The way in which these agreements are operationalized in each member country is quite different and, without structured public policies, there is little control over the degree of success of the changes adopted. This means that “lower obligations,” as conceived by Diego Vieira de Jesus (2013), can make it difficult to design research methodologies that include their development and deployment, as we aim to offer in this article.

Another problem to be raised is the clear prioritization of the areas of applied sciences and engineering to the detriment of others. The association of science with the hard sciences and the absence of a view that considers other sciences as strategically important for the development of these emerging countries. At least with regard to Brazilian policies of international scientific insertion, we can exemplify its orientation towards a “radical supremacy of the natural sciences” (De Almeida Dutra, Azevedo, 2016, p. 234) through the *Ciência sem Fronteiras* (“Science without Borders”) Program, which kept from humanities students the possibility of using the funds of the program to establish their international exchanges. In the Control Panel of the *Ciência sem Fronteiras* Program presented by Aveiro (2014), it can be seen that 45% of the grants provided by the program were intended for engineering and other technological areas, which highlights the priority area of the program during its implementation.

Nevertheless, it must be considered that the main characteristic of *Ciência sem Fronteiras* was to promote, to a great extent, the arrival of Brazilian students to central countries. In this sense, it is a very different premise from the Declaration signed in Cape Town. What we wish to emphasize by making such a comparison is that both reduce the concept of “science” to the natural sciences.

Thus, while the declaration recognizes the importance of scientific and technological development for the strengthening of the links between the BRICS countries and, simultaneously, the consolidation of the group’s countries as international powers, it delimits the scope of scientific and technological knowledge to applied and earth sciences and

engineering. Consequently, we are limited to the possibility of examining the same priority subjects as those outlined by the Cape Town Summit based on perspectives in other fields of knowledge. This means, specifically, to think about the causes and consequences of human actions on the topics considered priorities at the Summit and their meanings in the different forms of organization of the social groups contained in the countries of the group.

On March 18, 2015, the Second BRICS Ministerial Meeting on Science, Technology and Innovation took place in Brasília, Brazil. There, the belief in science was reinforced as a promoter of economic development and social inclusion, as well as its role in protecting and preserving the environment. Again, the exchange of scientific information through international cooperation was presented as strategic for the countries of the bloc. Nevertheless, the ninth topic of the document covers the creation of the Young Scientists Forum, without detailing in its name that it refers exclusively to engineering and applied science:

We support the creation of a BRICS Young Scientists Forum proposed by India, which intends to establish the platform for young students of science, engineering and applied disciplines as well as for those pursuing research careers in the age group of 22-35 years to gather for: (a) addressing the needs for advancement of skills, research competencies, career, talent and next generation scientific leadership; (b) sharing scientific research results and experiences; (c) discussing novel ideas in emerging frontline fields of S&T; (d) analyzing trends and features of globally important scientific issues; (e) suggesting measures to enhance trans-continental mobility in their scientific research careers.

Although the seventh topic of the document refers to the Brazilian and Russian proposal to include life sciences and biomedicine as a “new area of priority cooperation” (p. 2), we highlight the absence of human and social sciences in the scope of the sciences considered strategic. This discussion occurs concurrently with the need for alternative scientific circuits to the U.S.-Western Europe axis and to enable and facilitate the dialogue among researchers who develop common subjects.

If the BRICS represents a challenge to how global governance is organized (Albuquerque & Lycarião, 2018), it should equally be valid for the group to challenge the way the scientific circuit is currently structured. A channel among the group’s countries that privileges the human and social sciences as it does with applied sciences and, in recent years, life sciences and biomedicine could help us consolidate new flows for Science, Technology, and Innovation.

Furthermore, one difficulty to researchers of the human and social sciences inserted in countries and institutions located in non-privileged positions regarding the hegemonic system of production and scientific circulation is the access to categories that assist in the

understanding of the universe of problems to be analyzed. The reason for this is the tendency to replicate foreign entities, which often says more about the influence of researchers who diffused them than about the adequacy of the context (Connell, 2012). This unequal influence is due to an unequal universe in which the European and North American institutions maintain the leading scientific journals (Larivière, Haustein and Mongeon, 2015), and their members have comparatively more visibility on the international scene.

It is also necessary to point out the need for a greater scientific integration between the BRICS, by encouraging joint production and multilateral research among researchers from these countries, strengthening scientific, technological and economic development as a whole. As seen throughout this research, the investments of agencies outside the BRICS bloc directly influence the strengthening of research networks with the investing countries, particularly countries that are considered hegemonic in the production of Science, Technology and Innovation and form an oligopoly of scientific publishers, consolidating a market that is difficult for emerging countries, such as the BRICS members. We understand that Initiatives such as the BRICS STI Framework Program, for example, allow this integration to take place and that multilateral partnerships among stakeholders allow a strengthening of the interaction and research networks among them, promoting greater visibility of this network, enabling it to become a major competitor in the global scientific market.

It is also important to emphasize the need for a greater opening of scientific data, especially when it comes to a set of countries, whose scientific production dynamics vary in cultural, social, economic and identity aspects, as presented in the course of this discussion. Nevertheless, understanding science as a strategic area, the way in which the scientific production of emerging and peripheral countries has been made invisible and underrepresented (Wagner, Wong, 2012), it is important to overcome the perspective of thinking science from its productivity or its economic effectiveness, placing a focus on the relations between science and power and its mechanisms of power demonstration based on the production of Science, Technology, and Innovation. Thus, we argue that open, unrestricted, accessible and inclusive science is still the main mechanism to promote the visibility that has been overshadowed by the market dominance of the oligopoly of scientific publishing, allowing a greater impact of the production of BRICS countries. From this opening of the data of the entire scientific ecosystem, we can understand that the path to an active internationalization (Lima, Maranhão, 2009) is opened, which also consists in the understanding that “online visibility is not a form of vanity; it is now an essential requirement for participation in knowledge creation networks” (Czerniewicz, Goodier, 2014).

Final remarks

The BRICS countries, despite cultural, linguistic and economic differences, were among the leading emerging national economies, distinguishing themselves by their rapid and heterogeneous growth (Biggeman and Fam, 2011). The Cape Town Declaration, signed in 2013, showed the countries' consent to the role of science as a promoter of economic and social development. Furthermore, it has extended the challenge to global hegemony to the field of science.

We thus believe that the creation of international cooperation networks for the production of joint scientific studies is an important initial step for researchers from emerging countries to jointly solve common problems. It was in this regard that the Cape Town Declaration made a tremendous breakthrough by boosting the dialogue among BRICS member countries. By building new networks of dialogue with selected and prioritized guidelines, the statement in question began to question the pillars of the current scientific ecosystem. We argue, however, that such networking can only challenge the political relations governing scientific knowledge when the output of joint production can be accessed and analyzed by the members of the respective countries of the group.

Merton (1973) uses the metaphor of the 41st chair to describe all researchers who are outside the small prestige zone where renowned scientists congregate. The problem raised by the author is that there are a limited number of researchers capable of being acknowledged. This ability, in turn, is not necessarily tied to the researcher's talent or competence. A huge number of researchers as talented as the renowned ones will never receive the prestige expected by their work.

Therefore, there is a logic that selects winners according to criteria that go well beyond the competence and relevance of the work of the renowned scientist. Although Merton was more concerned with social and psychological aspects than with international power dynamics, we believe that the 41st chair phenomenon is symbolic for scientists in emerging countries.

In this article, we argue that the delegation of research and researchers of equal importance to places different from the system of scientific prestige is largely due to contemporary geopolitical dynamics (Bringel, Domingues, 2015). These dynamics delegate to the United States and Western Europe a central and privileged role in the current scientific ecosystem. As seen in this work, the centrality of the United States in Brazilian, Russian and South African networks is exemplary. Moreover, the existence of an international oligarchy that detains the main tools used for ranking academic journals (Vessuri, Guédon, Cetto, 2013).

We argue, however, that international cooperation for the production of knowledge in the defined areas should be performed in conjunction with a reformulation of the structures of circulation of scientific knowledge (Agnew, 2007). Thus, the expansion and redefinition of scientific production networks has limited practical effect when the product of these productions is not within easy reach of researchers in the bloc.

As seen in this study, the countries of the group currently have varying degrees of adherence to open access. Due to the difficulty of access and incorporation of the scientific research of some countries of the bloc, we add the difficulty in accessing the data to allow a clearer and more accurate view of the data on the production of the member countries. Thus, we consider that the sedimentation of the road constructed by the Cape Town Declaration will only be possible with the opening of the scientific production in the emerging countries.

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