

## The contribution of women in Brazilian science: A case study in astronomy, immunology and oceanography

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The performance of Brazilian male and female scientists in three scientific fields was assessed through their publications in the *Science Citation Index* from 1997-2001. Information on their sex and their ages, positions, and fellowship status was obtained from a census on all Brazilian scientists. The results showed that women participated most in immunology, moderately in oceanography and least in astronomy. Men and women published similar numbers of papers, and they were also of similar potential impact; they were also equally likely to collaborate internationally. Nevertheless, women were less likely than men to receive fellowships to supplement their salaries, suggesting that some sexual discrimination may still be occurring in the Brazilian peer-review process.

### Introduction

The low participation rate of women in scientific activities has been reported since the 1960s.<sup>1</sup> This trend, however, seems to have changed within some countries and fields as shown by the growing fraction of women enrolled on undergraduate degree courses in different countries during the 1980s.<sup>2</sup> A recent UNESCO report<sup>3</sup> showed that although women's participation in science and technology (S&T) in tertiary education has increased, especially in some developing regions of the world (such as Latin America, Eastern Europe and Asia), they are still in a minority in the sector. They may be even fewer in fields such as physics, where the percentage of women working on S&T activities was less than 10% of the workforce in several developed countries such as Germany, Japan, South Korea, Switzerland, and the USA.<sup>4</sup>

During the last two decades, increasing attention has been paid<sup>5-8</sup> to the problems faced by women in science and engineering that may partly be explained by the huge untapped economic potential that women represent.<sup>9</sup> Among the most frequent findings in the literature of "gender and science" are that (i) male scientists usually outperform

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females and (ii) females have less access to high academic positions as well as to research resources and high salaries.<sup>9–13</sup> The causes for such differences are complex and involve many factors, including cultural, social and economic ones.<sup>1, 10, 14</sup>

Several policies have been developed in order to try and improve matters for women in science and it is therefore necessary to devise means to monitor their success. One measure is the relative presence of women among the authors of scientific publications resulting from research. However this is normally difficult to analyse as most periodicals (and bibliographic databases based on them) only record the initials of their authors' names. Exceptionally, in Iceland, many "surnames" (actually, patronymics) of men end in "sson" and of females end in "dottir" and this enabled one of us<sup>15</sup> to see how women had fared in a small country, albeit one, like Brazil, with a market economy. In Poland many surnames display gender endings, which allowed Webster to carry out a similar study<sup>16</sup> in a country which for much of the period studied was a socialist state, with every encouragement given to women to participate in paid employment and in particular in science.

The findings for Poland were rather different from those in Iceland, where women's participation rose from barely 8% in 1980 to about 20% in the last few years. In Poland, women's share of publications declined modestly from about 35% after the end of socialism but is now almost back at its pristine level. In both countries, there was a clear tendency for women to be relatively much more active in biomedicine and the life sciences, and less so in the exact sciences such as physics and mathematics. Another finding was that women were less likely than men to be working on international projects, suggesting that travel restrictions were hampering their development of overseas contacts. However there was no significant difference in the potential impact of the papers, or, for Iceland, of the actual citation impact of the ones in clinical medicine.

In Brazil, studies of gender and science using a quantitative approach are still uncommon. Recently, Velho and León<sup>17</sup> tested the validity of the assumption that women are less productive than men by measuring some academic and scientific aspects of four research institutes at the State University of Campinas, one of the biggest and most important public universities in Brazil. They found that, although the fraction of women working at these institutes increased in recent decades, they were still concentrated in a small number of fields and they did not readily achieve top career positions. Using quantitative data, the authors discussed the participation of women within the social context of scientific production.

The aim of the present work is to determine whether or not the scientific production of Brazilian female scientists, in three different fields of knowledge, differs from that of male scientists, in terms both of quantity and quality. Using data on publications in astronomy, immunology and oceanography from the Institute of Scientific Information (ISI), we identified and counted Brazilian women's and men's outputs. We classified their papers by their extent of international collaboration and by their potential impact on other researchers as two indicators of the esteem in which the researchers were held. To identify the sex of the researchers, we used a census of Brazilian scientists active in 2000. This database also enabled us to characterise the researchers by age, by whether or not they were designated as group leaders, and whether they had been selected to receive an addition to their salary in the form of a fellowship. The availability of these census data allowed us to use bibliometric means to investigate the standing of female scientists in Brazil.

### **Methodology**

#### *Data on the Brazilian scientific community*

As mentioned above, one of the principal difficulties in studies on women in science is to identify the researchers' sex. Many studies involve manual comparisons, which are labour-intensive and costly, and may still result in some missing information. In order to bypass this difficulty, we asked the Brazilian National Council for Scientific and Technological Development (CNPq in its Portuguese acronym) to extract from its database some data on Brazilian researchers. CNPq is one of the most important Brazilian federal research support agencies, linked to the Ministry of Science and Technology, and grants fellowships to undergraduate and graduate students as well as to established scientists. Since 1993, this agency has carried out a regular national census of Brazilian research groups and has created a large database, the Directory of Brazilian Research Groups.<sup>18</sup> The database includes general information as well as data on the scientific publications of about 56500 names registered in 2002. However these publication data are contributed by the individual researchers and such lists tend to contain many errors. Moreover, the bibliographic details are not standardised: we therefore did not use them as publications data from the SCI are much more complete and accurate. CNPq estimates that its database covers around 80% of the whole Brazilian scientific community.

For the present work we requested a sub-set of the data and CNPq provided them in the form of eight MS Excel spreadsheets, one for each of eight major fields: agricultural

sciences, biological sciences, engineering, exact sciences, health sciences, humanities, languages and arts, and social sciences. The information recorded for each researcher in the Directory for the year 2000 were the following:

- full name
- reference name
- sex (if this field was missing, it was supplied by examination of the first or given name of the researcher by one of us, JL)
- date of birth
- e-mail address
- highest degree
- date of highest degree
- age when obtained highest degree
- whether leader or associate researcher in the group
- field of knowledge
- current institution
- whether in receipt of a CNPq researcher fellowship.

Based on the criterion of researchers' highest degree being a PhD, we have selected three fields for analysis where the percentages of females differ from those of males, namely astronomy, immunology and oceanography (Figure 1).

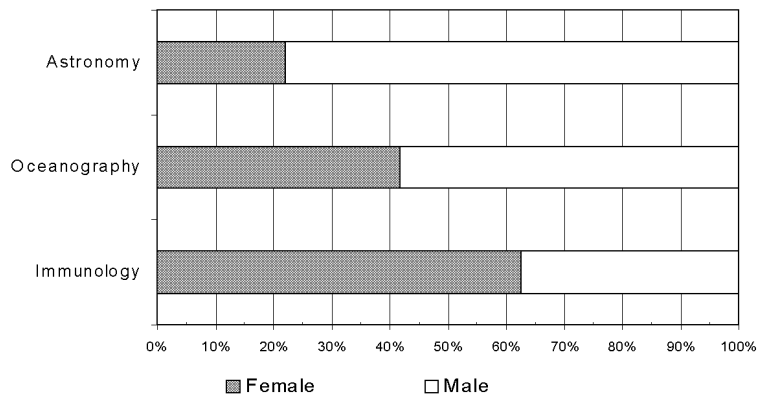


Figure 1. Percentages of Brazilian researchers with a PhD working in astronomy, oceanography and immunology in 2000 who are females (shaded) and males (clear)

*Identification of Brazilian publications in the SCI*

Many bibliometric studies delimit scientific fields by means of lists of journals. However this is unsatisfactory as it will miss papers in general journals (such as *Nature* and *Science*) and because some papers in the journals attributed to a field by the ISI may cover papers that are actually of little relevance to it. In other words, the “filter” of an inclusive list of specialist journals will lack both “recall” and “precision”. It is particularly important to include papers in general journals because these are often the most influential and will enjoy many citations.

We therefore used three filters based on both specialist journals, with more restricted lists than those published by the ISI, and on title words. The technique of development of such filters has been described elsewhere by Lewison<sup>19, 20</sup> For the present study, the astronomy filter was developed in India with the advice of Aparna Basu of the National Institute of Science Technology and Development Studies in 2000.<sup>21</sup> The immunology filter was developed for a study on Austrian biomedical research,<sup>22</sup> on the advice of Caroline Cross of the Wellcome Trust. Finally, the oceanography filter was developed specially for this study, based on the background knowledge of the field by one of us (GL). Table 1 shows the three filters, with their precision and recall, and the numbers of papers (articles and reviews only, because letters and other publication types do not represent peer-reviewed reports of research findings) in the SCI for the five-year study period (1997-2001) for the world overall and for Brazil. (“Precision” is the fraction of the papers retrieved by the filter that are considered (by the expert) to be relevant to the field, and “recall” is the fraction of papers relevant to the field that are identified by the filter.) In the table, the right-hand column, headed “Ratio”, shows the percentage presence of Brazil in world output in each field, using integer counts (i.e., with an internationally co-authored paper counted as unity for each country). It appears that Brazilian scientists have more relative presence in astronomy than in the other two fields, but in all of them it is increasing, particularly in oceanography.

Table 1. List of subject-based filters used for the study of Brazilian researchers, their precision and recall, and annual numbers of world and Brazilian papers in SCI, 1997–2001

Field	Filter	Precision	Recall	World	Brazil	Ratio
Astronomy	ASTRO	0.98	0.96	9609	191	1.99%
Immunology	IMMAL	0.91	0.93	24083	247	1.03%
Oceanography	OCEAN	0.83	0.82	10792	119	1.10%

One of the questions that frequently arise when bibliometric studies are being conducted on non-Anglophone and developing or scientifically peripheral countries is how much of their scientific output is not captured by the SCI because it appears in national or regional journals.<sup>23</sup> We thought that it would be useful to attempt to measure this. We therefore examined the references in Brazilian papers in the SCI in each of the three fields and, from those that appeared to be to papers in journals (because they contained a volume number) we marked those that were from Brazil and not in the SCI. In astronomy and immunology, the percentages of references in such journals represented well under 1% of all journal references (0.1% and 0.6%, respectively) but in oceanography they accounted for 6.5% of the total, indicating that there are a substantial number of Brazilian oceanography journals. It was not possible to list them satisfactorily as their names appeared in different formats, but the leaders were clearly *Revista Brasileira de Biologia* and *Boletim do Instituto de Oceanografia de São Paulo*.

The bibliographic details (authors, title, addresses, abbreviated source) of the Brazilian publications for the three fields were downloaded into MS Excel files. We then checked whether each of the 446 names of Brazilian researchers catalogued in the CNPq database within the three fields were listed amongst the authors of those papers, and then marked the names with a symbol (\$ or %) to indicate whether the author was male or female, preceded by the year of their birth. For example, here is the list of authors of one astronomy paper:

1938\$Kaufmann-P 1961\$Raulin-JP Correia-E 1956\$Costa-JER 1962\$Decastro-CGG  
1965%Silva-AVR Levato-H Rovira-M Mandrini-C Fernandezborda-R Bauer-OH

which has one female and four male Brazilian authors and six unidentified ones. For researchers in the CNPq database with no obvious papers, variants of, or strings of letters within, their names were used in order to try and obtain a match. If one was found, a check was made that there was an address on the paper(s) that corresponded to that in the CNPq database.

In astronomy, 9 of the 109 Brazilian researchers' names were not found, in oceanography 73 of 158 and in immunology 43 of 179. Papers with at least one listed CNPq author numbered 541 in astronomy (56.7% of the total), 135 in oceanography (23.8% of the total) and 407 in immunology (33.2% of the total). A count of the % and \$ symbols in the author field then gave an indication of the sex distribution of the Brazilian authors who had been identified for each paper. It was also possible to search the author field by year so as to show which papers had been produced by researchers in different age cohorts, though these data are not discussed here.

*Potential impact of the papers*

The journals in which the Brazilian papers were published were grouped in four categories according to the average frequency with which all papers in them were cited in the five years following publication,  $C_{0.4}$ . This value was taken from a file of Journal Expected Citation Rates purchased from the ISI, and covering 1996 publications cited from 1996 to 2000. The categories were called Potential Impact Categories (PICs), and were designated 1 (very low,  $C_{0.4} < 6$ ), 2 (low,  $6 < C_{0.4} < 11$ ), 3 (high,  $11 < C_{0.4} < 20$ ) and 4 (very high,  $C_{0.4} > 20$ ). The papers in each field with identified male and female Brazilian researchers could then each be given a PIC value, and hence a distribution for the two groups, male and female, could be calculated to give a comparison of the "quality" of their respective outputs.

**Results and discussion***Personal characteristics of the sample: sex and age*

As shown in Figure 1, the highest female-to-total ratio was found in immunology at 72% (129 of 179 researchers). Oceanography has an intermediate ratio at 42% (66 of 158), while the lowest is in astronomy, 22% (24 of 109). The different percentages of females between the three fields may be a result of the numbers of men and women enrolled in Brazilian universities. For example, data from the leading universities in the state of São Paulo (24) indicate that women's enrolments were highest in the biological sciences for 2000 while men's enrolments were more frequent in the exact sciences. These results are also in accord with those found earlier in Iceland and Poland.

The ages of Brazilian scientists were grouped into 11 ranges. The age distributions of men and women in our sample are presented in Figure 2.

In astronomy men were mostly 40-54 years old, with a peak at 50-54, while women were mostly 35-49 years old, with a peak at 35-39 years. This shows that the younger researchers are mostly women. For oceanography, most of the men and women were 35-49 years old and they both had the same peak at 40-44 years. Curiously, there were some women over 60 years old, whereas there were none of this age in astronomy. This indicates that women were working in oceanography earlier than in astronomy and immunology. Finally, for immunology men were mainly 30-44 years old, with a peak at 30-34 years, while women were mainly in the range 35-54 years, with a peak at 40-44. This indicates that men rather than women form the majority of new entrants to this field.

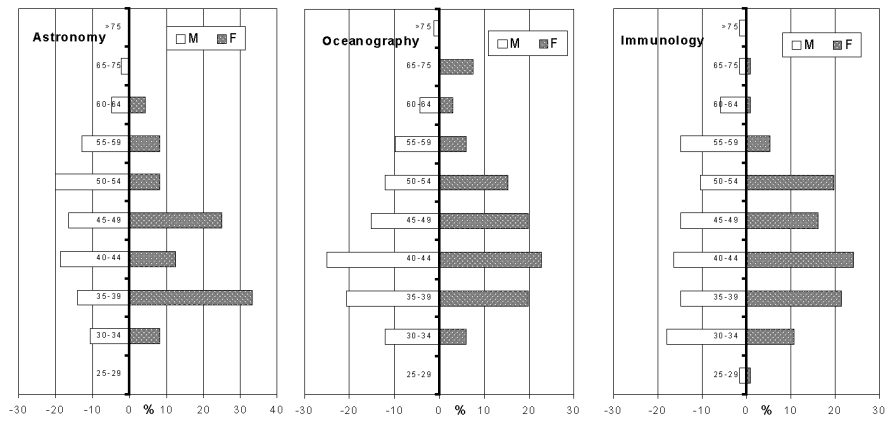


Figure 2. Age distributions for Brazilian male (M, clear) and female (F, shaded) researchers in three fields as recorded in the CNPq database for 2000

#### *CNPq fellowships and leadership of a research group*

Among the 43 101 fellowships awarded by CNPq to students and researchers working in Brazil in 2000, 7422 were granted to Brazilian research scientists while the other 36 000 were awarded to Brazilian undergraduate and graduate students. (A similar number are also awarded by CAPES, Coordenadoria de Aperfeiçoamento de Pessoal do Ensino Superior, another federal agency linked to the Ministry of Education, but CAPES does not award fellowships to researchers. Together, the two agencies award around 100 000 fellowships each year and probably there is no other country in the world with such a large S&T training programme.) This type of fellowship, entitled “productivity in research”, is a salary supplement which just a fraction of Brazilian researchers are successful in winning. The fellowship is renewed every year through a peer-review process that takes into account the researcher’s published outputs, among other factors. The data about the award of these fellowships to researchers in our sample were obtained from the CNPq database and are shown in Table 2. On average, 45% of men in our sample were awarded this type of fellowship. For women the percentages differ significantly between the three fields: 24% of women received the fellowship in oceanography, 36% in immunology and 54% in astronomy.



Table 2. Numbers of Brazilian researchers in three fields awarded a CNPq fellowship in 2000, and numbers that were research group leaders, divided by sex

Field	Sex	N	Group leaders		CNPq fellows		F/L Ratio
			N	%	N	%	
Astronomy	F	24	10	42	13	54	1.29
	M	85	36	42	34	40	0.95
Oceanography	F	66	38	57	16	24	0.42
	M	92	60	65	39	42	0.65
Immunology	F	129	70	54	46	36	0.67
	M	50	33	67	26	53	0.79

We also analysed whether or not the researchers were leaders of a research group in Brazil: a research group may have one or two leaders. Before each census, researchers are asked to complete the CNPq questionnaire and they are free to designate themselves as group leaders but before sending the questionnaire back to CNPq such a claim has to be approved by members of the researchers' departments or by their institution director. This is a similar process to that of peer review and may avoid some erroneous claims.

The data in Table 2 suggest that in both oceanography and immunology, women are less likely to receive a CNPq fellowship than their prominence in research, as determined by their leadership of a research group, would suggest. The situation in astronomy is apparently anomalous, with more female fellowships than research group leaderships, although the numbers are small.

#### *Women's participation in scientific publications*

The distribution of articles in the SCI according to the sex of the 446 Brazilian researchers found as authors is presented in Figure 3. Note that the sum of publications referred to as male and female in our sample exceed the total because there are cases where males and females from our sample were co-authors of a single article (as in the example for astronomy), so these articles were counted once for males and once for females.

Figure 3 shows that, of the 541 publications in astronomy, 152 (28%) have at least one female from the CNPq list as an author or as a co-author. For oceanography and immunology, females were more frequent authors: they were named on 58 of 135 (43%) and on 223 of 407 (55%), respectively. Although it may appear that women are less productive than men, their participation as authors of scientific articles is quite similar to their percentage presence in the respective fields – 22%, 42% and 63%, see Figure 1. Moreover in astronomy, a field traditionally known as a male-dominated field,

the scientific contribution of females is higher than their percentage presence as researchers. This may account for the unexpectedly high number of females appointed to CNPq fellowships noted above.

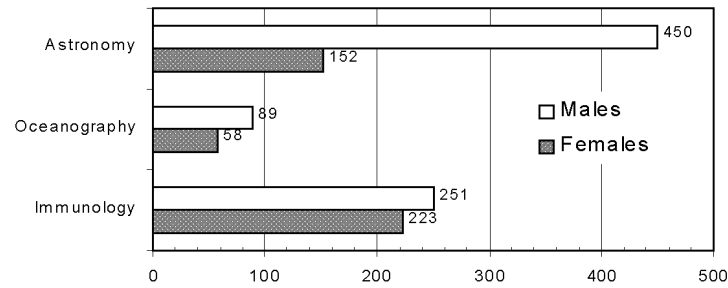


Figure 3. Numbers of Brazilian articles in SCI in astronomy, oceanography and immunology that were authored or co-authored by females (shaded) and males (clear) identified in sample

Figure 4 shows the distribution by potential impact category, PIC, of papers by men and women in our sample. None of the differences in PIC distribution are statistically significant, even if there looks to be one in astronomy, where women seem to publish more in PIC 4 journals and less in PIC 1 ones.

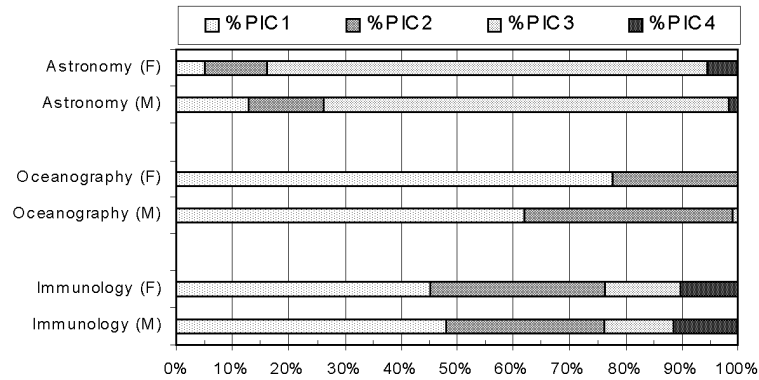


Figure 4. Distribution of Brazilian papers, 1997-2001, in three fields by potential impact category, PIC (1 = low, 4 = high) for identified male (M) and female (F) researchers

One feature of these data is that the Brazilian astronomy papers written by the identified researchers seem to be published much more in highly-cited journals than the papers in immunology and oceanography. This indicates that astronomy is, among the three fields, the most highly-cited one. On the other hand, oceanography papers, written by both men and women, were rarely published in highly-cited journals, classed as PIC 3 and 4. From our analysis of the references from these papers, we identified a relatively high presence of Brazilian domestic journals, suggesting that this field in Brazil may be more focused on local issues which would be less likely to be published in prestigious international journals.

*The effect of international co-authorship*

International collaboration has been increasing rapidly during recent decades.<sup>25-28</sup> Several studies have demonstrated that papers with an international co-authorship are cited more often and are more likely to be published in highly-cited journals!<sup>6, 29, 30</sup> These findings were replicated in our study, see Figure 5. Papers with a foreign address had a significant difference in their PIC distributions compared with those with only a domestic address. This difference is more obvious in immunology and oceanography, but it occurs also in astronomy.

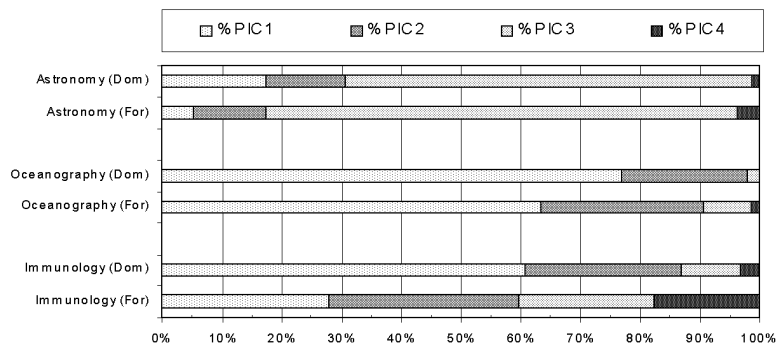


Figure 5. Distribution of Brazilian papers, 1997-2001, by journal Potential Impact Category (PIC; 1 = low, 4 = high) with only domestic addresses (Dom) and one or more foreign ones (For) for three fields

The similar PIC distribution of papers by Brazilian men and women in our sample (see Figure 4) could be a result of the level of international collaboration they have established. To determine whether this is an important factor, we investigated the frequency of domestic and foreign publications according to the sex of the authors, see Figure 6.

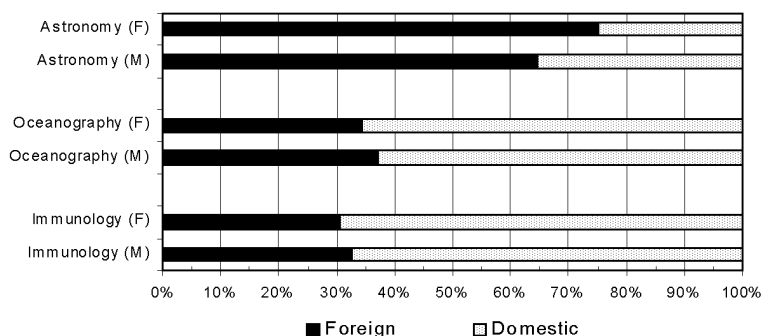


Figure 6. Percentages of Brazilian papers in three fields with identified male or female authors that had a foreign co-author, 1997-2001

Although it seems that women rather than men tend to collaborate internationally in astronomy, statistics show no significant difference in any of the three fields. That means that independently of sex, international collaboration within astronomy represents about 70% of the total production of our sample, whereas in oceanography and immunology it only represents 30-35%. The higher frequency of international collaboration in astronomy is undoubtedly an important factor influencing the higher visibility of this field, shown by astronomy papers being published preferentially in more highly-cited journals.

### Conclusions

The present study aimed to present quantitative data of the participation of Brazilian female scientists in the country's mainstream publications. Although the sample chosen represented a small fraction of the Brazilian scientific community (only 446 names out of approximately 56 000 in the CNPq database), we think that it could serve as a model to show whether Brazilian female researchers are as productive as men.

The analysis of the scientific production of Brazilian men and women in astronomy, oceanography and immunology in the period 1997–2001 shows that there is effectively no difference between them in potential impact, see Figure 4. One important factor that might have contributed to the similarity of male and female contributions and PIC distributions was the frequency of international collaboration and we found that female scientists tended to collaborate as much as men in all three fields, see Figure 6. This contrasts with the earlier findings that Icelandic and Polish scientists were less likely to collaborate internationally.

A possible cause for this difference in findings may be that we analysed only a small portion of the Brazilian scientific community while the studies in Poland and Iceland were carried out for the whole community, including fields with different levels of internationalization. Another possibility is the intrinsic characteristics of Brazilian society: the position of Brazilian women certainly differs greatly from that in the other two countries. During the last decade, Brazilian women have become more prominent not only in academe but in all sectors. This has undoubtedly helped Brazilian women to become more independent and liberal so that now female scientists can travel abroad and establish international connections more readily. It is possible that in the other two countries women have not passed through such a transformation.

Although the data clearly show that Brazilian women published as much as men, in terms of both quantity and quality, and were at least as likely to be research group leaders (Figure 4), we found some evidence that Brazilian women tend to receive fewer “productivity fellowships”. This may possibly indicate that there is some discrimination against women within the CNPq that bears further investigation. Discrimination against women is long-standing and occurs in all sectors, including the scientific peer-review process.<sup>31, 32</sup> It is unjustifiable, but also counter-productive, because women represent a significant fraction of the workforce and a fraction that is rapidly increasing. During the 1970s, of each 100 Brazilian women of working age only 18 were economically active, while in 1985 and 1995 this number increased to 37 and 47, respectively.<sup>33, 34</sup> Although more Brazilian females are working now, they suffer significant sexual discrimination, for example in their salaries.

For scientific work, data from CNPq show that the percentage of female scientists in the Brazilian scientific community increased from 39% to 46% from 1995 to 2002.<sup>35</sup> As most Brazilian scientists work at public universities, there should be no discrepancy in terms of the basic salaries that females and males receive because the salaries are paid directly by the federal government and do not vary by sex. Discrimination,

however, does exist as pointed out by Velho and León:<sup>17</sup> women infrequently occupy senior administrative positions and, as we show here, they are less likely to be granted CNPq fellowships on their merits.

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