

**INTERNATIONALIZATION: MAPPING OF INTERNATIONAL CO-AUTHORSHIP NETWORKS OF SCHOLARSHIP HOLDERS FROM CAPES POST-DOCTORAL PROGRAM ABROAD IN THE HEALTH AREA**

***INTERNACIONALIZAÇÃO: MAPEAMENTO DE REDES DE COAUTORIA INTERNACIONAL DE BOLSISTAS DO PROGRAMA DE PÓS-DOCTORADO NO EXTERIOR DA CAPES NA ÁREA DE SAÚDE***

***INTERNACIONALIZACIÓN: MAPEO DE REDES DE COAUTORÍA INTERNACIONALES DE BECARIOS DEL PROGRAMA DE POSTDOCTORADO EN EL EXTRANJERO DE LA CAPES EN EL ÁREA DE SALUD***



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**ABSTRACT:** The internationalization of science can occur through scientific production in co-authorship with foreigners. In this sense, the Post-Doctoral Programs abroad (PPDE) of CAPES aims to increase co-authored publications between researchers working in Brazil and abroad. The study aims to map the evolution of international co-authorship networks formed by scholarship holders from PPDE in the health area, before and after the end of the scholarship period, through the Social Network Analysis methodology. As a result, networks grow by increasing the number of co-author countries, of connections between nations or the frequency of collaboration between a pair of countries. In addition, one can see the variety of collaborating countries and their degree of importance for the analyzed groups. The presented methodology can serve as subsidy for public internationalization policies.

**KEYWORDS:** Internationalization of science. Co-authorship. Scientific production. Social network analysis. Post-doctoral abroad.

**RESUMO:** *A internacionalização da ciência ocorre por diversos meios, como por exemplo, a produção científica em coautoria com estrangeiros. Nesse sentido, o Programa de Pós-Doutorado no Exterior (PPDE) da CAPES prevê a ampliação de publicações conjuntas entre pesquisadores que atuam no Brasil e no exterior. O objetivo do estudo, portanto, é mapear a evolução das redes de coautoria internacionais formadas por ex-bolsistas do PPDE da Grande Área de Ciências da Saúde, antes e após a finalização da vigência da bolsa, por meio da metodologia de Análise de Redes Sociais. Como resultado, verifica-se o crescimento das redes pelo aumento do número de países coautores, do número de conexões entre nações ou da frequência de colaboração entre uma dupla de países. Além disso, percebe-se a variedade de países colaboradores e qual o grau de importância destes para os grupos analisados. A metodologia apresentada pode servir como subsídio para políticas públicas de internacionalização.*

**PALAVRAS-CHAVE:** *Internacionalização da ciência. Coautoria. Produção científica. Análise de redes sociais. Pós-doutorado no exterior.*

**RESUMEN:** *La internacionalización de la ciencia puede ocurrir a través de la producción científica en coautoría con extranjeros. Así, el Programa de Postdoctorado en el Extranjero de la CAPES busca aumentar las publicaciones en coautoría entre investigadores científicos que trabajan en Brasil y en el extranjero. El objetivo del estudio es mapear la evolución de las redes internacionales de coautoría formadas por antiguos becarios del PPDE de Ciencias de la Salud, antes y después de finalizar la beca, a través de Análisis de Redes Sociales. Como resultado, se nota crecimiento de las redes debido a un aumento en el número de países coautores, en el número de conexiones entre naciones o en la frecuencia de colaboración entre un par de países. Además, se puede ver la variedad de países colaboradores y su grado de importancia para los grupos analizados. La metodología presentada puede servir como subsidio para políticas públicas de internacionalización.*

**PALABRAS CLAVE:** *Internacionalización de la ciencia. Coautoría. Producción científica. Análisis de redes sociales. Postdoctorado en el extranjero.*

## Introduction

When it comes to science and education, internationalization, resulting from globalization, integrates teaching/learning processes, research and educational services in a global perspective (Cunha-Melo, 2015). In this sense, there are several instruments used in its promotion: mobility of researchers, research projects with participants from different nations, funding from international sources, publications in journals of global relevance, various scientific collaborations, among others.

Starting from the scientific focus, internationalization implies interconnectivity and interdependence between countries, culminating in the formation of collaboration networks, which demands analyzes that consider this perspective adapted to growing scientific complexity (Gui; Liu; Du, 2019).

From the point of view of the standard of scientific collaboration, the global scenario was remodeled, so that scientific publications went over the years from an individual production profile to production in institutional, national and finally international collaboration, in which the authors are each increasingly interconnected, as demonstrated by Adams (2013). This means that team scientific activity is growing.

Among the advantages highlighted by The Royal Society (2011) in relation to international scientific collaboration are the exchange of knowledge, expertise and ideas between nations in search of excellence, sharing of risks and pooling of resources, reduction of overlaps in research, improvement of impact and visibility of scientific productions.

One way to estimate, at least partially, the degree of scientific collaboration between countries is through the analysis of joint publications (Katz; Martin, 1997), using different methodologies, such as social network analysis (SNA).

That said, the objective of this study is to map the evolution of international co-authorship networks (at a level of collaboration between countries) formed by former scholarship holders from the CAPES Post-Doctoral Program Abroad (PPDE) in the Greater Area of Health Sciences, considering two moments, before and after the end of the scholarship period, in light of the ARS methodology.

## Methodological procedures

For the study in question, the international co-authored production indexed in the Scopus database of former fellows from the Post-Doctoral Program Abroad of the Coordination for the Improvement of Higher Education Personnel (CAPES) in the Greater Health Area was used as a sample.

The former fellows who composed the study were those who were registered as permanent professors in *stricto sensu* graduate programs of the National Graduate System (SNPG) in the base year of 2019 and who had their postdoctoral fellowships abroad terminated in the years 2015, 2016, 2017 and 2018, totaling 65 postdoctoral fellows.

From the list of former scholarship holders of interest, they were inserted into the SciVal platform, configuring four groups, one for each year of the end of the scholarships: PPDE 2015, PPDE 2016, PPDE 2017 and PPDE 2018.

Additionally, the FORD (*Fields of Research and Development*) for classifying Scopus sources, used in the Frascati Guide of the Organization for Economic Co-operation and Development (OECD), and the area of *Medical Sciences* was selected, whose scope includes basic medicine, clinical medicine and health sciences (OECD, 2007).

To obtain international co-authored publications from each group configured in SciVal, the Collaboration tab was used, located in the *Overview module*, from where it is possible to extract the list of publications with pre-selected attributes. In the case in question, the extraction included the title of the publications, list of authors, years of publications and countries of affiliation of the authors of each production.

From this, it was possible to separate the publications of each group into two analyzed periods: three years before the end of the postdoctoral fellowship (called period 1) and three years after (called period 2).

Then, adjacent relationship matrices between the countries were constructed in the Microsoft Excel<sup>®</sup> software, with each set of former fellows representing Brazil, the co-authors representing their countries of affiliation and the co-authored publications playing the role of relationships, being A weight was assigned to each relationship according to the amount of shared production that a pair of countries obtained in the periods analyzed.

The matrices, symmetric and with diagonal 0, were imported into the software Gephi, used to structure and visualize the co-authorship networks formed, as well as to calculate the metrics of interest in the study, analyzed in light of the Social Network Analysis methodology.

In this way, the graphs were created to allow visual examination of the size, structure and attributes of the network in the two periods studied. Three global quantitative measures were derived from social network analysis: average degree, average weighted degree, and graph density. Regarding the specific parameters of the actors in each network, degree, weighted degree, eccentricity, and measures of proximity centrality, betweenness and eigenvector were verified. The metrics measured quantitatively denote the behavior of scientific collaboration between countries, based on the co-authorship networks generated.

## Results and discussion

By crossing the bases of former postdoctoral fellows abroad and permanent *stricto sensu* postgraduate students in the CAPES Country in the Greater Health Sciences Area in 2019, a total of 65 individuals were obtained whose scholarships of the Postdoctoral Program Abroad ended in 2015, 2016, 2017 or 2018, shown in Table 1.

**Table 1** – Number of publications in international collaboration by group of former PPDE fellows three years before (period 1) and three years after the end of the fellowships (period 2)

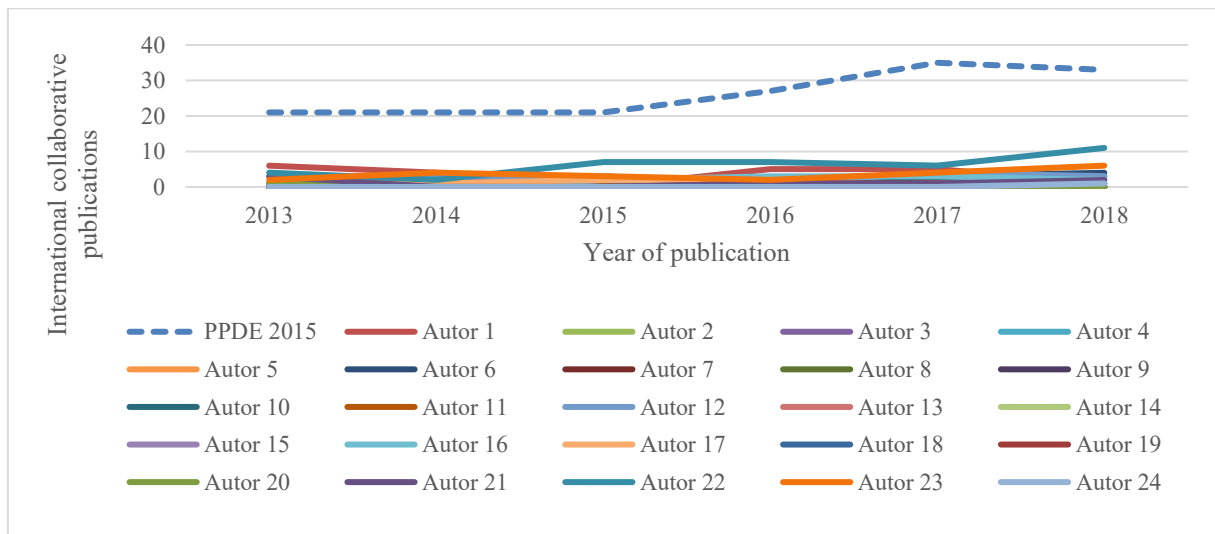
| Group     | Number of former scholarship holders | Period 1     | Number of publications - Period 1 | Publications per fellow (average) - Period 1 | Period 2     | Number of publications - Period 2 | Publications per fellow (average) - Period 2 |
|-----------|--------------------------------------|--------------|-----------------------------------|--|--------------|-----------------------------------|--|
| PPDE 2015 | 24                                   | 2013 to 2015 | 63                                | 2.63   | 2016 to 2018 | 95                                | 3.96   |
| PPDE 2016 | 16                                   | 2014 to 2016 | 14                                | 0.88   | 2017 to 2019 | 56                                | 3.50   |
| PPDE 2017 | 12                                   | 2015 to 2017 | 36                                | 3.00   | 2018 to 2020 | 71                                | 5.92   |
| PPDE 2018 | 13                                   | 2016 to 2018 | 118                               | 9.08   | 2019 to 2021 | 169                               | 13.00  |

Source: Prepared by the authors

In the three years prior to the end of the fellowship, these authors had 231 publications in international collaboration classified in *Medical Sciences* indexed in the Scopus database, and 391 in the subsequent three years, with the average number of international co-authored publications per fellow growing in all cases.

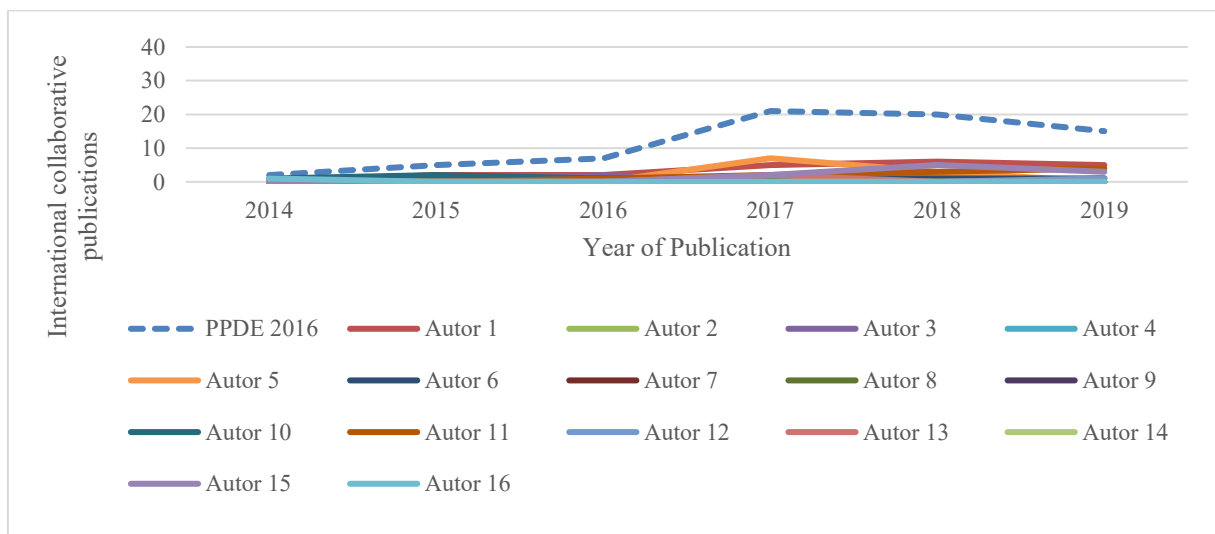
Below are four graphs that list the number of works in international collaboration by each author, as well as the sum of the group's publications, by year of publication, considering in each graph the period three years before and three years after the end of the grants.

**Graph 1** – Number of publications in international collaboration by each former fellow per year of publication in the six years analyzed – PPDE Group 2015



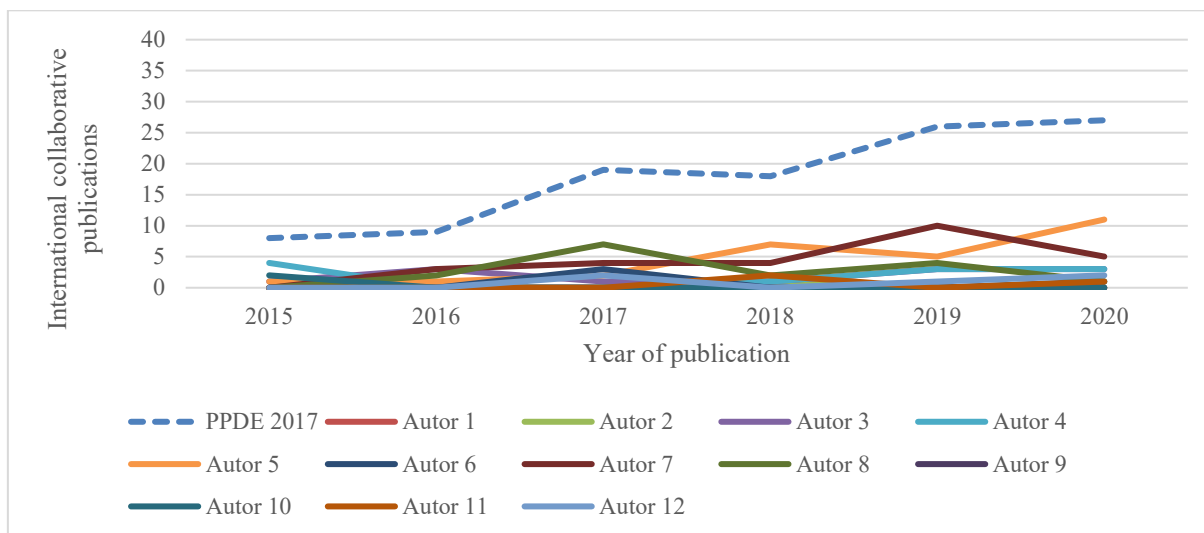
Source: Prepared by the authors

**Graph 2** – Number of publications in international collaboration by each former fellow per year of publication in the six years analyzed – PPDE Group 2016



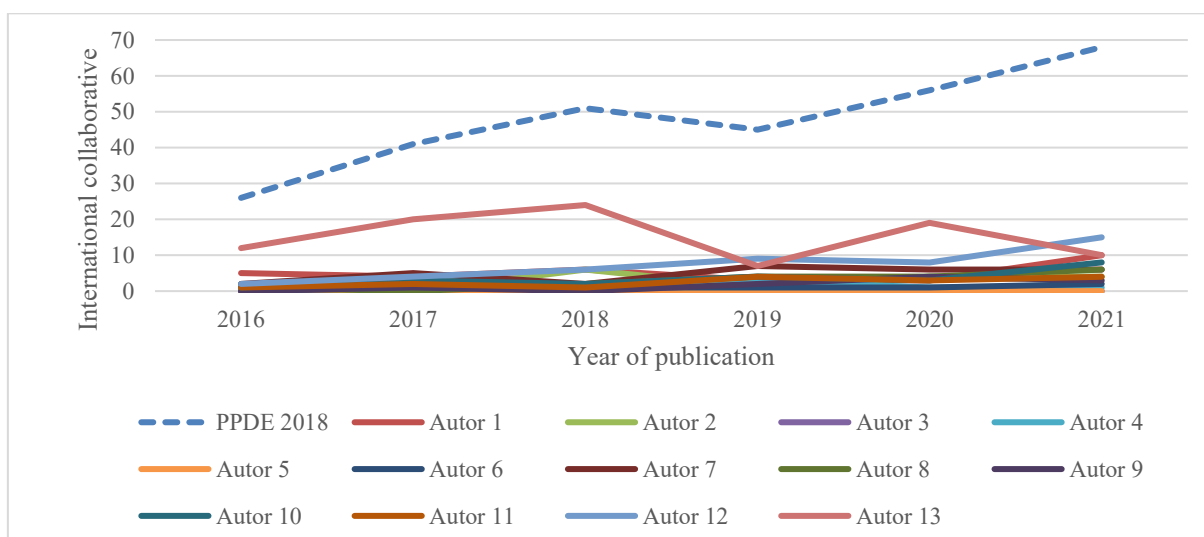
Source: Prepared by the authors

**Graph 3** – Number of publications in international collaboration by each former fellow per year of publication in the six years analyzed – PPDE Group 2017



Source: Prepared by the authors

**Graph 4** – Number of publications in international collaboration by each former fellow per year of publication in the six years analyzed – PPDE Group 2018



Source: Prepared by the authors

As seen in Graphs 1 to 4, in general, former scholarship holders are in the range of up to ten publications per year, with a greater discrepancy for an author who ended the scholarship in 2018.

Table 2 shows the evolution of the number of countries with which Brazil collaborated through the publications analyzed in period 1 and period 2.



**Table 2** – Number of countries with which Brazil collaborated through the publications analyzed for each group of former PPDE scholarship holders three years before (period 1) and three years after the end of the scholarships (period 2)

| Group     | Number of countries with which Brazil collaborated - Period 1 | Number of countries with which Brazil collaborated - Period 2 | Number of countries in common in both periods |
|-----------|---|---|---|
| PPDE 2015 | 24  | 29  | 21  |
| PPDE 2016 | 9   | 22  | 7   |
| PPDE 2017 | 20  | 19  | 11  |
| PPDE 2018 | 142   | 141   | 127   |

Source: Prepared by the authors

Through the publications in international collaboration of the individuals studied, for the group that ended the scholarship in 2015, Brazil went from collaborating with 24 countries to 29, with 21 nations appearing as affiliations of the co-authors in the two periods analyzed.

For the second group, we go from 9 countries to 22, with 7 of them remaining between the two periods. In the cases of the third and fourth groups, there is a quantitative decrease in a country after the end of the grant period, and for the third group there is a drop from 20 to 19 countries, with eleven countries in common for both time periods, while for the fourth group, we go from collaborating with 142 countries to 141, maintaining relationships with 127 countries between the two moments analyzed.

In period 1, counting the countries in common, the four groups studied published studies with Canada, the United States and the United Kingdom. Another 11 countries appear in three of the groups, 22 countries in two of the groups and the remaining 106 countries with which Brazil collaborated appear in publications from only one of the groups (and may appear in one or more publications from a group).

When checking period 2, in addition to maintaining the relationship with the three countries mentioned in common, Germany, Australia, Chile, Colombia, Spain, Italy, Malaysia and Mexico are added, collaborating in the four groups of authors. In three of the groups there are cooperations with 6 other countries. A total of 25 countries appear in productions from two groups, while 99 countries are registered affiliations in productions in just one of the alumni groups (with at least one publication involving each country).

It is important to highlight that, for the group that completed the scholarship in 2018, the majority of the productions analyzed were hyper-authored, which means that the list of authors of the same work is extremely long (Birnholtz, 2006). In the article entitled “Written by many hands” in the journalistic magazine *Pesquisa FAPESP*, the author provides an



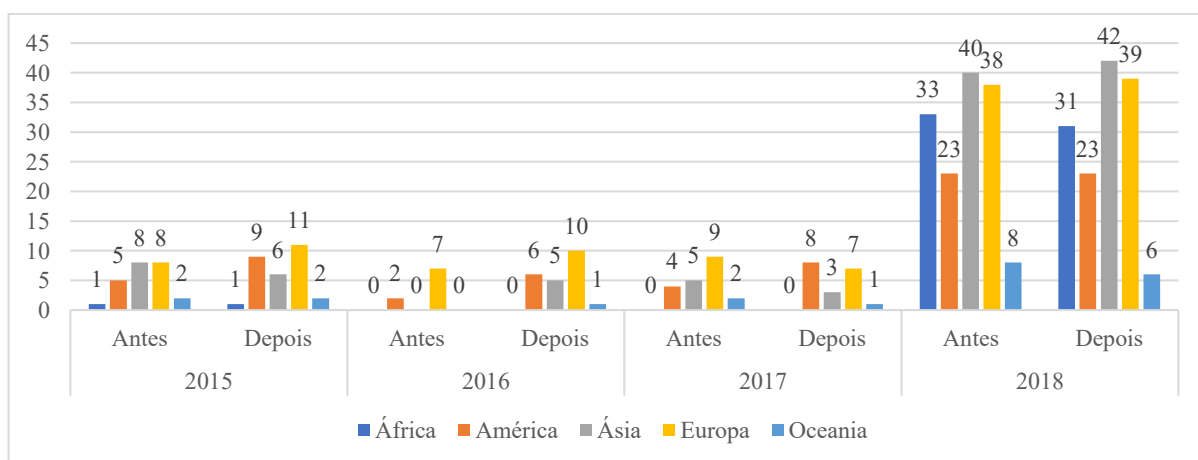
explanation from Martin Szomszor, head of research analysis at *the Institute for Scientific Information* about the phenomenon:

The multiplication of authors reflects a change in the nature of scientific research, today increasingly global and collaborative in various fields. “Many of these works are associated with complex themes, which require investments in equipment, data collection, analytical processing and large specialized teams spread across several countries” (Andrade, 2020, p. 42-45, our translation).

For this group, more than 50 productions have more than 100 authors, and some have more than 1000. Considering that the more authors in a publication, the greater the possibility of different countries being represented, this explains, therefore, the high number of nations represented in the 2018 PPDE Group, which does not mean that collaboration with such countries will generate other collaborations in the future, although they have the potential to increase citations and visibility of the study.

According to Graph 5 below, for the groups ending scholarships in 2015, 2016 and 2017, there is a predominance of countries from the American, Asian and European continents in the international collaborations considered, with the presence of co-authorship with at most one African country or even two countries in Oceania. For the 2018 group, there is a predominance of partnerships with a greater variety of countries on the African continent compared to the American continent, probably due to the profile of hyper-authored works in the group.

**Graph 5** – Number of countries on the five continents with which Brazil collaborated through co-authorship in the publications analyzed for each group of former PPDE fellows three years before (period 1) and three years after the end of the fellowships (period 2)



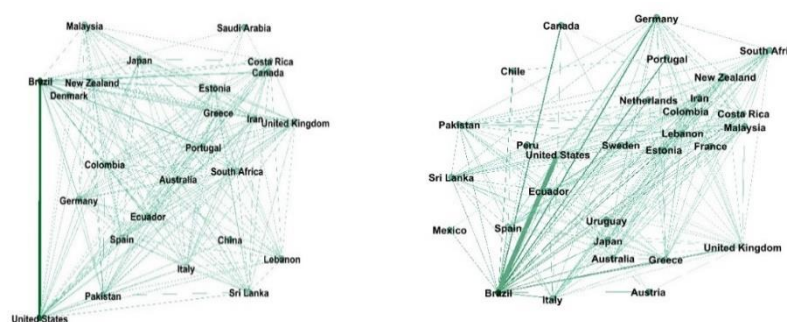
Source: Prepared by the authors

Next, the international co-authorship networks for each group of former fellows are presented, resulting from the sets of publications analyzed at both moments, before and after the end of the fellowships, periods 1 and 2, respectively.

Former fellows (and, perhaps, other Brazilian authors in the same publication) are represented as the Brazil node, just as co-authors are represented by their country of affiliation, and if there is more than one author with the same origin per publication, they are counted as just one vertex, referring to the respective country.

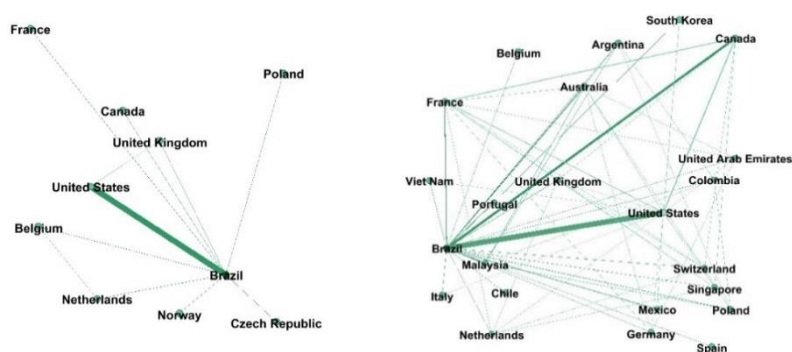
The edges represent co-authorships, so if an article has authors from three different affiliations, countries A, B and C, connections between the nodes are represented as follows: A connected to B, A connected to C and B connected to C. Because there is no order between the nodes, co-authorship networks are undirected, which means that there is no difference in the order of connection from A to B or from B to A. The more publications in co-authorship between two countries, the thicker it is the representation of the edge that connects them.

**Figure 1** – International co-authorship networks of the 2015 PPDE Group, three years before (period 1) and three years after the end of the grants (period 2).



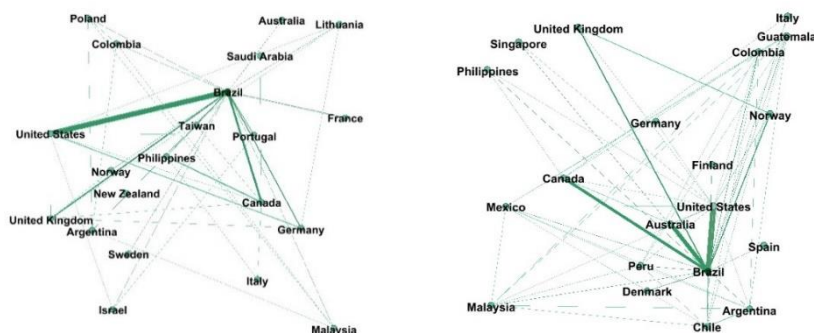
Source: Prepared by the authors

**Figure 2** – International co-authorship networks of the 2016 PPDE Group, three years before (period 1) and three years after the end of the grants (period 2).



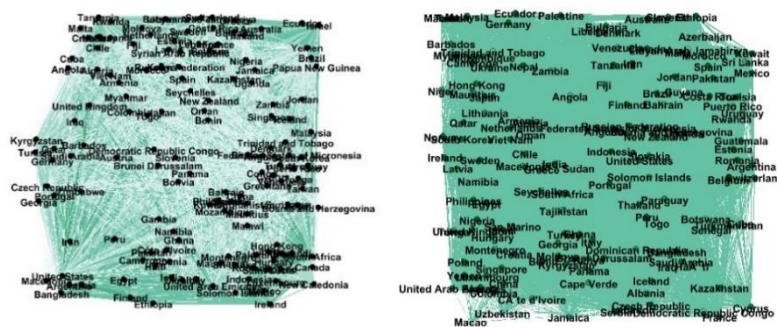
Source: Prepared by the authors

**Figure 3** – International co-authorship networks of the 2017 PPDE Group, three years before (period 1) and three years after the end of the grants (period 2).



Source: Prepared by the authors

**Figure 4** – International co-authorship networks of the 2018 PPDE Group, three years before (period 1) and three years after the end of the grants (period 2).



Source: Prepared by the authors.

Table 3 presents the general characteristics of the networks in the two periods evaluated:

**Table 3** – Global metrics of international co-authorship networks by group of former PPDE fellows three years before (period 1) and three years after the end of the fellowships (period 2)

| Group     | Period 1 |       |              |                        |               | Period 2 |       |              |                        |               |
|-----------|----------|-------|--------------|------------------------|---------------|----------|-------|--------------|------------------------|---------------|
|           | Us       | Edges | Medium Grade | Average Weighted Grade | Graph Density | Us       | Edges | Medium Grade | Average Weighted Grade | Graph Density |
| PPDE 2015 | 25       | 204   | 16,320       | 98,080                 | 0.680         | 30       | 215   | 14,333       | 70,467                 | 0.494         |
| PPDE 2016 | 10       | 11    | 2,200        | 7,200                  | 0.244         | 23       | 64    | 5,565        | 25,391                 | 0.253         |
| PPDE 2017 | 21       | 41    | 3,905        | 13,905                 | 0.195         | 20       | 58    | 5,800        | 28,400                 | 0.305         |
| PPDE 2018 | 143      | 9,224 | 129,007      | 3,565,538              | 0.908         | 142      | 9,109 | 128,296      | 1,351,239              | 0.910         |

Source: Prepared by the authors

When comparing the graphs referring to the period before the end of the scholarship and after its conclusion, it is clear that, for the PPDE 2015 and 2016 groups, there was an expansion in the size of the networks related to the increase in the number of co-author countries, in the PPDE groups 2015, 2016 and 2017 saw an increase in the number of connections between network actors, and in all cases it was also seen that there was an expansion in relation to the frequency of collaboration between Brazil and some countries, visualized by the thickness of the edges.

The degree of a node is related to the number of links established by it, and the average degree refers to the average of the degrees of all nodes in a network, which, for the study in question, implies the average of countries with that a nation collaborated in each of the networks. Additionally, the average weighted degree considers the weight of connections, which in co-authorship networks can be understood based on the quantity of productions shared by a pair of actors, giving a better idea of the number of relationships occurring. The representation in the graphs of the multiplicity of co-authorships between the same pair of countries was due to the thickness of the edges: the more publications a pair of countries share, the thicker the edge that connects them (Newman, 2010).

Thus, in the groups studied, in two cases there was an increase in the average number of nations with which each country published, while in the other groups there was a decrease in the average degree. The same behavior was verified regarding the average weighted degree measuring the number of shared publications.

The density of a network, which varies between zero (0) and one (1), represents the number of connections made in relation to the total number of possible links in a given graph, that is, the more interconnected the vertices are, the denser becomes the network (Hanneman; Riddle, 2011). The closer to one (1), the denser the network.

When analyzing this parameter of the first period *versus* that of the second, with the exception of the first group, the densification of the networks is noticeable, but with low density (values closer to zero than one) in most cases.

The lower density in the first case occurs due to the increase in countries in period 2, which increases the possibility of links between nodes, not accompanied by a sufficient increase in connections to maintain or exceed the density of period 1. As for the second group, despite As the number of countries increases, there is a greater increase in connections between them, reflecting the growth in network density. For the group ending the scholarship in 2017, there is a decrease in the number of countries between the first and second periods, but an increase in

the number of edges, ensuring a denser network than in the first moment. In relation to the last group, there is a decrease in both the number of nodes and the number of connections between them, however, the decrease did not affect the density, obtaining similar values between the periods.

Density can positively or negatively impact a network. While high density is associated with speed in the dissemination of information and good understanding among the actors involved in the network, the capacity for innovation and access to external information is questioned (Connie *et al.*, 2019). Pauli *et al.* (2019) argue that there is a non-linear effect of network density, but rather a curvilinear one.

Moving on to the analysis of specific parameters for each network, its degrees, weighted degrees, eccentricity, proximity centrality, betweenness centrality and eigenvector centrality were verified for each node.

As for degrees, for the PPDE 2015 group, the countries with links to more nations besides Brazil were the United States and Italy in period 1 and the United Kingdom and the United States in period 2. However, when checking the weighted degree, Germany takes the place of Italy and the United Kingdom in the first and second moments, respectively.

In the PPDE 2016 group, in the first period, three countries appear tied with the greatest degree in relation to the other actors in the network (with the exception of Brazil): Belgium, the United States and the United Kingdom, but the United States stands out with a greater weighted degree. In the second moment, the United States and France take the lead, with Canada replacing France in weighted terms.

In the PPDE 2017 group, after Brazil, in period 1, Canada and the United States are equal as countries linked to the largest number of other nations, with the United States standing out for establishing more connections, followed by Canada. In period 2, disregarding Brazil, the United States comes first and Colombia comes second in terms of degree, but when checking the weighted degree, Australia takes second place behind the United States.

For the PPDE 2018 group, due to the characteristic of the production being largely hyper-authored, it appears that 58 countries in the first period have the same degree as Brazil, the differentiation being due to the weighted degree in which the States stand out after Brazil. United States, followed by Australia. For the second period, 42 countries matched Brazil in terms of degree, with emphasis on the United States, followed by Canada in relation to weighted degree.

In this way, the importance of the United States in the networks of former Brazilian postdoctoral fellows studied abroad is noted, both as a country, after Brazil, with connections to a greater number of countries, and in volume of publications in co-authored with the other nations represented.

Eccentricity refers to the greatest geodesic distance between an actor and any other in the graph (Hage; Harary, 1995). In the cases studied, only the PPDE 2017 group presents countries with eccentricity of up to 3, whereas in the other groups in both periods 1 and 2, the eccentricity is 1 or 2 for the nodes, which demonstrates that network participants They are quite close, making it necessary to pass through a maximum of three vertices to connect to a more distant one. Furthermore, only in the PPDE 2018 group was there a change in the eccentricity of some countries between the first and second periods.

Unlike eccentricity, proximity centrality relates to how close a vertex is to the others, that is, the smaller the distance between the node and each of the others, the greater the geodesic measure of proximity will be (Cerqueira; Costa; Carvalho, 2014).

Considering this, the PPDE 2015 group repeats the same countries from the degree analysis with a higher measure of proximity centrality. For the PPDE 2016 group, after Brazil, in the first period it appears with the same values, in addition to the countries mentioned in the grade analysis, the Netherlands. In the second period the pattern presented in relation to the degree remains. For the PPDE 2017 group, the same nations listed with the highest degree are those with the highest proximity centrality. As for the PPDE 2018 group, all countries with the same degree as Brazil are also listed as being closer.

Moving on to discussing eigenvector centrality, it is clear that a given node in a network has its importance modified by the connections it establishes, therefore, its importance may be related to the number of connections it makes or which actors in the network it is interacting with, or both situations (Newman, 2010).

After Brazil, with eigenvector centrality equal to 1 in all networks (as it relates to all participants), the PPDE 2015 network records 15 countries tied in period 1 with the highest value, and in the second period, the United Kingdom, followed by the United States, are presented as countries with higher centrality values, reinforcing the importance of these countries for Brazil in the networks studied. Furthermore, three countries stand out that increased their importance in the second period in relation to the first, Ecuador, Japan and the United Kingdom.



In relation to the PPDE 2016, in the first period, four countries presented a higher value for the parameter in question, and in the second period, the United States stood out, followed by France. In addition to these two countries, the Netherlands and Canada had higher eigenvector centrality in period 2 than in period 1.

For the PPDE 2017, the United States followed by the United Kingdom stand out in terms of importance in the first instance, and in the second, Colombia takes the position of the United Kingdom, behind the United States, so that, in addition to the last two mentioned, Argentina, Malaysia, Australia and Italy showed an increase in importance in the time interval analyzed.

Finally, in the 2018 PPDE Group, Brazil is joined by another 58 countries with centrality 1 in the first period, and 43 in the second. Furthermore, 36 countries had their importance increase from one period to the next.

### **Final remarks**

From the results obtained in the study, it can be seen that there was an increase in the average number of publications in international co-authorship by former fellows of the Post-Doctoral Program Abroad (PPDE) of CAPES in the Greater Health Science Area between the periods analyzed, with a noticeable quantitative improvement in terms of scientific production in the period after the end of the post-doctorate, and, as described by Wagner and Leydesdirff (2005), the growing scientific aptitude of a given country can increase its connectivity capacity on a global level.

In line with this, a good variety of co-authors' countries of affiliation can be seen, demonstrating that, even if the groups' main collaborating countries are maintained (United States, United Kingdom, Canada, Germany, Australia, Chile, Colombia, Spain, Italy, Malaysia and Mexico), space is opened for broader collaboration with various nations around the globe, such as countries in Africa, Central America and Eastern Europe, which increases the potential for visibility and citation of the publications made, two desirable effects.

Specifically in relation to the co-authorship networks formed, there is a differentiated growth in the groups after the end of the scholarship, which may be due to an increase in the number of co-authoring countries, an increase in the number of connections between nations or an increase in the frequency of collaboration between a pair of countries.



The ARS methodology allows the visual representation and mapping of a network's interactions, which enables monitoring, evaluation and even the planning of public policies related to such circuits.

The case in question allowed us to analyze and visualize the collaboration networks established through co-authorship, providing interesting metrics, such as centrality measures, demonstrating which countries are most important for the groups studied in promoting international scientific productivity.

In addition to face-to-face collaboration, which is sometimes limited by logistical and financial issues (especially when it comes to international collaboration), what is currently clear is that collaboration has been facilitated by technological advances, especially mediated by the internet, which allows virtual contact in real time, in addition to sharing data and files.

It is important to highlight that the results presented here refer only to publications in international collaboration indexed in the Scopus database produced by former PPDE fellows in the 3-year period up to the year of completion of the respective grants in comparison with their publications in the period of 3 years after the year of the end of the postdoctoral fellowship, and should not be extrapolated for interpretations in relation to the other countries mentioned in the study, including Brazil as a whole. However, they can serve as a basis for public policy makers to understand which actors are interesting in the context of each area, directing involvement with other partners that they deem important in a given field of knowledge, as well as identifying necessary changes. The ARS methodology in question, together with bibliometric analysis tools, can provide important information for conducting strategic scientific policy.

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**Ethical approval:** As this information is available in open data, there was no submission to an ethics committee.

**Availability of data and material:** Primary data can be obtained through the CAPES Open Data Portal. The other data resulting from the methodological procedures applied can be obtained on the SciVal platform.

**Author contributions:** The author Luciana Gasparotto Alves de Lima collected, analyzed and interpreted the data and wrote the text. The author Renato Barros de Carvalho contributed to generating the study results (graphs and related statistics). The author Maria do Rocio Fontoura Teixeira contributed to the guidance, review and supervision of the article.

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