

# Bibliometrics: Global gender disparities in science

Vincent Larivière, Chaoqun Ni, Yves Gingras, Blaise Cronin & Cassidy R. Sugimoto

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**Cassidy R. Sugimoto and colleagues present a bibliometric analysis confirming that gender imbalances persist in research output worldwide.**

**Subject terms:** Authorship Careers Research management Society

Despite many good intentions and initiatives, gender inequality is still rife in science. Although there are more female than male undergraduate and graduate students in many countries<sup>1</sup>, there are relatively few female full professors, and gender inequalities in hiring<sup>2</sup>, earnings<sup>3</sup>, funding<sup>4</sup>, satisfaction<sup>5</sup> and patenting<sup>6</sup> persist.

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One focus of previous research has been the 'productivity puzzle'. Men publish more papers, on average, than women<sup>7</sup>, although the gap differs between fields and subfields. Women publish significantly fewer papers in areas in which research is expensive<sup>8</sup>, such as high-energy physics, possibly as a result of policies and procedures relating to funding allocations<sup>4</sup>. Women are less likely to participate in collaborations that lead to publication and are much less likely to be listed as either first or last author on a paper<sup>7</sup>. There is no consensus on the reasons for these gender differences in research output and collaboration — whether it is down to bias, childbearing and rearing<sup>9</sup>, or other variables.

It has been suggested that what women lack in research output they make up for in citations, particularly in fields with 'greater career risk'<sup>8</sup> — that is, fields with long lags between doctoral education and securing a faculty position, such as ecology. But again, there is no consensus on the relative impact of women's work compared to men's.

The present state of quantitative knowledge of gender disparities in science has been shaped primarily by anecdotal reports and studies that are highly localized, monodisciplinary and dated. Furthermore, these studies take little account of the rise in collaborative research and other changes in scholarly practices. Effective policy cannot be built on such foundations.

Therefore, we present here a global and cross-disciplinary bibliometric analysis of: first, the relationship between gender and research output (for which our proxy was authorship on published papers); second, the extent of collaboration (for which our proxy was co-authorships); and third, scientific impact of all articles published between 2008 and 2012 and indexed in the Thomson Reuters Web of Science databases (for which our proxy was citations). We analysed 5,483,841 research papers and review articles with 27,329,915 authorships. We assigned gender using data from the US Social Security database, among other sources (see Supplementary Information).

We find that in the most productive countries, all articles with women in dominant author positions receive fewer citations than those with men in the same positions. And this citation disadvantage is accentuated by the fact

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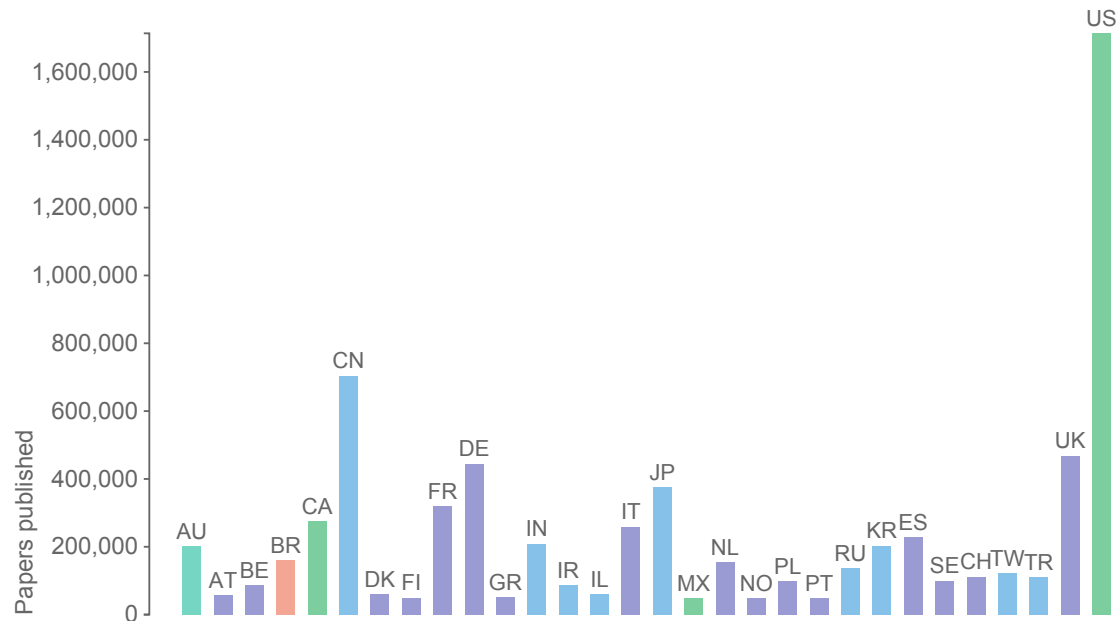


**Nature special:**  
Women in science

INTERACTIVE: Gender, output, collaboration and citation

Scientists in these 30 countries contributed the largest shares of the more than 5 million papers published between 2008 and 2012. Explore below to discover what proportion of output was contributed by women and men, and how the gender of lead authors influenced the citation of papers from lone authors, national and international collaborations.

Total papers published



FIELD

- ☒ Total papers published
- ☐ Single author
- ☐ Last author (national collaboration)
- ☐ Last author (international collaboration)
- ☐ Female to Male Ratio
- ☐ First author (national collaboration)
- ☐ First author (international collaboration)

CONTINENT

- ☒ All
- ☒ Europe
- ☒ Asia
- ☒ North America
- ☒ Australasia
- ☒ South America

COUNTRY

- ☒ Australia (AU)
- ☒ Austria (AT)
- ☒ Belgium (BE)
- ☒ Brazil (BR)
- ☒ Canada (CA)
- ☒ China (CN)
- ☒ Denmark (DK)
- ☒ Finland (FI)
- ☒ France (FR)
- ☒ Germany (DE)
- ☒ Greece (GR)
- ☒ India (IN)
- ☒ Iran (IR)
- ☒ Israel (IL)
- ☒ Italy (IT)

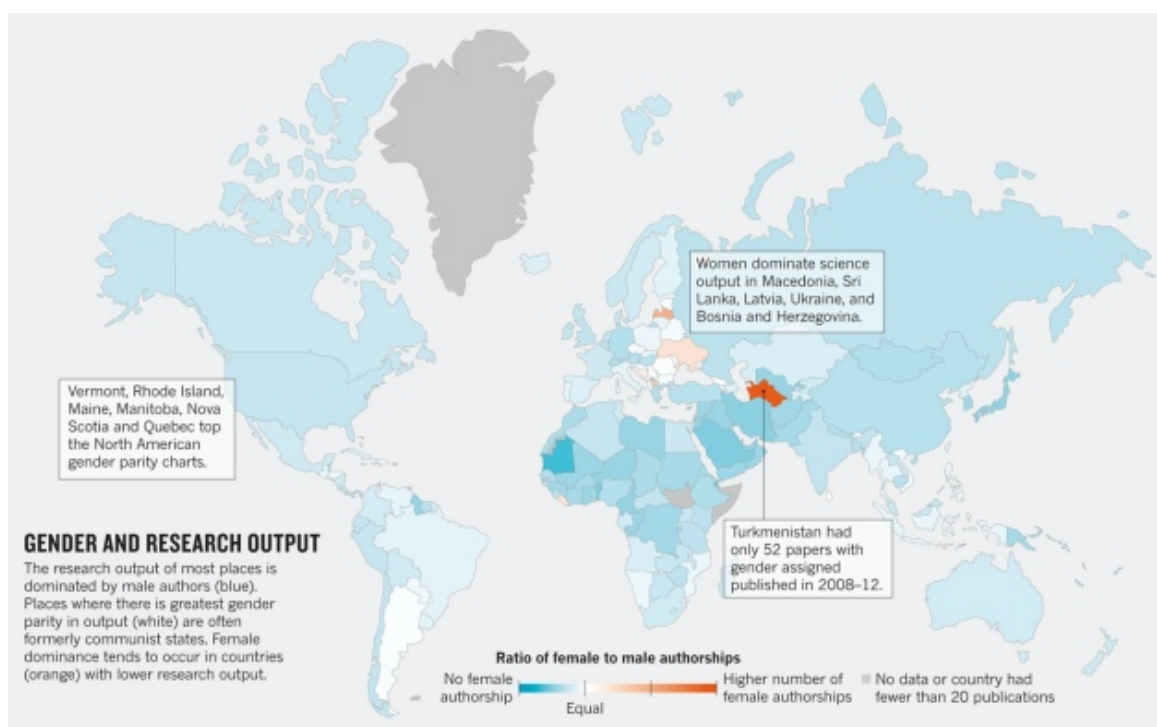
✓ Japan (JP)	✓ Mexico (MX)	✓ Netherlands (NL)
✓ Norway (NO)	✓ Poland (PL)	✓ Portugal (PT)
✓ Russia (RU)	✓ South Korea (KR)	✓ Spain (ES)
✓ Sweden (SE)	✓ Switzerland (CH)	✓ Taiwan (TW)
✓ Turkey (TR)	✓ United Kingdom (UK)	✓ United States (US)

Gender, output, collaboration and citation data

In our view, the scale of this study provides much-needed empirical evidence of the inequality that is still all too pervasive in science. It should serve as a call to action for the development of higher education and science policy.

### Bias by numbers

Men dominate scientific production in nearly every country; to what extent varies by region (see 'Gender and research output'). We probed the proportion of each gender's output by comparing the proportion of identified authorships for each gender on any given paper. For example, for a paper with eight authorships, of which six were assigned a gender, each of the authorships would be granted one-sixth of a paper. These gendered fractions were then aggregated at the levels of countries and disciplines. It should be stressed that these are authorships, not individuals, therefore no author name disambiguation was necessary (see Supplementary Information).



[Click here for an interactive version of this map](#)

Globally, women account for fewer than 30% of fractionalized authorships, whereas men represent slightly more than 70%. Women are similarly underrepresented when it comes to first authorships. For every article with a female first author, there are nearly two (1.93) articles first-authored by men.

South American and Eastern European countries demonstrate greater gender parity. Eastern Europe may support the idea

that communist and formerly communist states may have greater gender balance than other countries. Only nine countries had female dominance in terms of proportion of authorships, and five of these (Macedonia, Sri Lanka, Latvia, Ukraine, and Bosnia and Herzegovina) had more than 1,000 articles in our analysis. In other words, female authorship is more prevalent in countries with lower scientific output.

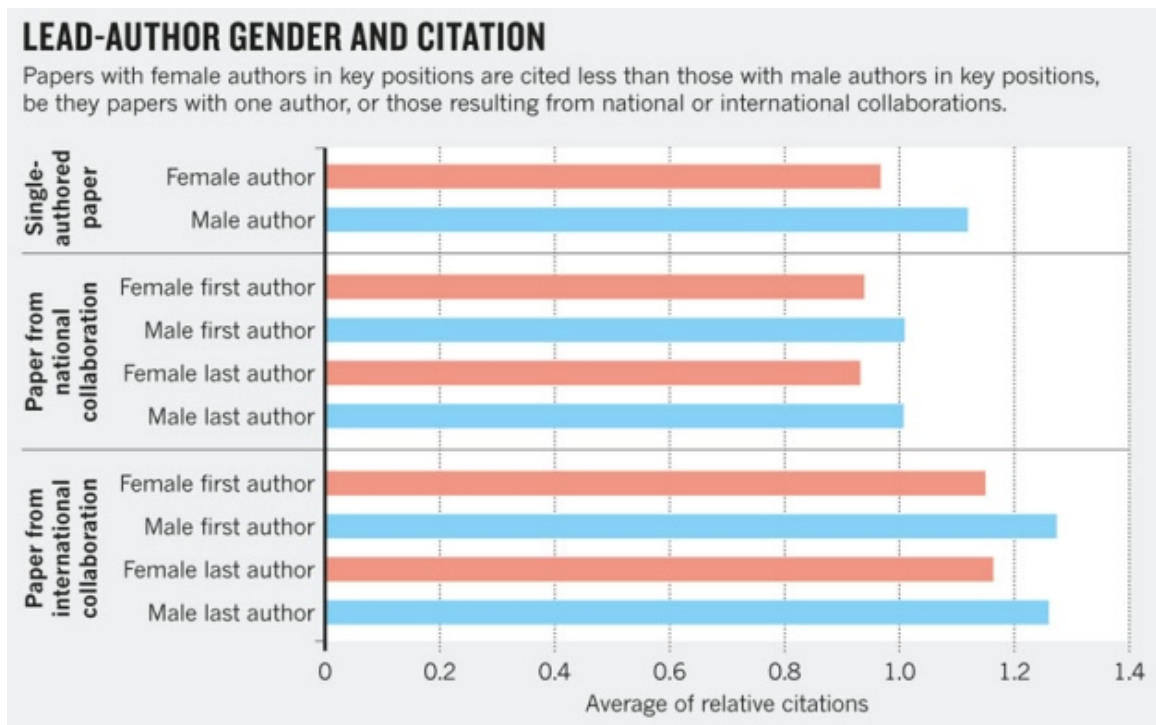
**“Programmes fostering international collaboration for female researchers might help to level the playing field.”**

Countries with more than 1,000 papers and high degrees of male dominance include, unsurprisingly (in order of output): Saudi Arabia, Iran, Japan, Jordan, the United Arab Emirates, Cameroon, Qatar and Uzbekistan. US states with more than 1,000 articles with a gender assigned and high male dominance include New Mexico, Mississippi and Wyoming. The US states and Canadian provinces that are closest to achieving gender parity (and have more than 1,000 articles) include Vermont, Rhode Island, Maine, Manitoba, Nova Scotia and Quebec. Again, some of these states and provinces are among the lowest ranking in terms of scientific output.

Our disciplinary results confirmed previous findings and anecdotal knowledge about fields associated with 'care'. Specialties dominated by women include nursing; midwifery; speech, language and hearing; education; social work and librarianship. Male-dominated disciplines include military sciences, engineering, robotics, aeronautics and astronautics, high-energy physics, mathematics, computer science, philosophy and economics. Although disciplines from the social sciences show a larger proportion of female authors, the humanities are still heavily dominated by men.

Next we looked at collaboration. We analysed the proportion of papers by gender that are the result of national collaboration, compared with those that result from international collaborations. For the 50 most productive countries in our analysis (accounting for 97% of the total publications), female collaborations are more domestically oriented than are the collaborations of males from the same country.

And what of impact? We analysed prominent author positions — sole authorship, first-authorship and last-authorship. We discovered that when a woman was in any of these roles, a paper attracted fewer citations than in cases in which a man was in one of these roles (see 'Lead-author gender and citation'). The gender disparity holds for national and international collaborations.



### Age-old story

There are several limitations to the conclusions that can be drawn from our findings. Foremost among them is that age indisputably has a role — perhaps even the major role — in explaining gender differences in scientific output, collaboration and impact. As is well known, the academic pipeline from junior to senior faculty leaks female scientists, and the senior ranks of science bear the imprint of previous generations' barriers to the progression of women. Thus it is likely that many of the trends we observed can be explained by the under-representation of women among the elders of science. After all, seniority, authorship position, collaboration and citation are all highly interlinked variables.

Another key limitation is that authorship of papers is only one of many indicators of research activity. Our analysis includes only journal articles, not books, conference proceedings, database construction or code, for example. Also problematic is the lack of universal norms associated with authorship attribution and position. For example, it is possible that some women do not appear as authors despite their contribution to research activities, and there are fields in which authors are listed alphabetically. There is also a concern that gender-assignment techniques can introduce errors (see Supplementary Information). We have tried to mitigate this with validation exercises, but there is always room for improvement.

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Future research should drill into questions raised by this analysis. What distinguishes pockets of anomalously high parity? Are there characteristics of the work itself that contribute to disparities in output and citation? Are there other, perhaps less quantitative, aspects of scholarship that reveal a different story regarding gender balance in science? Furthermore, is there anything intrinsic to certain disciplines or cultures that make them more or less appealing to scientists of a particular gender?

### Levelling the playing field

Those of a misogynistic bent might read this study as confirming their view that women's research is weaker than men's and there is less of it. Such a simplistic interpretation dismisses the vast implications embedded in these data. Our study

lends solid quantitative support to what is intuitively known: barriers to women in science remain widespread worldwide, despite more than a decade of policies aimed at levelling the playing field. UNESCO data show<sup>10</sup> that in 17% of countries an equal number of men and women are scientists. Yet we found a grimmer picture: fewer than 6% of countries represented in the Web of Science come close to achieving gender parity in terms of papers published.

For a country to be scientifically competitive, it needs to maximize its human intellectual capital. Our data suggest that, because collaboration is one of the main drivers of research output and scientific impact, programmes fostering international collaboration for female researchers might help to level the playing field.

That said, if there were a simple solution or programme that could improve matters, this issue would already be solved. Unfortunately, behind this global imbalance lie local and historical forces that subtly contribute to the systemic inequalities that hinder women's access to and progress in science. Any realistic policy to enhance women's participation in the scientific workforce must take into account the variety of social, cultural, economic and political contexts in which students learn science and scientific work is performed. Each country should carefully identify the micro-mechanisms that contribute to reproducing the past order. No country can afford to neglect the intellectual contributions of half its population.

*Nature* **504**, 211–213 (12 December 2013) doi:10.1038/504211a

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## Supplementary information

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### Excel files

1. Supplementary Table S4 (47K)
2. Supplementary Table S5 (44K)

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## 11 comments

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Anne-Mieke Vandamme • 2014-01-09 05:12 PM

As a female lab director of a gender balanced lab at all levels, I would like to share that it takes on average more convincing for a female than a male scientist to claim deserved first or last authorship. Similarly, I have the impression that it is easier for women than for men to forsake first or last authorship to those who deserve or need it more. It is no wonder then that in absence of a lab director with the proper sensitivities; men will more easily end up in those desired positions. This should not surprise us given the evolutionary drive for men to compete, and for women to keep peace. Whether this is a problem, and if so, how it should be solved, I don't know. While an objective competitive scientific career is still desirable above a "serve your friends" promotion, the inherent competitive nature may remain a tougher obstacle for capable women than for men. There are many situations where a collaborative rather than a competitive attitude may be desired, especially when facing the global challenges of this era. So perhaps we need to rethink how to academically reward. What is most valuable to boost in an academic environment, a competitive individual or a team working towards long term goals? Perhaps our society needs more women at crucial positions, and they will not get there without help.



Cassidy Sugimoto • 2014-01-10 01:04 AM

Thank you for your comment! I wonder whether targeted doctoral mentoring regarding authorship practices and author negotiation techniques might serve to alleviate some of these problems?



Joslyn Osten • 2013-12-19 07:28 PM

On December 11, the Chronicle of Higher Ed article "New Data Show Articles by Women Cited Less Frequently" by Megan O'Neil, caused anthropologists, Virginia Dominguez, Matthew Gutmann and Catherina Lutz, to look introspectively at the discipline of anthropology. In the article, O'Neil notes "Research papers and peer-reviewed articles written principally by women are cited less frequently than those whose dominant authors are men, compounding the underrepresentation of women in scholarly publishing, according to a new study."

Dominguez, Gutmann and Lutz agree with O'Neil in their *Anthropology News* article, released today, "Problem of Gender and Citations Raised Again in New Research Study", these anthropologists recognize that the citation problems are not only prevalent in the fields O'Neil reveals (computer science, engineering, mathematics), but also in anthropology itself.

Although O'Neil's article focuses on gender disparities, anthropologists note that "this issue is not restricted to questions of gender and should also be extended to race and other forms of distinction." While strides have been made over the years to bring women to the forefront of the discipline, "it is a question of citing top scholarship in all our work, and explicitly recognizing that this process must include vigilance against bias of all kinds related to factors like gender, race, class, and nationality." In pledging their citation vigilance, the authors call their colleagues and the institutions to action in augmenting citations of all top scholarship.

Problem of Gender and Citations Raised Again in New Research Study at [www.Anthropology-News.org](http://www.Anthropology-News.org).





Cassidy Sugimoto • 2014-01-10 01:06 AM

Thank you for directing us to this research. I agree that there are many other important variables that merit investigation in understanding issues of equality in the scientific workforce.



Paul Hartley • 2013-12-17 03:29 PM

This is fascinating and really well presented. Is the raw average citation data available for each field ? And what does the average citation data for the different fields imply about citation behaviours? For example, do some fields cite more than others and if so, why?



Cassidy Sugimoto • 2014-01-10 01:15 AM

Thank you for your interest. We have made our data available here: <http://info.ils.indiana.edu/gender/> Feel free to email us if there is other data that interests you. Yes, there is a large body of work in scientometrics and sociology of science describing field differences in referencing practices. This why we used field normalized citation rates, to avoid skewing towards "high-citing" fields.



Jonathan Mellon • 2013-12-16 12:30 AM

Could be really good to plot the countries on a funnel plot (see <http://understandinguncertainty.org/files/images/funnel2.png>) to get a feel for which are significantly under or over representing women and by how much. The map doesn't give much idea about significant deviations in smaller countries.



Cassidy Sugimoto • 2014-01-10 01:17 AM

Thank you for this suggestion. We will definitely consider this in our future work, which is focusing on differences among countries.



Luis Portilla • 2013-12-12 02:16 PM

So, Mexico is now in Southamerica? Interesting...



sara abdulla • 2013-12-12 01:16 PM

Yes. See supplementary info, quote: "Citation measures account for all citations received by a given paper, from its publication year to the end of 2012. To compare data between different specialties, each article's number of citations is divided by the average number of citations received by articles in the same discipline published that year. When the average of relative citations (ARC) is above 1, a given article is cited above the world average for the same field. Conversely, an ARC below 1 means that the number of citations received is below the world average. Of course, the well-known limitations of bibliometrics apply to this analysis, as the Web of Science does not index

all the world's scholarly literature. This is more problematic for the social sciences and the humanities, where (a) there is virtually no coverage of research output in media other than journal articles and (b) there is very limited coverage of research output in the form of articles written in languages other than English." .



Bob O Hara • 2013-12-12 11:16 AM

When looking at citation, was subject area controlled for? There could be a classic case of Simpson's paradox: women could (for whatever reason) tend to find themselves in subject areas that have lower citation rates.

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