GENDER AND THE SCISSORS GRAPH OF BRAZILIAN SCIENCE: FROM EQUALITY TO INVISIBILITY

GÊNERO E O EFEITO TESOURA NA CIÊNCIA BRASILEIRA: DA IGUALDADE À INVISIBILIDADE

GÉNERO Y EL GRÁFICO DE TIJERA DE LA CIENCIA BRASILEÑA: DE LA IGUALDAD A LA INVISIBILIDAD

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Abstract

Women are underrepresented in science and their participation decreases as the career progresses; an international phenomenon clearly displayed in a scissors graph. This decrease is usually attributed to maternity, lower number of publications and less ability of receiving grants. Here we present a comprehensive study of the Brazilian science and technology system, covering 8,877,626 people, and analyzing the participation of women from the undergraduate to ministerial levels. The study used different databases to develop relevant indicators of the participation of women, some of them over a period of 15 years. Our results suggest that the decrease of women as the career advances is due to a combination of barriers that need to be faced and eliminated to promote equity for a better science.

Keywords: Gender; Women in science; Misogyny; Brazilian case study.

Resumo

As mulheres estão sub-representadas na ciência e sua participação diminui à medida que a carreira avança; um fenômeno internacional claramente exibido em um gráfico de tesoura. Esse decréscimo geralmente é atribuído à maternidade, menor número de publicações e menor capacidade de recebimento de bolsas. Aqui apresentamos um estudo abrangente do sistema de ciência e tecnologia brasileiro, abrangendo 8.877.626 pessoas, e analisando a participação das mulheres desde a graduação até os níveis ministeriais. O estudo utilizou diferentes bases de dados para desenvolver indicadores relevantes da participação das mulheres, alguns deles ao longo de 15 anos. Nossos resultados sugerem que a diminuição de mulheres à medida que a carreira avança se deve a uma combinação de barreiras que precisam ser enfrentadas e eliminadas para promover a equidade para uma ciência melhor.

Palavras-chave: Gênero; Mulheres na ciência; Misoginia; Estudo de caso no Brasil.

Resumen

Las mujeres están subrepresentadas en la ciencia y su participación disminuye a medida que avanza la carrera; un fenómeno internacional que se muestra claramente en un gráfico de tijera. Esta disminución generalmente se atribuye a la maternidad, menor número de publicaciones y menor capacidad para recibir becas. Aquí presentamos un estudio integral del sistema brasileño de ciencia y tecnología, que abarca 8.877.626 personas, y analiza la participación de mujeres desde niveles de grado hasta ministeriales. El estudio utilizó diferentes bases de datos para desarrollar indicadores relevantes de la participación de las mujeres, algunos de ellos durante 15 años. Nuestros resultados sugieren que la disminución de mujeres a medida que avanza una carrera se debe a una combinación de barreras que deben abordarse y eliminarse para promover la equidad para una mejor ciencia.

Palabras clave: Género; Mujeres en la ciencia; Misoginia; Estudio de caso en Brasil.

Introduction

Although there are more female than male undergraduate and graduate students in many countries Organization for Economic Co-Operation and Development (OCDE) (2019), women compared with men publish less papers West *et al*. (2013); Huang *et al*.

(2020) and patents Ding *et al*. (2006), receive lower funding Ley and Hamilton (2008) and are last or first author of publications in lower numbers West *et al*. (2013), particularly in fields which require a higher level of funding to build the research infrastructure, to hire staff and where there are higher publication fees Duch *et al*. (2012). Consequently, fewer women reach the high positions of full professors UN (2007).

The absence of women in high ranked positions has been explained as the consequence of childbearing and rearing Ceci and Williams (2011). However, these two barriers cannot explain the absence of female scientists without children in the top-level position. In addition, evidence shows that women are less represented in STEM fields at all levels Hill *et al*. (2010); Ginter and Kahn (2006); NSF (2010) and this might be related to stereotypes Reuben *et al.* (2014) across the STEM pipeline Moss-Racusin *et al*. (2011); Reuben *et al*. (2014); Knobloch-Westerwick et al. (2013b,a); Schroeder (2013); Sheltzer and Smith (2014); Steinpreis *et al*.(1999); Jaschick (2014).

The bias, as any social construction, starts at early ages, at primary education, Bian *et al*. (2017) and goes up to university Emily M. Marshman *et al*. (2018). Looking at the career track, this bias can be observed in the hiring Moss-Racusin *et al*. (2011) process, in the way people refer to the professional using their first or surnames Atir and Ferguson (2018), in the way laboratory instructions are formulated Quinn *et al*. (2018) and in the way scientific production is evaluated Handley *et al*. (2015).

The bias has two components, one universal and one local. The scissor effect UN (2007), the decrease of the percentage of female researchers progressively as we advance from the undergraduate to the professorship level, is present in all countries UN (2007). However, the specific numbers change from country to country.

A global and cross-disciplinary bibliometric assessment performed by *Lavie`re* and co-authors shows that the relationship between gender and research output, the extent of collaboration and the scientific impact of all articles published between 2008 and 2012 and indexed in the Thomson Reuters Web of Science databases are heterogeneous in different fields and countries Knobloch-Westerwick *et al*. (2013a). South American and Eastern European countries have higher gender parity, even though women account for fewer than 30% of co-authorship, whereas men represent slightly more than 70%.

That study also confirmed that fields associated with 'care', such as nursing; midwifery; speech, language and hearing; education; social work and librarianship are female dominated, while military, exact sciences, engineering, robotics, aeronautics and astronautics, high-energy physics, mathematics, computer science, and philosophy are male dominated fields. The same is true for Brazil Abreu *et al*. (2016). These differences in fields and among countries clearly indicate the relevance of cultural aspects in the construction of the bias.

In an attempt to measure how the participation of women in the authorship of papers changes with time and varies among world regions, Elsevier produced a global survey. They used data from Scopus, an abstract and citation database of more than 62 million documents. The authors broke the data down into 27 subject areas and compared them across 12 countries and regions for two 5-year blocks of time: 1996-2000 and 2011-15. The report included only researchers who were listed as authors on at least one publication within either of the two five-year periods. Although the proportion of women in science has grown globally, the rates were different across countries or disciplines. Brazil was the gender champion with an increase of 11% between the two periods and reaching almost 50% of women authors in 2015 Mobed (2017).

Elsevier's results suggest that gender bias might not be a problem in Brazil since the scientific community managed not only to have the highest percentage of female scientists publishing at Scopus, but also showed the largest increase in this number in the period analyzed. This result was seen by some as a study reinforcing the idea that a country in which families have access to childcare, either institutionalized or through hiring maids, can reach gender equality.

To understand if the equality observed in the Brazilian publication score at Scopus represents a real advance we analyzed the percentage of male and female participation in scientific knowledge production in Brazil from undergraduate to the top-level positions, such as ministers of education and science and technology. The aim was to verify whether the equality seen at the global scenario of publication rates would also be observed at the top levels in Brazilian scientific and technological system. If not, this would show that the high percentage in the publication, in fact, hides a persistent bias where women are present at the initial stages of a scientific career, but not at the top, in a clear glass ceiling effect.

Methods

The data collected for constructing the first sector of Figure 1, called technical, refers to year 2015. The numbers of undergraduate students and lecturers were taken from the Higher Education Census, adding up to 8,027,297 and 401,299 observations, respectively Inep (2015). The data of students (n = 338,035) and lecturers (n = 90,307) of graduate programs were extracted from the Capes website Capes (2015a). That institution makes available in open access part of its current and historical databases, making it possible to find information from 2005 onward, depending on the variable of interest Capes (2015a).

The second sector of Figure 1 was constructed using two strategies. For the information regarding positions with large number of individuals, we used data from one year, while for positions with a smaller number of members we employed data from over a decade. For example, the graduate courses coordinators in 2015 were 5,199 Capes (2015b). The number of CNPq research fellowship recipients in 2015 was 14,102 CNPq (2015). For the CNPq advisory committee members we used the numbers of 2005, 2010, 2015 Brasil CNPq (2011) and, 2019 CNPq (2019). These years were selected because this position lasts from three to four years. The number of 124 coordinators of Capes area of knowledge from 2004 to 2018 was obtained by searching within official appointment ordinance. The position lasts from three to four years.

The data of the third sector of the graph, the political positions, took into consideration all of the leaders since the creation of each organization. Information was obtained using both websites of the organizations and by requesting information from the different institutions using the Law of Information Access. The total number of leaders for each organization is: for the State Foundations of Support for Research, n = 104, Brazilian Society for the Progress of Science - SBPC, n = 19, area Coordination for the Improvement of Higher Education Personnel - CAPES, n = 21, Brazilian Academy of Sciences - ABC, n = 16, National Council for Scientific and Technological Development - CNPq, n = 27, Ministry of Education - MEC, n = 62 and Ministry of Science, Technology and Innovation – MCTI, n = 22.

Results

Figure 1 illustrates the Brazilian science and technology system. The graph is separated in three sectors: only technical, both technical and political and only political. The first group shows the percentage of male (orange) and female (purple) undergraduate and graduate students who were studying in Brazil in 2015. It also shows the percentage of male and female lecturers teaching at the undergraduate level of the universities and colleges, and the percentage of male and female lecturers at graduate programs, both collected in 2015 in Brazil. In Brazil, lecturers at the graduate programs are also advisors of students and active researchers. They are ranked as adjunct, associated or full professors. At this sector of the graph, women are the majority as undergraduate and graduate students, but their number decreases as lecturers and as the prestige of the position of lecturer at undergraduate and graduate courses increases.

The second sector in Figure 1 shows the percentage of man (orange) and women (purple) in positions that, even though being associated with technical skills, also require some political or networking aspects. For example, each graduate program in Brazil elects a coordinator responsible for the definition of the program policies during a period of time, which varies from two to four years. This position is occupied by a professor with a large experience as an advisor but also recognized by his/her peers as a leader. The total number of graduate programs in 2020 is 5,199 Capes (2015b). The graph illustrates the percentage of man (orange) and women (purple) as graduate program coordinators in 2020. The graph shows a decrease in the percentage of women in this position when compared with the number of women working as lecturers and advisors. The difference, however, is not very large and can be explained by the fact that this position, although associated somewhat with power, also implies a lot of bureaucratic work.

Another position of leadership is represented by being granted a CNPq research fellowship. This is a fellowship given to researchers with a permanent position at a university or research center usually with 10 years of PhD and considered of excellence. Of the 71.841 researchers that are advisors in graduate courses Capes (2015a) (one of the requirements for this research grant), 14.102 (19.6%) CNPq (2015) have this type of fellowship. In order to receive such grant, the researcher has to combine scientific productivity with leadership. Figure 1 shows the percentage of man (orange) and women (purple) as CNPq research fellowship recipients in 2015. The graph indicates that the

percentage of women with this prestigious fellowship is not only smaller than the percentage of women working in the courses as lectures and advisors but it is also smaller than the percentage of women as graduate program coordinators.

Next, we analyzed the percentage of women as CNPq advisory committee members. This group is responsible for deciding which researchers receive grants, and in particular, the research fellowship in each area of knowledge. It usually involves 10-20 people in each area of knowledge. Figure 1 shows the percentage of man (orange) and women (purple) as CNPq advisory committee members from 2005 to 2019. This position is associated with power and requires knowing and being known by the scientific community of each area. The percentage of women is smaller than the percentage of women as CNPq research fellowship recipients, which is the universe from which CNPq advisory committee members are selected.

The last group in this sector of Figure 1 is represented by the coordinators of areas of knowledge at Capes. Capes is Brazil's post-graduate education agency responsible for evaluating graduate programs and giving scholarships to graduate students, granted to the better evaluated programs in the country. Each area has one coordinator. The CAPES area coordinators have more power and prestige than the CNPq committee members do, because the decisions of the committee they chair directly affect the graduate programs. They lead the activities that confer grades to the graduate programs every four years, and if the programs are badly evaluated, they will receive fewer scholarships to distribute to their students and might even, if they are among the lowest grades, be forbidden to confer a diploma. Figure 1 shows the percentage of man (orange) and women (purple) as Capes area of knowledge coordinators from 2011 to 2022 (the current coordinators have mandate until 2022). The numbers are related to the average over this period instead of looking at one year, since the number of coordinators indicated in each year is very small. The percentage of women in this position is even lower. This can be attributed to the large amount of power involved in this position.

The third sector, which we defined as political, involves leadership positions in academies, science funding agencies and ministries. These positions, which in several cases are occupied by scientists, have large visibility and considerable power. In this case, the percentage was computed or the period in which the position existed. The Brazilian Society for the Progress of Science (SBPC) is a non-profit organization involving students

and professionals in science and education. The membership is by voluntary registration. It has similarities with the American Association for the Advancement of Science (AAAS) in the United States. The association has an important role in promoting and defending education, science, culture and democracy. Brazil has three large-scale grant agencies: Capes, which funds and evaluates the graduate programs; CNPq, which supports individual researchers and funds large research projects; and the State-level science funding agencies (FAP) (one per state) which funds research and graduate students within the State. It is interesting to notice in Figure 1 that the percentage of women as president of Capes, FAP's and CNPq decreases from 16% to 0% indicating that research areas are more prestigious than agencies that rule over educational aspects. The same can be observed when comparing SBPC to the Brazilian Academy of Sciences (ABC). The ABC members are elected by the current members and the percentage of women is much lower than the percentage of women as researchers or even researchers at the top of the career Ferrari *et al*. (2018). Finally, when the ministry of science and technology is compared to the ministry of education, one can see that while no women were ever appointed as minister of science and technology, Brazil had one woman as minister of education.

Discussion

The combination of the three sectors illustrated in Figure 1 shows that in the Brazilian science and technology system the percentage of women decreases as the position increases in power, illustrated by the well-known scissors graph. This process was first identified and measured by the European Commission in data from the late 1990's Commission (2003). Since then, the European Commission keeps track of the percentage of women in science in different countries from undergraduate to full professorship Commission (2015, 2018). This analysis, however, though quite interesting, does not reveal some of the mechanisms behind the leakage of women out of science as the career advances.

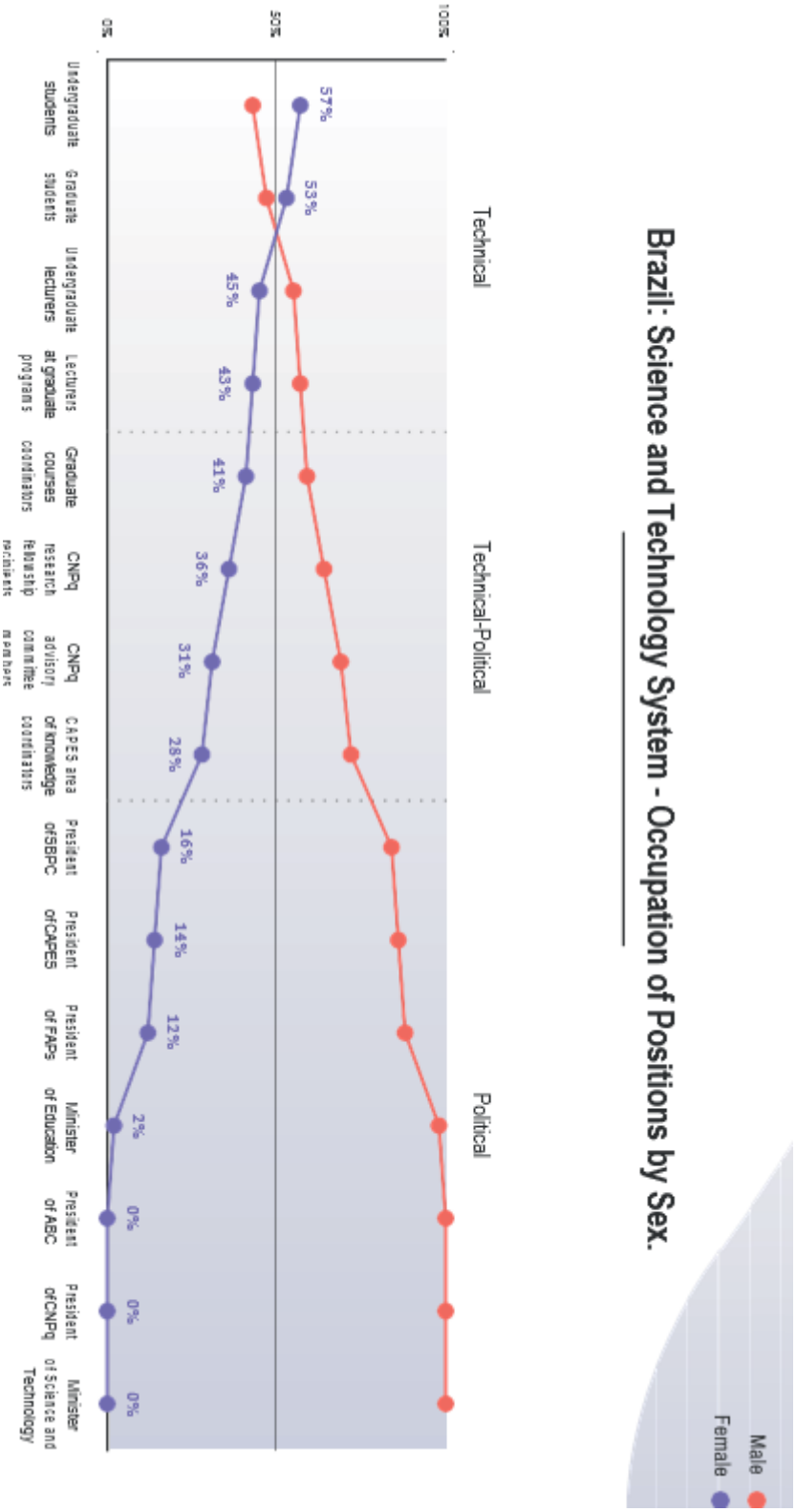
The three sectors in Figure 1 suggest three mechanisms for exclusion. The first sector covers technical-only positions and shows how the career progresses from student to lecturer, which requires technical skills with a long period of training. The evidence from literature has several explanations for the difference in numbers of men and women at this stage, from the impact of maternity in the career of women in childbearing age to

the cultural norms and standards that greatly favor men, making this an institutional issue. The relatively high percentage of female authors in Brazil in Elsevier's study reflects this sector of the graph Mobed (2017) where women are still present, in spite of the obstacles and challenges.

The second sector of Figure 1 is related to activities that require technical skills, but also a perception of excellence by peers and by the applicant. In general, women are seen by peers or even by the students as less eminent Atir and Ferguson (2018); Araujo *et al*. (2017) and less deserving of eminence-related benefits and awards. In many cases, women also have a self-image of being less capable Lerchenmueller *et al*. (2019), Emily M. Marshman *et al*. (2018). These two ingredients explain the gradual decrease in the percentage of women in this sector of the graph. Our results confirm the tendency shown in the many previous studies cited.

Figure 1.

Brazil: Science and Technology System - Occupation of Positions by Sex.



Source: Brazilian Government data basis. Detailed on the Materials and Methods section.

The third sector of Figure 1 shows the political dimensions. It involves positions filled by a single person who represents excellence, power and leadership. Women are absent of this type of positions at all sectors of human activity. In the particular case of Brazil, the absence of an affirmative action policy perpetuates this scenario.

Some say that the presence of women at the lower levels of academic life could bring some optimism for the future generations. The high percentage of women as lectures could suggest that in some years the percentage of women as CNPq research fellowship researchers would be equal to men. However, strong evidence indicates that this is not the case. Analysis of 15 years of CNPq research fellowship recipients showed that the percentage of women in this category increased only 4% Areas *et al*. (2019) in 15 years. A similar study in the area of physics also showed that very small changes were observed over a decade Baggio-Saitovitch *et al*. (2015).

Therefore, we can say Figure 1 suggests that the decrease of percentage of women from undergraduate level to top research and to ministerial and political levels in science and technology is a combination of barriers that need to be faced and eliminated to promote equity for better science Nielsen *et al*. (2017).

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