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An analysis of the gender gap among African scientists

Sophie Dabo-Niangⁱ, Maria J. Estebanⁱⁱ, Colette Guillopéⁱⁱⁱ, Marie-Françoise Roy^{iv}

Introduction.

The demand for equal representation of women and men in academic positions as well as in politics, in corporate management positions in firms and in local institutions has become very strong nowadays. A wide range of international institutions have taken initiatives to promote inclusion of women to achieve gender equality, which also happens to be one of the United Nations' seventeen sustainable development goals¹, thus turning the issue of gender equality into a topic of global debate. Some studies on the global gender gap in science can be found in [8-13].

This paper provides a detailed analysis of the answers from Africa to the Global Survey of Scientists [1]. The questions we address are the following: are the answers from Africa and the answers from the World similar? In which cases is the situation in Africa different from the situation in the World? Better or worse?

These questions are particularly relevant given the specific situation of the African continent in terms of science, which is quite distinct from the situation of science in the World. Indeed, there are very few scientists in Africa, fewer than 100 per 1 million inhabitants, whereas the World average in 2020 is over 1,000 per 1 million inhabitants [2], and the level of funding of scientific R&D in Africa is low, the share being 0.4 % of the GDP compared with a World average of 1.7% [3]. Given this specific situation, what are the characteristics of the gender gap among scientists? The percentage of women among scientists in Africa is about 31.8%, which is slightly higher than the proportion of women worldwide [4]. How do these women scientists in Africa experience their studies, their careers, the balance between professional and family life or specific problems such as sexual harassment, compared to women scientists worldwide?

In 2017, as part of the activities organized within the “Gender Gap in Science” project (2017-2019) [5, 6], a global survey among scientists of all continents was launched to evaluate and understand the gender gap in science. A total of 30,037 persons responded globally, half of them women and half men.

The results of this survey were analysed in the book “A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences: How to measure it, How to Reduce it?” [6], where the analysis made was global and did not go into too much detail about specific topics or World regions. In this article we aimed to further understand the results of the survey for the African continent, to analyse in detail the gender gap in Science among scientists working in Africa, but also to compare these results with the rest of the World, to see how economic and cultural differences may affect the gender gap among scientists. To do

¹ <https://sdgs.un.org/goals>

this, a specific statistical analysis of the data has been carried out. (See the Appendix and [7].)

In that survey, the questions were broadly organized around 9 themes: (1) Secondary degree; (2) First university degree; (3) Master and Doctoral degree; (4) Employment; (5) Grants, publications, and related topics; (6) Interruptions in studies and career; (7) Marriage, partnership, and parenthood; (8) Discouragement and discrimination; and (9) Sexual harassment. It should be noted that this survey addresses several aspects that are often not measured in bibliographic metadata, such as work-life balance, family support, access to resources and sexual harassment.

It is also important to note that although the number of answers was high, both in Africa and worldwide, these figures are low compared to the overall population of scientists. In addition, the questions also ask what people feel about a specific topic. All this to say that the image given by this survey, and what we will state out below, is only an image that probably reflects aspects of reality, but one that should be taken with a grain of salt.

Next, let us explain the methodology we used to collect the data. As there is no single network or resource available for contacting all students and professional scientists worldwide, we used a *snowball* sampling method to tap into as many personal networks as possible. We used the contact databases of the project's partner organizations of the project to reach students and professional scientists around the World and asked them to complete the survey and invite their contacts to complete it. *Snowball* sampling is a non-probability data collection method that does not provide a statistically representative sample. As a result, our findings only indicate trends observed among those who responded to the survey, not the overall population of scientists. However, the consistency of most of our findings across disciplines, geographical zones and level of development is reassuring. For more details about the methodology, see the Appendix and [7].

The results of our statistical analysis of data concerning Africa and the World are presented on the website below². This article presents some of the main results which can be consulted on this website, where more visual information is gathered.

Collected data.

Considering the filtering process described above, the survey received a total of 1,265 answers in Africa where the gender was indicated, 774 from women (61%) and 491 from men. On average, the age of African women (43) who answered the survey was higher than that of the men (40). The answers came from the 28 African countries that took part in the survey. They are, in alphabetical order, Algeria, Benin, Botswana, Burundi, Burkina Faso, Cameroon, Democratic Republic of the Congo, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Mauritius, Morocco, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Sudan, South Africa, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe (Fig. 1).

2 <https://gender-gap-in-science.org/africavisualisation/>

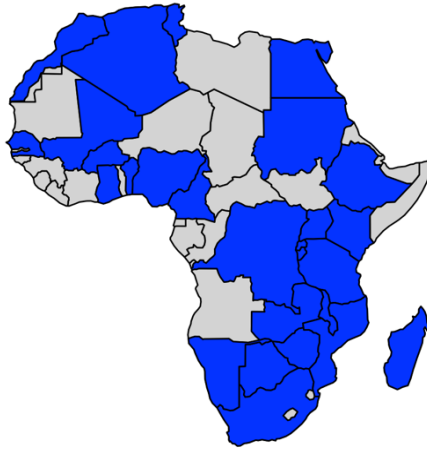


Fig. 1. Sample countries are shown in blue.

Studies.

A large majority of the respondents had a university degree: 98% of women compared with 96% of men, a master’s degree (82% of women, 74% of men) and a doctoral degree (58% of women, 56% of men).

The level of women’s most recent degree was higher in Africa than at the global level, while it was lower for men (Fig. 2).

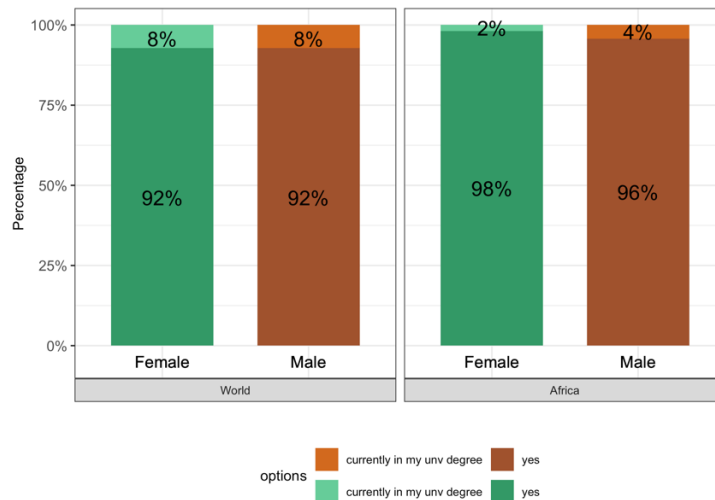


Fig. 2. Answers to the question: “Do you have a university or equivalent degree?”.

When it comes to the subjects of their first university degree, men in Africa study more than women in Physics and Engineering, but less than women in Biology, Chemistry, Education, and Environmental Science, and slightly less in Computer Science, while their proportions are comparable in Mathematics (Fig. 3).

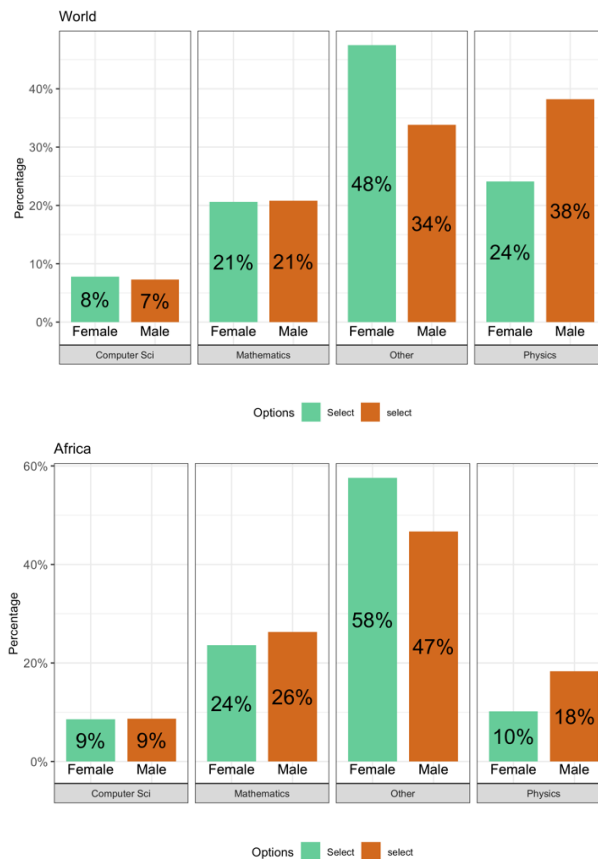


Fig 3. Distribution of women and men in various scientific areas or in various parts of the World (above) and in Africa (below).

The same trends can be observed about the main subjects chosen for their master's degrees, for both women and men.

A large majority of those who obtained their secondary degree in an African country also obtained their first university degree in Africa, for both women and men, and among those who left Africa to go to university, there were more women than men (Fig. 4).

But after undergraduate studies, when doctoral studies were due to begin, more Africans left their countries for other continents: 28% of women compared with 32% of men, so the proportions have changed in this case. Of these, more men went to Western Europe³, Northern America⁴, and Eastern and Southeastern Asia⁵, in that order, while more women went to Western Europe, Northern Europe⁶ and Northern America (Fig. 5). Only in Northern Europe did they go in greater percentage than men. As a result, women left Africa less than men when they want to go to university for graduate studies, or to work after their studies.

³ Austria, Belgium, Switzerland, Germany, France, Liechtenstein, Luxembourg, Monaco, Netherlands (the).

⁴ Canada, United States.

⁵ Brunei Darussalam, China, Indonesia, Japan, Cambodia, Korea (The Republic of), Laos, Myanmar, Mongolia, Malaysia, Philippines (The), Korea (The Democratic People's Republic of), Singapore, Thailand, Timor-Leste, Taiwan, Viet Nam.

⁶ Denmark, Estonia, Finland, United Kingdom, Ireland, Lithuania, Latvia, Norway, Sweden.

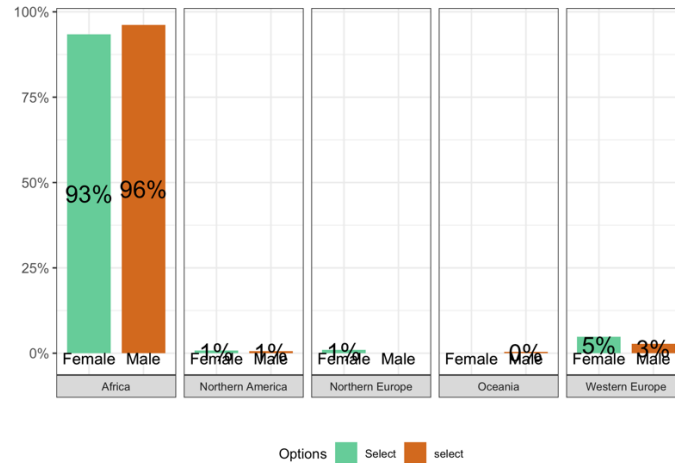


Fig. 4. Where did the students who graduated from secondary school in Africa obtained their first university degree?

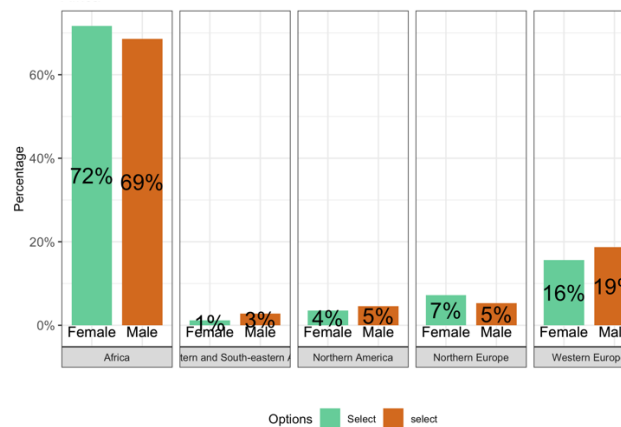


Fig. 5. Where did the students who had their first university degree in Africa obtained their doctoral degree?

In terms of the environment in which African scientists grow and work, we observe that in Africa, during their studies, women feel much less supported than men by their teachers and mentors, whereas away from Africa, both women and men are very much supported by teachers, professors, and mentors (Fig. 6).

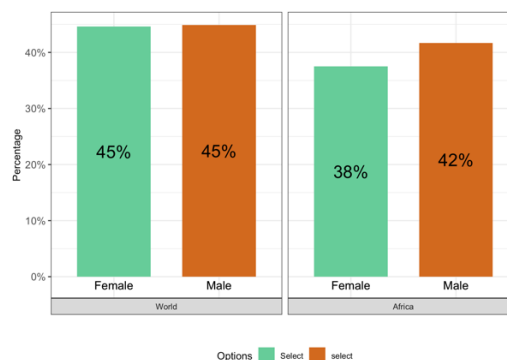


Fig. 6. Percentage of women and men who feel encouraged in their studies by their teachers.

Another major difference is observed in spousal or partner support, which is favorable to women everywhere, but shows a much greater gap in Africa than worldwide between women and men (Fig. 7).

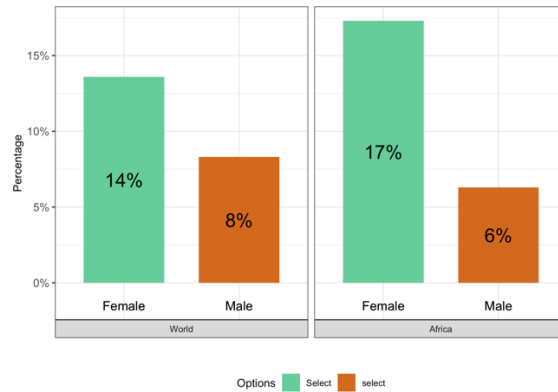


Fig. 7. Percentage of women and men who feel encouraged in their studies by their spouse or partner.

Other interesting comparisons appear concerning the support felt by women or men from their community or friends and from other students (Fig. 8).

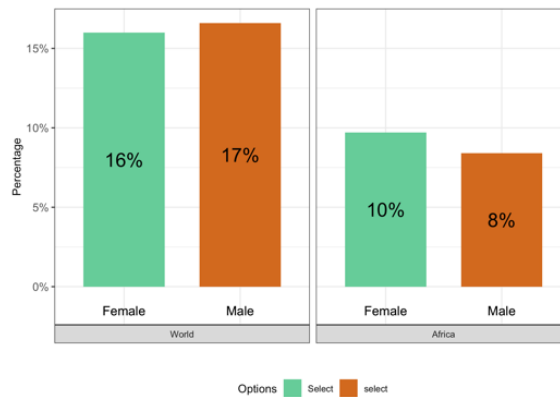


Fig 8. Percentage of women/men who feel encouraged in their studies by other students.

Let us now look at what the survey tells us about the doctorate level in Africa. Still at this level, we find that among scientists who answered the survey, there are more men than women who obtained a doctoral degree in Physics, Mathematics and a little more in Computer Science, but fewer in other fields, including Biology, Chemistry, Social Sciences, etc. The percentages are more or less the same on other continents. We note an interesting fact: while in Africa the same percentages of men and women studied Mathematics at undergraduate and master's level, contrary to what happens worldwide, at doctoral level we find in Africa, as worldwide, a greater percentage of men than women (Fig. 9).

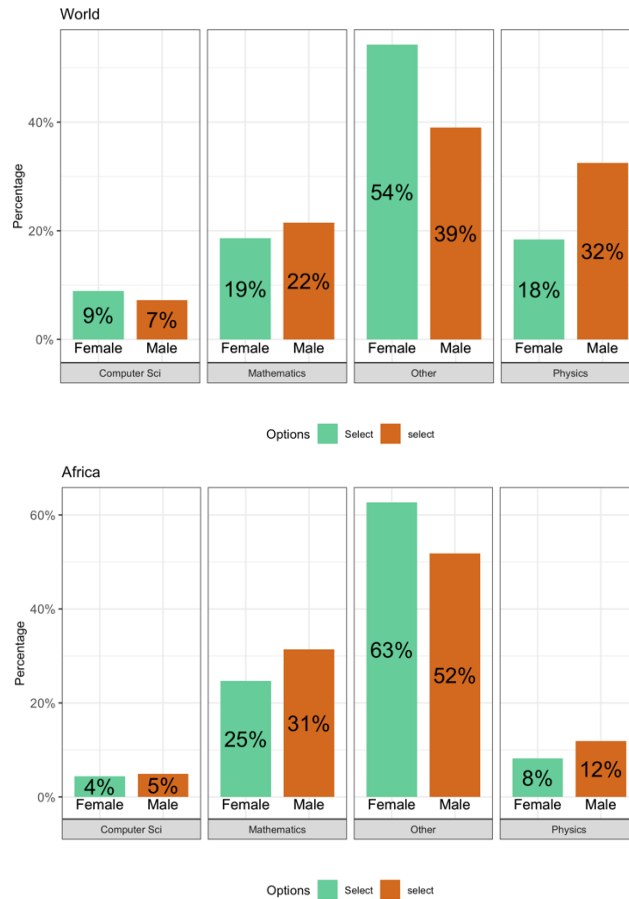


Fig. 9. Percentage of women and men who pursue doctoral degrees in Physics, Mathematics, Computer Science, and other fields, including Biology, Chemistry, and the Social Sciences, worldwide and in Africa.

Women and men are more satisfied in Africa than worldwide with their doctoral program, the relation with their supervisors, the quality of the program and the number of professional contacts, but less satisfied with respect from other students, particularly women. African women are less satisfied than men with their relationship with their PhD supervisor (Fig. 10, 11).

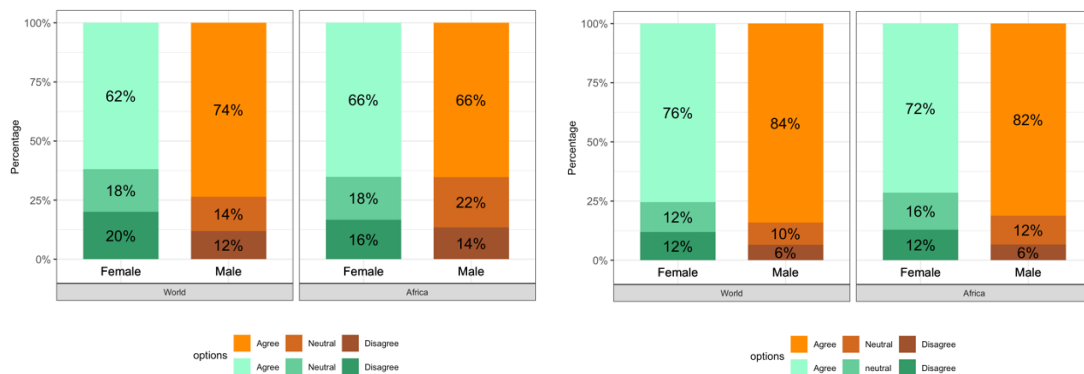


Fig. 10. Percentage of women and men who think that their doctoral program treated everyone fairly (left); and that other students were respectful of everyone (right).

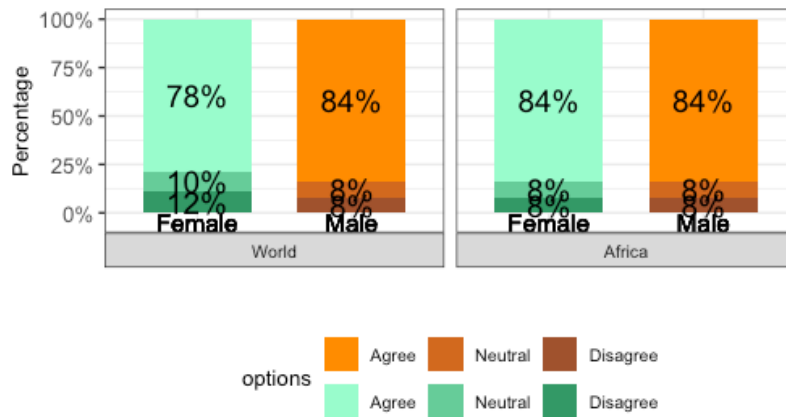


Fig. 11. Percentage of women and men who think that they had support from their advisor or supervisor.

The positive impressions of African scientists about their doctoral program described above seem to be at odds with the fact that they feel less satisfied with the level of funding, office and laboratory space, travel money, clerical support, computing facilities, access to scientific literature, access to data and technical support they have obtained, compared to what people in other continents think about these matters. And in all these respects, African men tend to be even less satisfied than women (Fig. 12-16).

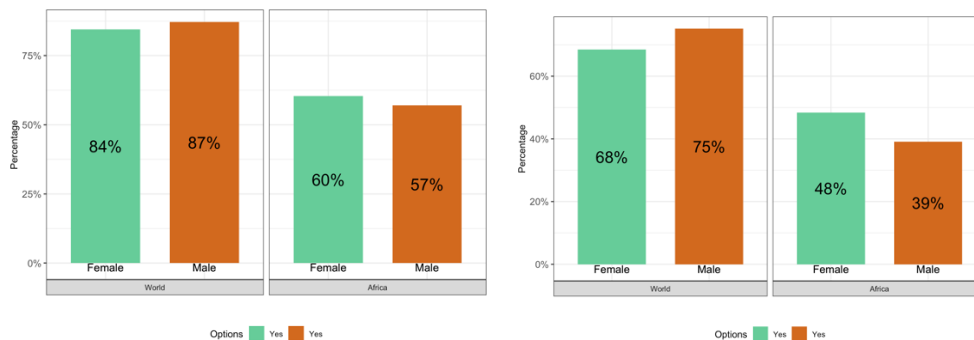


Fig 12. Percentage of women and men who, during the doctoral studies, have enough access to equipment (left) and clerical support (right) to conduct or present their research.

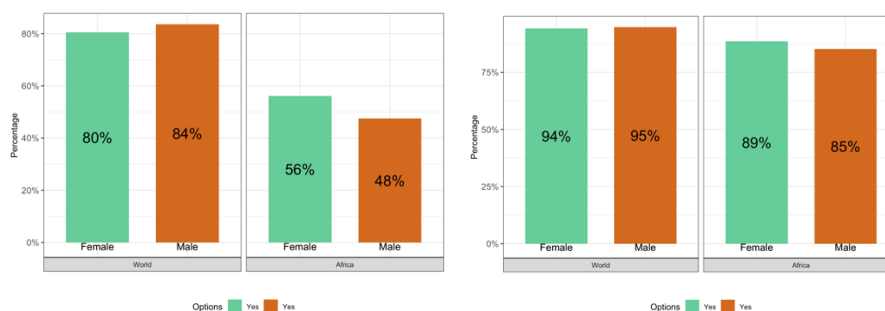


Fig 13. Percentage of women and men who, during the doctoral studies, have enough funding (left) and access to scientific literature (right) to conduct or present their research.

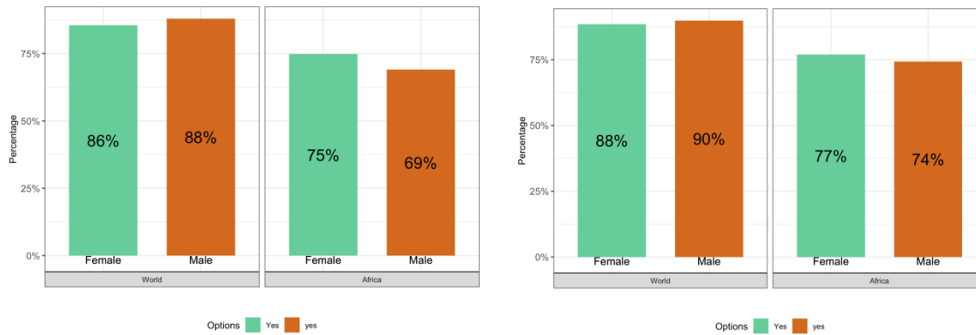


Fig. 14. Percentage of women and men who, during their doctoral studies, have enough of computing capability (left) and access to data (right) to conduct or present their research.

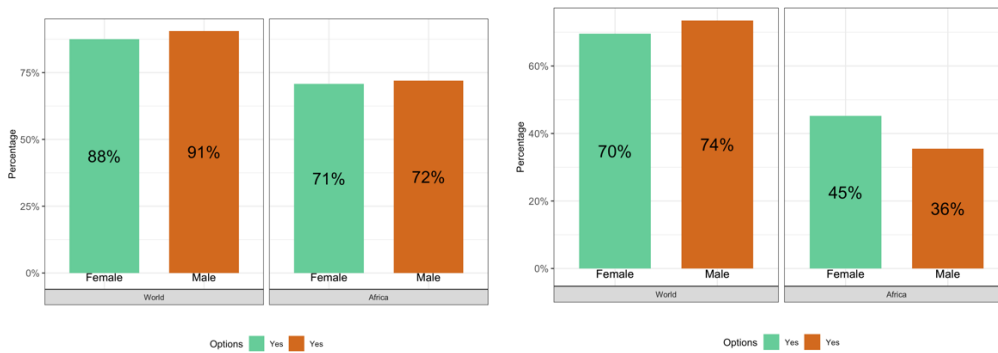


Fig. 15. Percentage of women and men who, during their doctoral, studies have enough office space (left) and money to travel (right) to conduct or present their research.

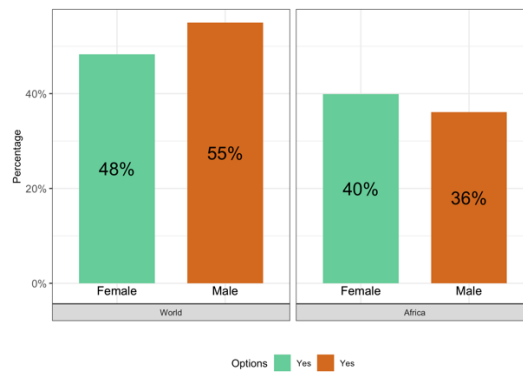


Fig. 16. Percentage of women and men who, during the doctoral studies, had enough support as a working parent to conduct or present their research.

Regarding how scientists finance their doctoral studies, we find that in Africa the money for PhDs comes more from personal and family sources or loans than worldwide, whereas in other continents the opposite is true (Fig. 17, 18).

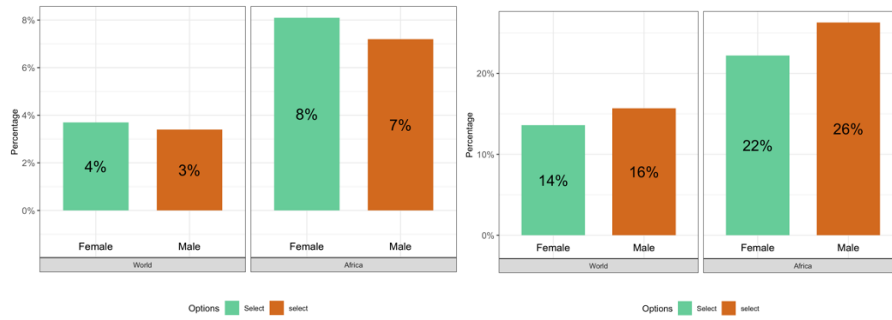


Fig 17. Primary sources of financial support during the doctoral studies: loans or debit (left); parents or family (right).

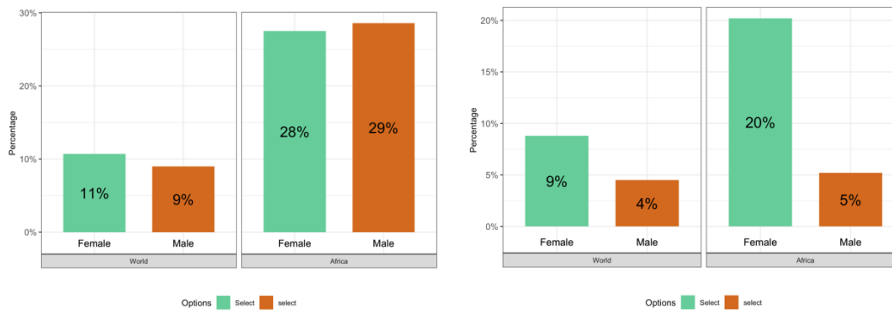


Fig. 18. Primary sources of financial support during the doctoral studies: personal savings (left); spouse or partner (right).

The above comparison between women and men in Africa shows that women receive more scholarships and funding from jobs other than teaching and research than men, and significantly more from their spouses or partners, but less from all other sources.

If we consider the interruptions that occurred during doctoral studies, both men and women had more of them in Africa than worldwide, especially women who had more than men everywhere. When we look at this subject in Africa alone, we see that men had many more interruptions than women due to military service, of course, and also due to unemployment, financial difficulties, political turmoil and conflict, but far less than women due to family obligations of all kinds, even if we note that in this *respect*, both women and men have more interruptions in Africa than worldwide (Fig. 19, 20).

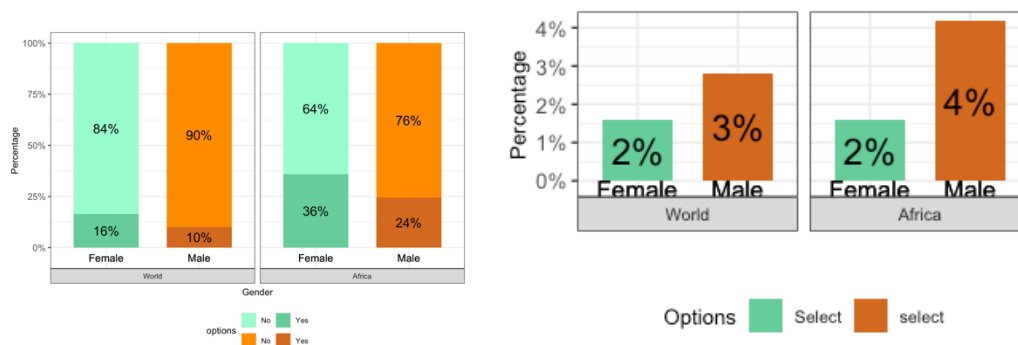


Fig. 19. Interruptions during the doctoral studies (left); for political turmoil, conflict, or war (right).

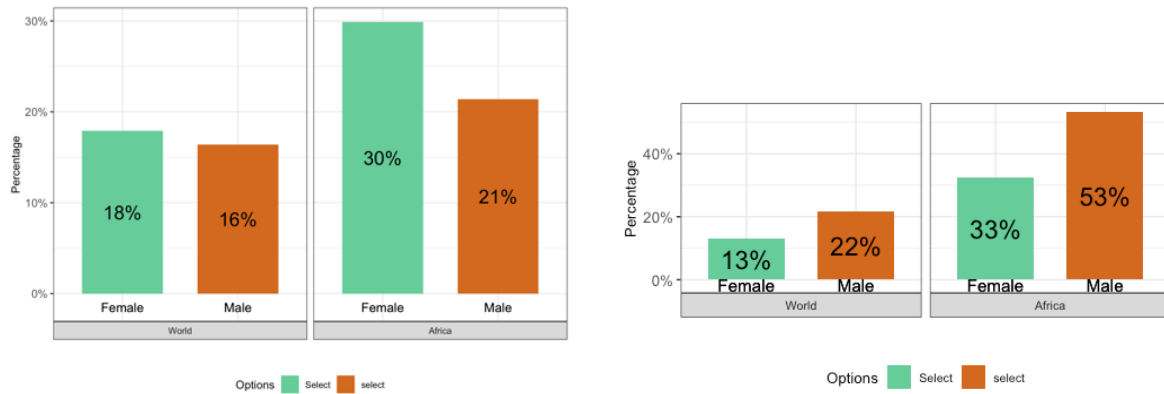


Fig 20. Interruptions during the doctoral studies for family obligations or change in family situation (left); for financial constraints (right).

Work.

Let us now look at the employment and working conditions of African scientists. In Africa, as worldwide, most of the people who answered the survey work in universities, but some also have jobs in government or in companies, and others are students. Not surprisingly, among those employed in Africa, and indeed worldwide, there are more men than women in Physics-related jobs (13% compared with 5% in Africa, and 23% compared with 13% worldwide), almost as many in percentages in Mathematics (18% compared with 17% in Africa, and 19% compared with 15% worldwide), fewer in other fields, including Biology, Chemistry, the Social Sciences, and less in Computer Science, a difference with other continents.

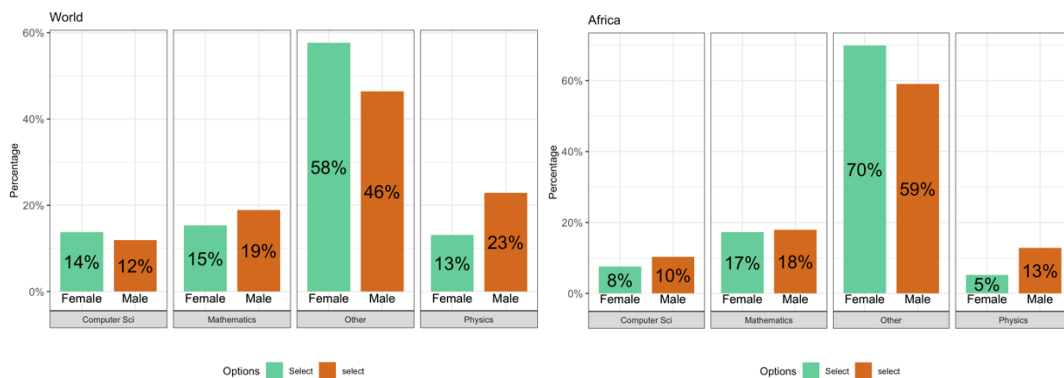


Fig. 21. Percentage of women and men employed in various scientific fields worldwide and in Africa.

From what we have said above, we already know that of those employed in Africa, most obtained their secondary diploma in Africa, but only a quarter obtained their doctorate there, for both women and men.

In terms of how scientists in Africa feel treated by their bosses and employers, both women and men feel better treated than in other continents, especially women (Fig. 22).

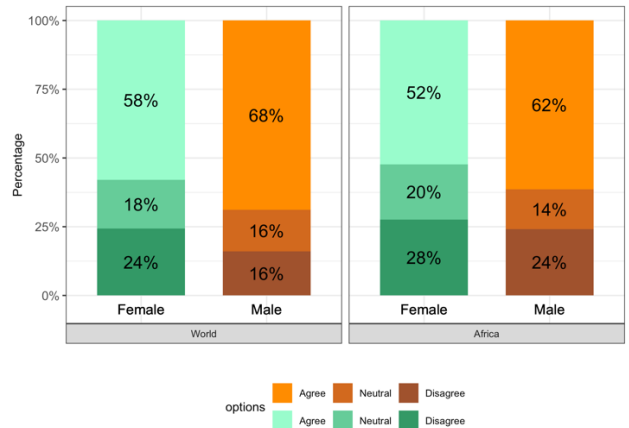


Fig 22. Answers to the question: “Does your employer treat everybody fairly?”.

When it comes to the working conditions, African scientists are less satisfied than scientists worldwide, in terms of funding levels, travel money, access to data, office and laboratory space, equipment and so on. African women are only more satisfied than men when it comes to the support they receive as working parents and access to data and the scientific literature; in all other areas, they feel less happy than men (Fig. 23, 24).

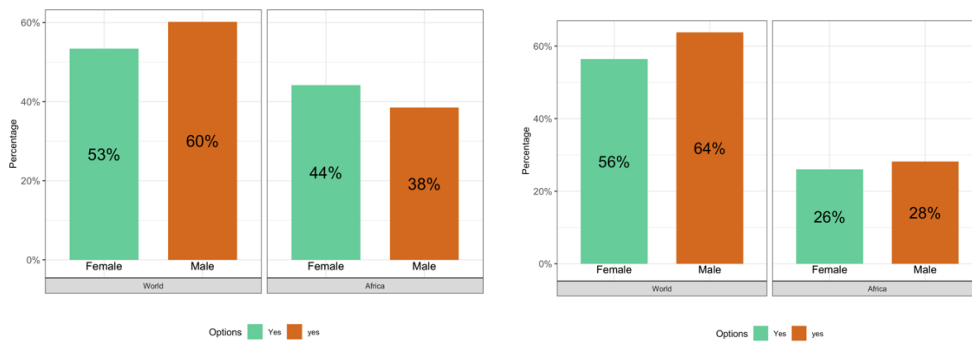


Fig. 23. Percentage of women and men acknowledging support as working parents (left), and in terms of travel money (right).

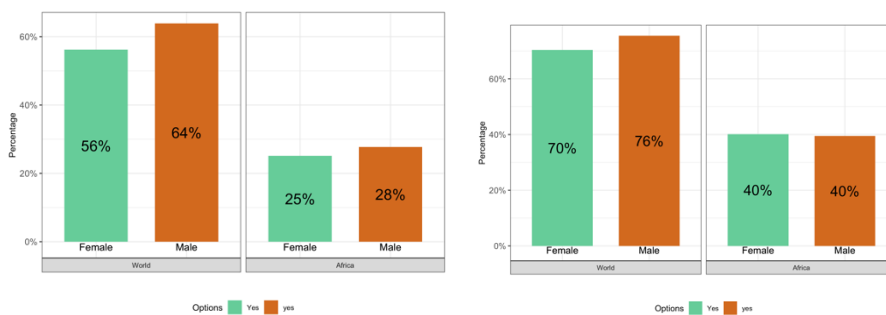


Fig. 24. Percentage of women and men acknowledging support in terms of funding (left), and of equipment (right).

In Africa, scientists have more difficulties than worldwide in finding a job or a position, and women even more so than men. This is a general trend, not only in Africa, but in all regions of the World, namely the difficulty for women to find employment.

When it comes to salary, African women feel less satisfied than men, which is unfortunately a universal reality. When it comes to career progression in relation to those with whom they

studied in the past, men in Africa are more satisfied than men on other continents and more satisfied than women in Africa.

Regarding the distribution of grants (research trips, etc.), scientists in Africa obtained more grants than those worldwide among those having answered the survey. This simply means that, for one reason, those who have answered in Africa are more those who have got grants. But in all cases, women received fewer grants than men, even if the difference is not significant.

In Africa, as worldwide, women give fewer lectures than men at conferences, but they attend them more often. Women conduct less research abroad and, as worldwide, women in Africa are less likely than men to hold positions of responsibility. One positive point in Africa is that women are as likely as men to be in boards of directors and granting agencies, but on the other hand they are more rarely members of editorial boards.

In Africa scientists who answered the survey are much more likely to be in the leadership of learned associations than worldwide, and women even more so than men (Fig. 25).

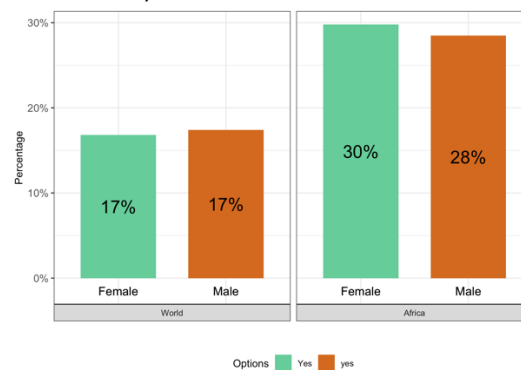


Fig. 25. Percentage of women and men who lead learned associations.

If we talk about publication patterns and look at publications in top journals, we can see that everywhere women submit more articles when it comes to people who submit few articles, but if we talk about who publish a lot, men submit more articles than women, both in Africa and worldwide, without the differences being huge. Another important issue in certain scientific fields is the way in which the ranking of authors is decided in publications. The order is determined by professional ranking more often for men than for women in Africa, but not worldwide (Fig. 26).

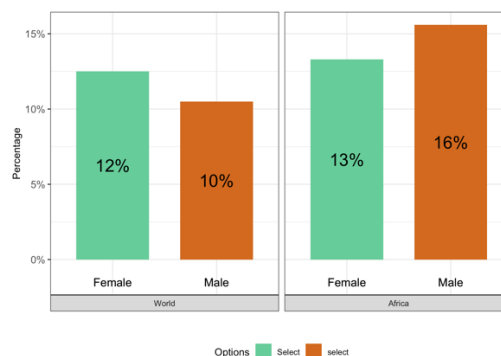


Fig. 26. Ranking criteria to determine who will be the first, middle, or last author: professional ranking.

Another subject that is important to study and analyse in relation to the gender gap is the number and duration of interruptions that occur during scientists' careers (22% versus 31% in Africa for men and women, and 16% versus 34% worldwide). As we saw above, African scientists seemed to have experienced more interruptions during their studies, in some cases for family reasons (women) and in other for political or social ones (men). But if we look at interruptions once the scientists have a job or position, we find that women have fewer interruptions in Africa than worldwide, but the opposite is true for men (Fig. 27).

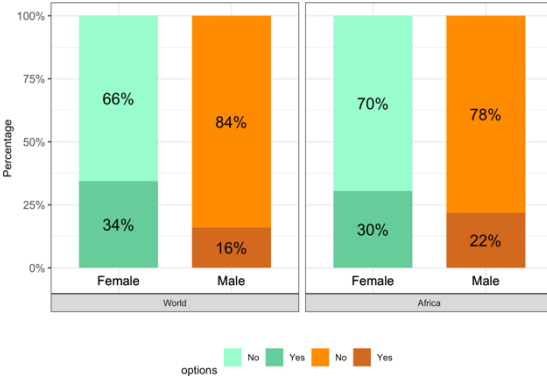


Fig. 27. Percentage of career breaks after receiving the highest degree.

In Africa, women and men take leaves more often (six times more) than worldwide to take care of children, and they both take leaves much more often to look after other family member than children, particularly men. African men seem to interrupt their career relatively often to take care of their family members, much more than men in other continents (Fig. 28).

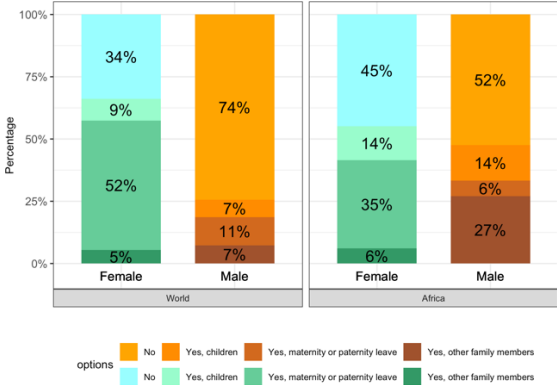


Fig. 28. Interruptions to care for family members.

It is interesting to note that career breaks seem to affect the careers of both women and men in Africa less than worldwide. And men's careers seem to be globally less affected overall than those of women worldwide (Fig. 29).

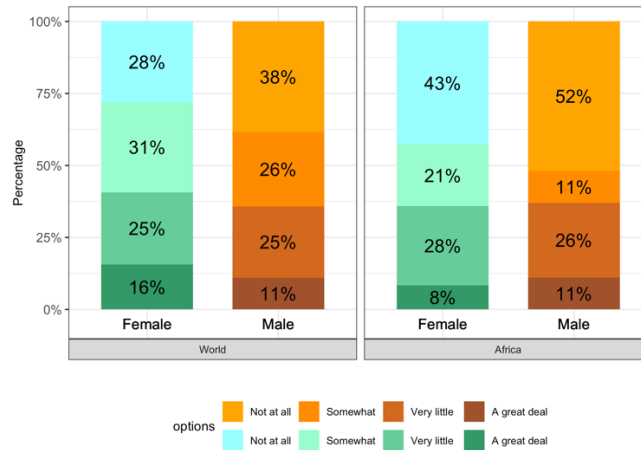


Fig. 29. Answers to the question: “Did interruptions break or slow down professional credibility or reputation?”.

This can certainly be explained by the fact that in Africa, obligations to the extended family weigh heavily on the shoulders of those with a profession, both because of the rules of society and the lack of social security.

Balance work-family life.

How do the family life and the existence of partners, spouses and children affect African scientists? First, it should be noted that more African scientists who answered the questionnaire are married or living with a partner than on other continents, and it is clear pattern is that both women and men in Africa married or started living with a partner earlier than on other continents, often during their university studies or doctorate, especially for women (Fig. 30).

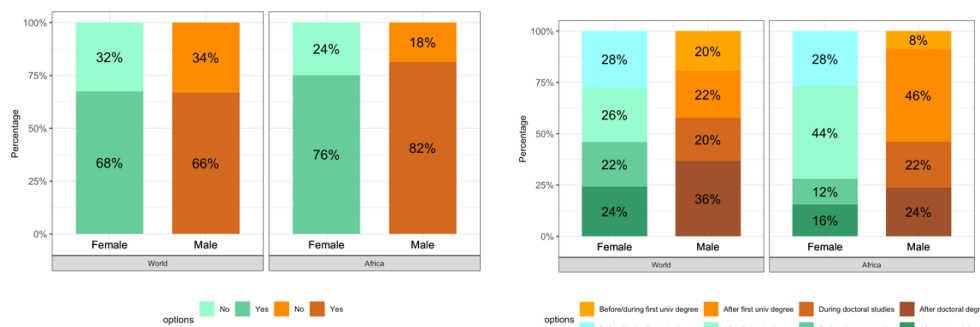


Fig. 30. Answers to: “Have you been married or in a similar long-term partnership?” (left); “Since when are you in your current or most recent marriage or long-term partnership?”(right).

The same applies to the age at which a woman has her first child. African women feel less supported than men when it comes to their careers, and less supported than on other continents. The reverse is true for men, who feel more supported than worldwide. Another interesting fact revealed by the survey is that the academic level (degree level) of spouses is generally lower in Africa than worldwide, for both women and men, and especially for women. In Africa, men are more often married to unemployed spouses (Fig. 31).

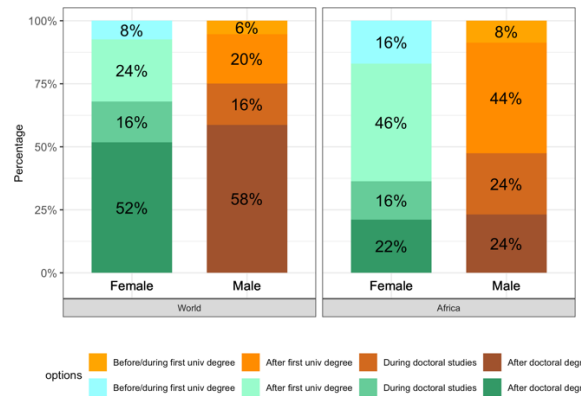


Fig. 31. Percentage of ages at which the first child was born.

As far as salaries are concerned, it is not surprising that everywhere they are lower for the spouses of male scientists than for the spouses of female scientists. Also, men everywhere are more likely to be married to someone in their own field than women, and this phenomenon is more marked in Africa than worldwide.

As far as the guardianship of children is concerned, both women as well as men in Africa are much more often in this position than on other continents (Fig. 32). Regarding maternity and paternity leave, we do not find a big difference for women in Africa compared to other continents, but we do find that men take fewer paternity leave in Africa, which is consistent with other results of the survey that we have already discussed.

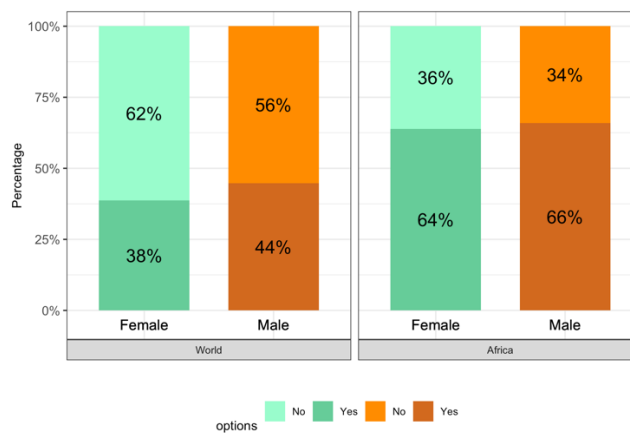


Fig. 32. Answers to the question: "Are you the guardian of at least one child?".

At the same time, bringing up children seems to affect parents in Africa less than worldwide: they ask for flexible working hours less often than worldwide, for instance, both women and men, although women do so more often everywhere, of course; they also change their employment less often; they do not reduce working hours to the same extent. And it has not affected their productivity, or they have not felt that their parenthood has slowed down their careers as much as on other continents (Fig. 33).

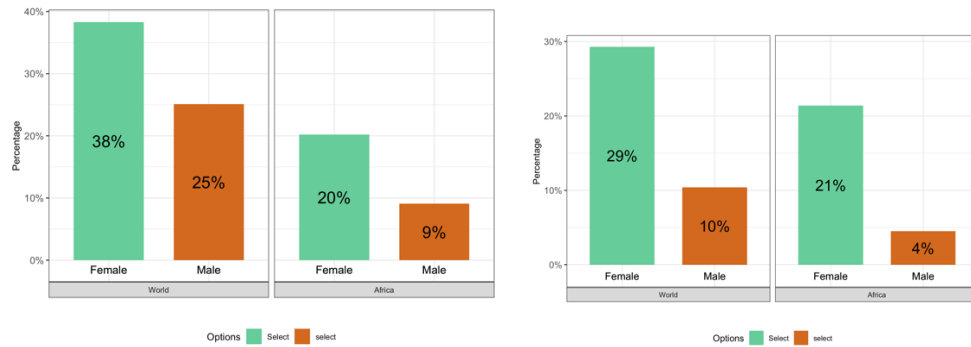


Fig. 33. Percentage of respondents who said that they spent less time at work because they are parents (left) and that bringing up children has slowed down their careers (right).

But if we look at the percentage of scientists who have become parents staying at home at some point, we see that more women have done so in Africa than worldwide, and that many more men have done so too (Fig. 34).

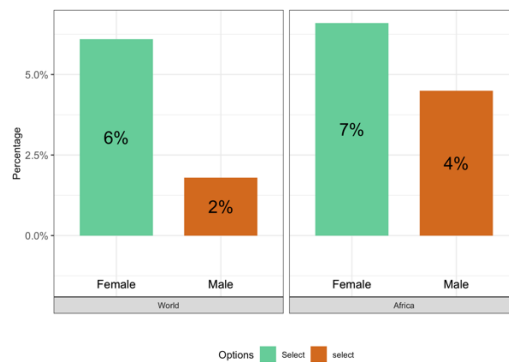


Fig. 34. Percentage of women and men becoming a stay-at-home parent.

Overall, scientists in Africa feel that having children has affected their careers less than in other continents, particularly men. One interesting point concerns the effect that taking care of family members (not children) on their careers, and we find that in Africa this happens much more often than worldwide to everyone, men, and women alike, which has to be interpreted in sociological terms, of course.

As far as the support received from employers or bosses is concerned, men in Africa say that they have received little support compared to what happens worldwide, while women receive the same support everywhere, but not that much (Fig. 35).

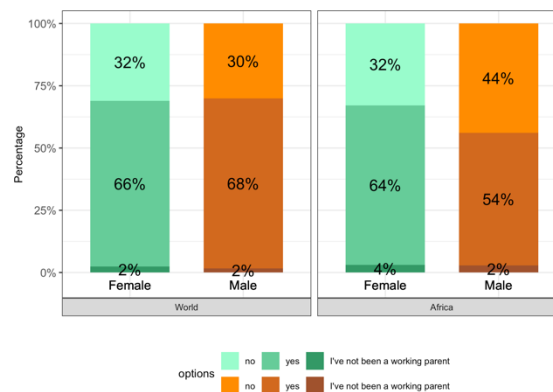


Fig. 35. Percentage for support from employers as working parents.

But if we look at who does the household chores, we see that unfortunately, in African households, it is women who seem to do most of the work, much more so than in other continents. Equal sharing is much less frequent in Africa than in the rest of the World. On the other hand, help of domestic workers is more common in Africa than in the rest of the World (Fig. 36).

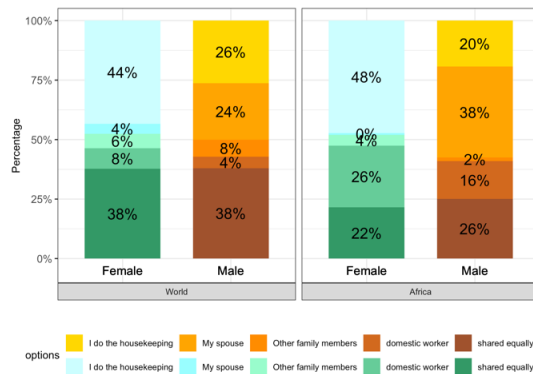


Fig 36. Who is responsible for **most** of the housekeeping in your household?

When it comes to discouragement among scientists during their careers, women are always more discouraged than men, everywhere and on every subject. But overall, scientists in Africa feel more discouraged by the lack of funding, the work environment and family commitments, but less so by research, interaction with colleagues and personal life.

Difficulties.

In Africa, scientists find it more difficult to raise concerns about their career with their boss or supervisor than in other continents, and the percentage is the same for women and men. As far as discussions with colleagues and co-workers are concerned, women in Africa discuss funding less often than men, but this is not the case worldwide. When it comes to personal life and family commitments, the same is true, but a greater difference between Africa and other continents is observed. On the other hand, the opposite seems to be true when it comes to salary. One positive difference is that scientists in Africa feel less that they have not lived up to expectations at certain periods of their careers. This is the case for both women and men; but, of course, the overall situation here remains worse for women than for men.

Women everywhere find it more difficult than men to give birth to what they are supposed to do because of pregnancy and childcare, but the percentage is unfortunately much higher in Africa (44%) than worldwide (33%).

Interestingly, men and women in Africa experience the same proportion of difficulties in caring for family members. We also find fewer mental health problems in Africa (6% compared to 12% for women and men in Africa; 21% compared to 28% worldwide) and it is interesting to note is that the percentage of divorce-related difficulties are about 50/50 worldwide, but very low for women compared to men in Africa (Fig. 37).

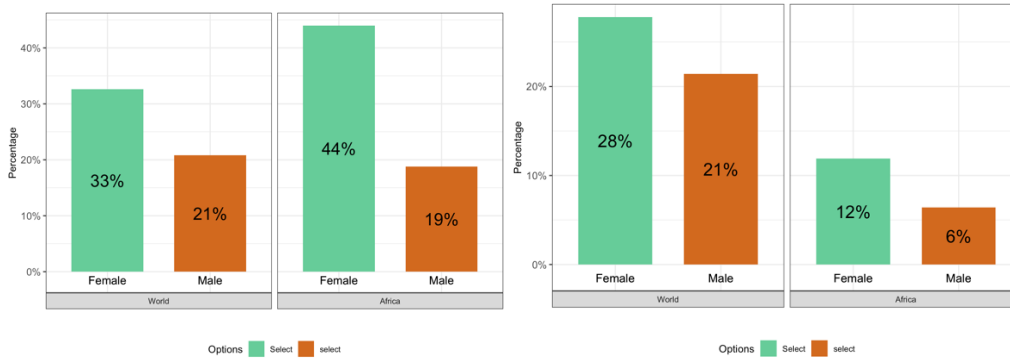


Fig. 37. Percentage of women and men who were unable to do what was expected of them at work because of childcare or pregnancy (left); because of mental health problems (right).

We now come to the question of discrimination and find that although women everywhere feel much more discriminated against than men in their work (43% compared to 5%), the proportion is lower in Africa than worldwide (8.7% compared to 10.1%). Women feel more discriminated against than men in Africa about age (18% compared to 10%) and much more about gender, religion, and marital status, but less about social status and race. Overall, men feel less discriminated against in Africa than worldwide, but women feel slightly more discriminated against (Fig. 38).

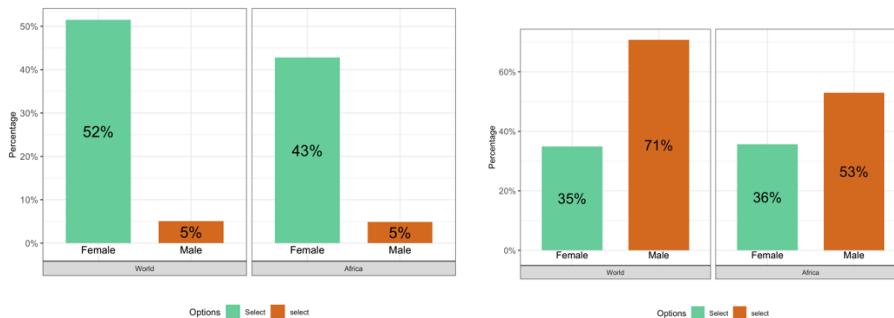


Fig 38. Percentages of women and men who have felt discriminated against at work because of gender (left), and never felt discriminated against at work (right).

The final question in this survey concerned sexual harassment, another important subject when it comes to the gender gap. Here too, we found some interesting answers: in Africa as elsewhere, women experience and witness more sexual harassment situations than men, but far less than in other continents (Fig. 39).

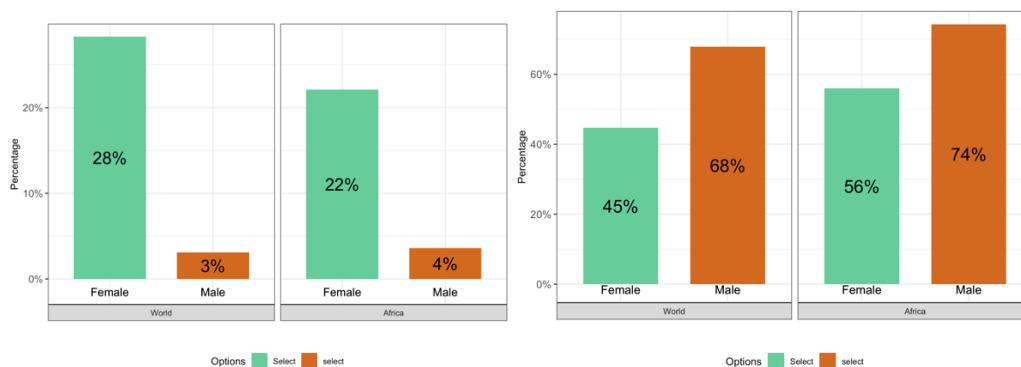


Fig 39. Percentages of women and men who responded to the question of sexual harassment: “yes, it has happened to me” (left); “no, I have not encountered it” (right).

With regard to sexual harassment in science, interesting data and analyses can be found in [14].

Conclusion.

While African girls are discriminated against in primary education¹, African women scientists do not seem to be discriminated against in relation to men in cases where the opposite occurs overall in the World. This is the case when it comes to the encouragement received from spouses, partners, family, friends, and other students during their university studies.

During the doctorate, African women do not seem to be discriminated against in terms of general support as mentioned above, and here again in terms of support from their thesis supervisor during the doctorate. They do not seem to be discriminated against either in terms of access to data or scientific literature, office and laboratory space, equipment, money for travel and support as a working mother.

In terms of research activities once employed, women in Africa do not seem to be discriminated against with respect to access to equipment and computing facilities nor in terms of support for working parents. The same applies to participation in conferences abroad or membership of granting body committees and learned associations.

In all the cases mentioned above, we do not see any unfavorable gender gap for women among scientists in Africa, whereas we clearly see it worldwide. There are therefore important aspects of study and the working conditions that seem to be better balanced within the scientific community in Africa than worldwide.

But there are of course many areas in which women are discriminated against compared to men in Africa. For instance, when they study, women receive much less support than men from their teachers and mentors, which is not the case worldwide. When it comes to their working conditions, women in Africa are more satisfied than men only in terms of the support they receive as working parents and access to data and scientific literature; in all other areas, women in Africa are less satisfied than men. Similarly, unlike worldwide, once they have their first child, women feel less supported than men in terms of their career and less supported than on other continents. Even though women find it harder than men to do what they are supposed to do because of pregnancy and childcare, the percentage is unfortunately much higher in Africa (44%) than worldwide (33%).

As far as discrimination based on who you are or what you do is concerned, women in Science in Africa feel very much discriminated against because of their gender and marital status, and to a large extent because of their religion, but not because of their social status. The percentages of women and men in science outside of Africa who say that they never experienced discrimination is significantly lower than in Africa.

Finally, where the gap between female and male scientists in Africa is most marked, and far greater than worldwide, is in the career breaks they experience in their studies or careers for

family problems, childcare, and housework. In these areas, African women fare less well than their non-African colleagues, but, surprisingly, they do not seem to complain about it, and do not seem to think that it affects their careers too negatively. In any case, these feelings seem to be much less acute than outside Africa.

The results of this survey show that the gender gap among scientists is less harsh in Africa than in other parts of the World and that, in some cases, it is even non-existent in situations where it is clearly observed outside Africa. Having said that, we also observe that scientists in Africa, both women and men, enjoy more difficult study and work conditions than worldwide. For instance, as noted above, scientists in Africa are less satisfied than scientists worldwide, about funding levels, travel money, access to data, office and laboratory space and equipment. These results are consistent with the limited funds available for research in Africa.

Finally, it should be noted that by seeking to compare the gender gap in Africa and the world among scientists, we were able to draw some interesting conclusions about the African scientific community as a whole, compared with the World scientific community.

Appendix: Methods of data analysis.

Data.

We use aggregated data collected as part of the Gender Gap project. The data was accessed and extracted via a platform (Aircloak) based at the American Institute of Physics, which protects and anonymizes individual data. Aircloak ensures anonymity by applying some filters and distortion to the extracted information, which had the effect of limiting the access of the data.

The databases at our disposal are anonymized, aggregated and available in the form of frequency tables.

It is important to mention that all the data we are working with is categorical, which means that it has a structure of possible answers. Most questions have two possible answers like ‘yes’ or ‘no’, but we also have questions with three or more possible answers. For instance, for the question “*Have you encountered sexual harassment at school or work?*” The possible answer choices are “selected” or “not selected”. Gender is identified as "female" or "male", and the Human Development Index (HDI) has four categories: "Very high", "high", "medium", and "low".

Considering the aggregated structure of our data, in a first statistical analysis we looked at the gender distribution for each question, then we apply comparison of proportions tests to assess whether the distributions of the question studied for the two populations of interest (men and women) are statistically equal. This gives an indication of the distribution of individuals and makes it possible to distinguishing the existence of groups sharing similar characteristics in our data.

In addition to these analyses, we perform multivariate analysis using Logistic and Multinomial aggregated regression models [15] since most questions have two possible answers (e.g., ‘yes’, ‘no’), and a small number of questions have three or more possible answers. The logistic (resp. multinomial) regression model uses a distribution function to model a binary dependent variable

(resp. one with multiple nominal values) in relation to other exogenous variables. Using these models, in particular the odds-ratio, we can estimate a potential effect of the gender gap that we want to measure given a certain number of confounding variables. It is important to note that these multivariate models are adapted to take into account the aggregated structure of our data.

In all the results we presented in the article to illustrate the gender gap, the multivariate analysis confirmed that the difference we observe between women and men is not due to confounding variables such as age, sector of employment, geographical region, or the country's HDI (human development index).

Filtered Data.

Filtering was performed on the original individual data using a zero-mean *Gaussian noise* and low *count filtering* to avoid accessing individual answers and infrequent answers. The zero-mean noise filter adds a zero-mean Gaussian noise to the query output tables containing the number, sum, mean, standard deviation, and variance. The noise is proportional to the users most influential on the output, and it means that the extracted tables will contain a variation from one to six observations from the raw tables. Noise is proportional to query complexity, meaning that the more complex the query, the more noise is introduced in the output table. For example, a simple query requesting frequency tables for two variables has a base noise layer equal to 2. It modifies values of outlying data, particularly those associated with minimum and maximum values.

Low count filtering eliminates values that do not appear frequently enough, or outlying observations. It removes a line when the individual contributing to a single output is too small. More precisely, when the output line contains several observations less than or equal to four, the line is automatically hidden.

In some cases, the data may pass the low-count filtering, but there is not enough information to provide the aggregate value requested, such as the average, variance, etc. In this case, the output table will indicate a null value for the lines concerned.

The reported table may contain some lines in italics, which means that the aggregate for that specific line is calculated with several observations less or equal to 15. This is also as a reminder that the results contain a high relative noise.

In addition, we observe that the more disaggregated the information we want to extract from a single table, the more that table will be penalized. In line with the recommendations of the Aircloak user guide, we construct a query by placing categorical variables with few possible answers first and adding categorical variables with greater number of possible answers at the end. So instead of having individual data with specific characteristics, we have a group of individuals who share those specific characteristics.

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