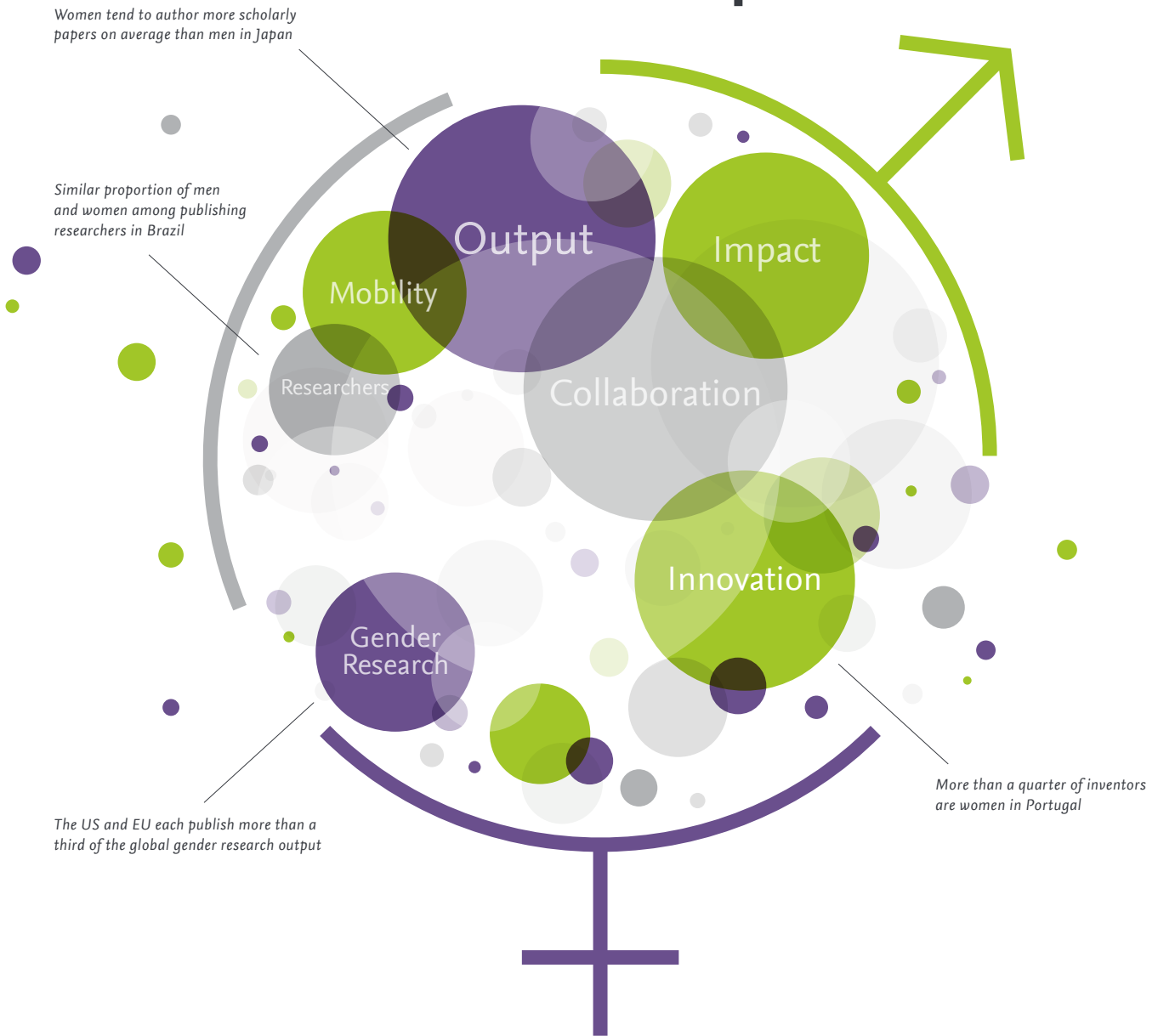


Gender in the Global Research Landscape



Analysis of research performance through a gender lens across 20 years, 12 geographies, and 27 subject areas

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Preface

As a steward of world research, Elsevier has a responsibility to promote gender equality in STEM (Science, Technology, Engineering, and Mathematics) and advance understanding of the impact of gender, sex, and diversity in research. In this regard, Elsevier fully supports the United Nations' Sustainable Development Goal 5, “to achieve gender equality and empower all women and girls,” and the Global Research Council's Statement of Principles and Actions Promoting the Equality and Status of Women in Research.

Through its New Scholars program, the Elsevier Foundation has contributed to the advancement of early- to mid-career women scholars for more than a decade via grants and other partner investments. These efforts laid a foundation of success upon which Elsevier has built broader corporate level gender initiatives. Last year, Elsevier placed a priority on fostering a gender-balanced workplace by implementing the EDGE (Economic Dividends for Gender Equality) program across our eight core business centers in numerous locations worldwide, thereby being among the first information service and technology companies in the world to be certified globally. Concomitantly, we formed a trans-business Gender Working Group to address external-facing issues such as enhancing sex and gender reporting in research and achieving gender balance for journal editorial boards and conferences. Further, Elsevier is committed to establishing a research framework for addressing gender issues to help advance policy. An important aspect of our commitment is this comprehensive report, *Gender in the Global Research Landscape*, a follow-on to Elsevier's groundbreaking 2015 report, *Mapping Gender in the German Research Arena* [\[1\]](#).

Critical issues related to gender disparity and bias must be examined by sound studies. Drawing upon a collection of high-quality global data sources and analytical expertise, Elsevier has produced this report as an evidence-based examination of the outputs, quality, and impact of research worldwide through a gender lens and as a vehicle for understanding the role of gender within the structure of the global research enterprise. *Gender in the Global Research Landscape* employs bibliometric analyses and methodologies that enable gender disambiguation of authors within the Scopus® abstract and citation database and includes comparisons between twenty-seven subject areas, across twelve comparator countries and regions, over two decades. Elsevier partnered with expert stakeholder organizations and individuals around the world who provided advice on the report's development, including the research questions, methodologies, and analytics, and a policy context for the report findings. Our intention is to share powerful insights and guidance on gender research and gender equality policy with governments, funders, and institutions worldwide and to inspire further evidence-based studies.



Ron Mobed
Chief Executive Officer, Elsevier

Key Findings

The proportion of women among researchers and inventors is increasing in all twelve comparator countries and regions over time.

CHAPTER 1

Women publish fewer research papers on average than men, but there is no evidence that this affects how their papers are cited or downloaded.

CHAPTER 1

Women are less likely than men to collaborate internationally on research papers.

CHAPTER 2

Women are slightly less likely than men to collaborate across the academic and corporate sectors on research papers.

CHAPTER 2

In general, women's scholarly output includes a slightly larger proportion of highly interdisciplinary research than men's.

CHAPTER 2

Among researchers, women are generally less internationally mobile than men.

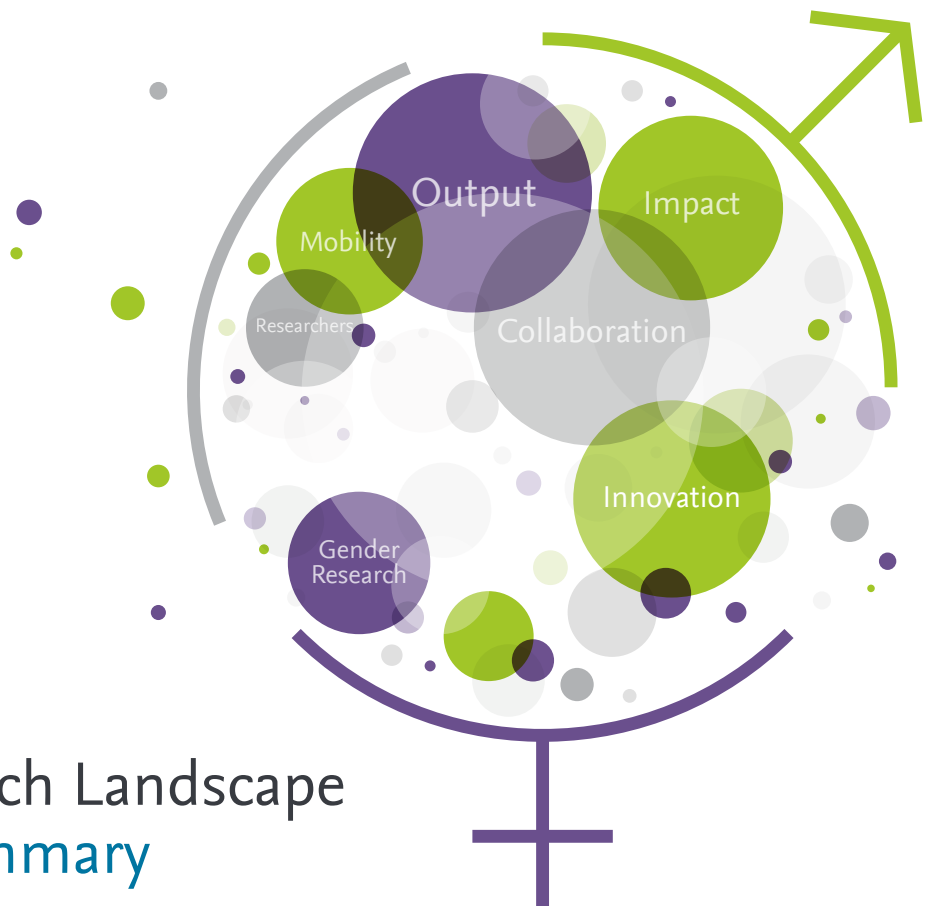
CHAPTER 2

Gender research is growing in terms of size and complexity, with new topics emerging over time.

CHAPTER 3

The former dominance of the United States in gender research has declined as research activity in the European Union has risen.

CHAPTER 3



Gender in the Global Research Landscape Executive Summary

Gender affects all facets of life and the world of research presents no exception. In this report, Elsevier and experts from around the world examined this issue using large-scale datasets to track various aspects of the global research enterprise over 20 years, 12 comparator countries and regions, and 27 subject areas.

The proportion of women among researchers and inventors is increasing in all twelve comparator countries and regions over time.

In nine of the twelve comparator countries and regions analyzed, women comprise more than 40% of researchers (2011–2015): the United States, European Union, United Kingdom, Canada, Australia, France, Brazil, Denmark, and Portugal. This is an improvement from 1996–2000, at which time only Portugal has more than 40% of women among researchers. The results vary substantially by field of research, with women better represented in the Life and Health Sciences. In the Physical Sciences, women are still generally and markedly underrepresented, with women comprising less than 25% of researchers in these fields in the majority of comparators. The global share of women among inventors listed in patent applications increases between 1996–2000 (10%) and 2011–2015 (14%), yet women remain strongly underrepresented across all comparators.

Women publish fewer research papers on average than men, but there is no evidence that this affects how their papers are cited or downloaded.

In all comparator countries and regions with the exception of Japan, men publish more papers on average over a five-year period than women. This imbalance in scholarly output is not mirrored in the downloads or citations that those papers receive. While differences in field-weighted

download impact and field-weighted citation impact between women and men are small, the former indicator slightly favors women while the latter slightly favors men. In Engineering and Nursing, there is evidence to suggest that underrepresentation of one gender tends to correlate with underrepresentation of that gender in lead authorship positions on published papers.

Women are less likely than men to collaborate internationally on research papers.

In all twelve comparator countries and regions, women are less likely than men to collaborate at an international level on research papers. However, despite an increase in research collaboration over time among both women and men, there has been no notable change in the difference between men and women's likelihood to collaborate internationally.

Women are slightly less likely than men to collaborate across the academic and corporate sectors on research papers.

Our analysis shows that there is relatively little variation between comparator countries and regions in the percentage of cross-sector collaboration between academia and industry. For all comparators in both periods, the proportion of scholarly output resulting from academic-corporate collaboration is slightly lower for women than for men among researchers.

In general, women's scholarly output includes a slightly larger proportion of highly interdisciplinary research than men's.

The differences across genders are fairly limited; however, for most comparator countries and regions, women tend to have a slightly higher share of the top 10% of interdisciplinary scholarly output relative to their total scholarly output than men. There is little variation in this indicator across comparators.

Among researchers, women are generally less internationally mobile than men.

In selected analyses of researcher mobility for the United Kingdom, Canada, Brazil, and Japan, we observe varying degrees of overrepresentation of women researchers classed as non-migratory (those researchers who do not exhibit international mobility in the period 1996–2015). However, the highest citation impact is associated with transitory researchers (those who move internationally for periods of less than two years).

Gender research is growing in terms of size and complexity, with new topics emerging over time. The former dominance of the United States in gender research has declined as research activity in the European Union has risen.

Published papers using the term “gender” in the title are split between biomedical and social science research topics. Over time, new themes have developed, with more papers published on topics such as feminism, gender stereotyping, and gender classification and identification. Gender research is growing at a relatively fast pace: faster than the rate of growth of scholarly literature as a whole over the same period. The rate of growth varies by comparator country and region, with gender research becoming less concentrated in the United States (50% of papers in 1996–2000) and more equitably split between the United States and the European Union in 2011–2015 (34% from the former, 35% from the latter). The highest impact papers come from the countries and regions that are represented most frequently in the research, including, in particular, the United States and several countries in the European Union.



The full report is available at elsevier.com/research-intelligence/resource-library/gender-report
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Contents

Preface	3
Key Findings	5
Executive Summary	6
Contents	9
Introduction	10
CHAPTER 1	
The global research landscape through a gender lens	15
Key Findings	16
1.1 Proportion of women and men among researchers	17
1.2 Scholarly output, impact, and usage patterns of women and men researchers	28
1.3 Proportion of women and men among inventors and their patents	34
INTERVIEW Miyoko O. Watanabe, Deputy Executive Director, Office for Diversity and Inclusion, Japan Science and Technology Agency (JST), Japan	38
INTERVIEW James Stirling, Provost, Imperial College, United Kingdom	42
CHAPTER 2	
Gender and research leadership, collaboration, interdisciplinarity, and mobility	45
Key Findings	46
2.1 First and corresponding authorship	47
2.2 International collaboration	51
2.3 Academic-corporate collaboration	54
2.4 Interdisciplinary research	56
2.5 International mobility	58
INTERVIEW Vladimir Šucha, Director-General, Joint Research Centre, European Commission, European Union	62
CHAPTER 3	
The gender research landscape	65
Key Findings	66
3.1 Identifying and mapping gender research	67
3.2 Gender research scholarly output and impact	71
INTERVIEW Londa Schiebinger, The John L. Hinds Professor of History of Science and Director, Gendered Innovation in Science, Health & Medicine, Engineering, and Environment, Stanford University, United States	74
Conclusion	77
Appendices	79
A Project team, Subject experts, and Acknowledgements	80
B Methodology and data sources	84
C Glossary of terms	88
D Subject classification	90

Gender and innovation

Diversity is integral to innovation.¹ In both academic and private-sector research, the diversity of research teams ensures that new perspectives and ideas are brought to the table. Diversity adds to the collective intelligence of a research group,² and not only enhances creativity, but also provides new contexts for understanding the societal relevance of the research itself. One of the key aspects of diversity is gender. The unique perspectives and contributions of women to scientific research teams have been recognized globally.³ Increasing the participation of women in the STEM fields to drive innovation and achieve excellence in research is a stated goal of the United Nations Educational, Scientific and Cultural Organization (UNESCO)⁴ and the Global Research Council (GRC).⁵ The GRC has called for specific policy changes to promote gender equality in the scientific workforce, including training to correct unconscious gender biases and exploring new career pathways by which women are able to succeed in research and rise to leadership positions. These efforts echo calls by the United Nations (UN) Development Programme to achieve gender equality and empower women and girls worldwide. The UN Sustainable Development Goal 5 seeks development and implementation of policies and legislation that will ensure that women are able to achieve full and effective participation in the workforce and have equal opportunities for leadership.⁶

A large and growing body of evidence has revealed persistent gender-based differences in demographics, productivity, and advancement within the scientific workforce.⁷ UNESCO reports that in 2015, only 28% of researchers around the globe are women.⁴ Though nearly equal numbers of men and women pursue bachelor's and master's degrees in the STEM fields, the loss of women from the research career path begins at the PhD stage and continues through the highest organizational levels—a phenomenon somewhat controversially described as a “leaky pipeline.” The representation of women in STEM varies geographically, with certain countries having relatively high proportions of women among researchers (Bolivia 63%, Venezuela 56%), while others have lower proportions (Republic of Korea 18%, Japan 15%). Only 25% of researchers in France, Germany, and the Netherlands are women.⁴ Gender differences also vary by discipline—representation by women is highest in health and life sciences and lowest in engineering and computer science.⁴

Beyond the gender imbalance in the number of researchers, the literature consistently reports a large gender disparity in terms of scholarly publication.⁸ A large study of 5.5 million papers and 27.3 million authorships reveals that men produce a greater number of papers (70%) and hold more first authorships (66%) than women, even in the most productive countries.⁹ In another study of 1.5 million papers and 2.8 million authorships, men are found to be more likely to hold the prestigious first and last author positions.⁹ Other studies report a gender imbalance in the impact of publications, utilizing citations as a proxy. One study finds that only 13% of highly cited authors in 2014 were women; this number varies by discipline, from 3.7% in engineering to 31% in the social sciences.¹⁰

- 1 Duran, A., Lopez, D. *Impact of Diversity on Organization and Career Development*. C. Hughes (Ed.). Hersey, PA: IGI Global; 2015. doi:10.4018/978-1-4666-7324-3; Hewlett, A., Marshall, M., Sherbin, L. “How diversity can drive innovation.” *Harvard Business Review*. 2013. <https://hbr.org/2013/12/how-diversity-can-drive-innovation> Forbes Insights. *Fostering Innovation Through a Diverse Workforce*. http://images.forbes.com/forbesinsights/StudyPDFs/Innovation_Through_Diversity.pdf
- 2 Thompson, D. “The Secret to Smart Groups: It’s Women.” *The Atlantic*. 2015. <http://www.theatlantic.com/business/archive/2015/01/the-secret-to-smart-groups-isnt-smart-people/384625/> Woolley A.W., Chabris C.F., Pentland A., Hashmi N., Malone T.W., “Evidence for a collective intelligence factor in the performance of human groups.” *Science*. 2010;330(6004):686-688. doi:10.1126/science.1193147.
- 3 Lee, H., Pollitzer, E. *Gender in Science and Innovation as Component of Inclusive Socioeconomic Growth*. London, UK: Portia Ltd; 2016.
- 4 Huyer, S. “Is the Gender Gap Narrowing in Science and Engineering?” In: *UNESCO Science Report: Towards 2030*. Paris, France: UNESCO Publishing; 2015. <http://unesdoc.unesco.org/images/0023/002354/235406e.pdf>
- 5 Global Research Council. *Statement of Principles and Actions Promoting the Equality and Status of Women in Research*; 2016. <http://www.rcuk.ac.uk/documents/documents/GRC2016StatusofWomen-pdf>
- 6 United Nations. *Sustainable Development GOALS - 17 Goals to Transform our World*; 2016. <http://www.un.org/sustainabledevelopment/sustainable-development-goals>
- 7 Shen, H. “Inequality quantified: Mind the gender gap.” *Nature*. 2013;495(7439):22-24. doi:10.1038/495022a.
- 8 Larivière, V., Ni, C., Gingras, Y., Cronin, B., Sugimoto, C.R. “Global gender disparities in science.” *Nature*. 2013;504(7479):211-213. doi:10.1038/504211a.
- 9 West, J.D., Jacquet, J., King, M.M., Correll, S.J., Bergstrom, C.T. “The role of gender in scholarly authorship.” *PLoS One*. 2013;8(7):e66212. doi:10.1371/journal.pone.0066212.
- 10 Bornmann, L., Bauer, J., Haunschild, R. “Distribution of women and men among highly cited scientists.” *J Assoc Inf Sci Technol*. 2015;66(12):2715-2716. doi:10.1002/asi.

Gender disparities have also been reported with regard to the salaries and advancement of STEM researchers.¹¹ In one study of more than 25,000 researchers, being a man is found to be a positive predictor of becoming a Principal Investigator (PI), even after correcting for all other publication and non-publication factors.¹² Other studies have reported a slower pace of advancement by women compared to men, with women spending a greater amount of time at the assistant professor level than men.^{11, 13} Persistent bias in favor of hiring men, as well as in offering them higher starting salaries, start-up funds, and mentoring support compared to women, has also been described.^{14, 15} Several studies have also noted gender differences in the number of patent applications.^{16, 17}

Factors underlying gender disparities in STEM

Gender research has suggested several factors that underlie the observed gender inequities in STEM.⁴ Persistent bias in hiring, authorship, recognition, and promotion has been noted. One study describes the “Matilda Effect,” in which women authors are associated with a lower perceived quality of publication and interest in collaboration compared to men.¹⁸ Women are more likely than men to have a non-linear career path, and are more likely to leave the academic track because of personal factors, such as maternity leave.¹⁹ Issues of work-life balance may interfere with publication productivity and advancement differently for men and women.²⁰ Gender differences in publication number and impact may also be related to differences in collaboration patterns, as collaborator network reach has been associated with greater publication counts and impact, as well as greater promotion. While women researchers collaborate more often than men, their collaborator networks are more often domestic compared to those of men.^{22, 23} Women researchers have also been shown to specialize less than men, which may also be linked to lower productivity and promotion.^{24, 25}

- 11 Committee on Gender Differences in Careers of Science, Engineering, and Mathematics Faculty; Committee on Women in Science, Engineering, and Medicine; Committee on National Statistics, Division of Behavioral and Social Sciences and Education, National Research Council. *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty*. Washington, DC: The National Academies Press; 2010. doi:10.17226/12062.
- 12 van Dijk, D., Manor, O., Carey, L.B. “Publication metrics and success on the academic job market.” *Curr Biol*. 2014;24(11):R516-R517. doi:10.1016/j.cub.2014.04.039.
- 13 Van den Besselaar, P., Sandström, U. “Gender differences in research performance and its impact on careers: a longitudinal case study.” *Scientometrics*. 2016;106(1):143-162. doi:10.1007/s11192-015-1775-3.
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- 15 Sege, R., Nykiel-Bub, L., Selk, S. “Sex differences in institutional support for junior biomedical researchers.” *JAMA*. 2015;314(11):1175. doi:10.1001/jama.2015.8517.
- 16 Whittington, K.B., Smith-Doerr, L. “Gender and commercial science: Women’s patenting in the life sciences.” *J Technol Transf*. 2005;30(4):355-370. doi:10.1007/s10961-005-2581-5.
- 17 Whittington, K.B., Smith-Doerr, L. “Women inventors in context: disparities in patenting across academia and industry.” *Gen Soc*. 2008;22(2):194-218. doi:10.1177/0891243207313928.
- 18 Knobloch-Westerwick, S., Glynn, C.J., Hoge, M. “The Matilda effect in science communication: an experiment on gender bias in publication quality perceptions and collaboration interest.” *Sci Commun*. 2013;35:603-625. doi:10.1177/1075547012472684.
- 19 Ramos, A.M.G., Cortés, J.N., Moreno, E.C. “Dancers in the dark: Scientific careers according to a gender-blind model of promotion.” *Interdiscip Sci Rev*. 2015;40(2):182-203. doi:10.1179/0308018815Z.000000000112.
- 20 Kyvik, S., Teigen, M. “Child care, research collaboration, and gender differences in scientific productivity.” *Sci Technol Human Values*. 1996;21(1):54-71. doi:10.1177/016224399602100103.
- 21 Warner, E.T., Carapinha, R., Weber, G.M., Hill, E. V., Reede, J.Y. “Faculty promotion and attrition: The importance of coauthor network reach at an academic medical center.” *J Gen Intern Med*. 2015;31(1):15-17. doi:10.1007/s11606-015-3463-7.
- 22 Uhly, K.M., Visser, L.M., Zippel, K.S. “Gendered patterns in international research collaborations in academia.” *Stud High Educ*. September 2015:1-23. doi:10.1080/03075079.2015.1072151.
- 23 Abramo, G., D’Angelo, C.A., Murgia, G. “Gender differences in research collaboration.” *J Informetr*. 2013;7(4):811-822. doi:10.1016/j.joi.2013.07.002.
- 24 Leahey, E. “Gender differences in productivity: Research specialization as a missing link.” *Gen Soc*. 2006;20(6):754-780. doi:10.1177/0891243206293030.
- 25 Leahey, E., Keith, B., Crockett, J. “Specialization and promotion in an academic discipline.” *Res Soc Stratif Mobil*. 2010;28(2):135-155. doi:10.1016/j.rssm.2009.12.001.

Regional and local initiatives to address gender disparities in STEM

The imbalance in opportunities for women in STEM is a global reality that has prompted an examination of the causal factors as well as the development, implementation, and evaluation of potential solutions. Several regional, national, and local organizations have announced initiatives aimed at improving gender equity in STEM.²⁶

United States

The United States government is committed to examining gender representation in STEM, as demonstrated by initiatives from the White House Office of Science and Technology Policy²⁷ and reports from the US Government Accountability Office.²⁸ The National Institutes of Health (NIH) has formally recognized the need to address the gender imbalance in the United States' biomedical research workforce, not only to ensure fairness, but also to channel all available intellectual capacity towards building knowledge and improving human health.²⁹ In 2015, the NIH called for research into four cross-cutting challenges to workforce diversity: (1) understanding the impact of diversity on research quality and outputs, (2) determining which approaches to improving biomedical training and retention work best, (3) identifying the factors that limit workforce diversity, and (4) developing strategies to implement and sustain diversity within the scientific workforce. Likewise, the National Science Foundation (NSF) has called for the support of all talented researchers, regardless of gender, to ensure the highest-impact scientific discoveries and advances.³⁰ Through its ADVANCE program, the NSF funds research and initiatives to identify and eliminate organizational barriers to the participation and advancement of women academic researchers. Local level efforts to understand the drivers of gender inequity in STEM research, as well as develop and test potential interventions, include those by the Gendered Innovations program based at Stanford University,³¹ Harvard University,^{21, 32} and Reed College.³²

Europe

In 2015, the European Commission (EC) released the *Strategic Engagement for Gender Equality*, its plan for work aimed at promoting gender equality.³⁴ The *Europe Gender Equality Strategy*, developed in 2013 by the Council of Europe, also proposes a set of strategic objectives to advance and empower women, including promoting gender-balanced organizational structures.³⁵ In line with these statements, the European Union's Horizon 2020 research funding programme specifically calls for strategies to balance gender representation in research teams and policy and decision-making groups to improve innovation and research quality.³⁶ Working within the Horizon 2020 programme, the Joint Research Centre (JRC) is actively involved in overseeing the conception, development, implementation, and monitoring of policies for achieving gender equity across the European Union. The European Institute for Gender Equality (EIGE), established an independent body within the European Union to promote gender equality and fight against discrimination, also provides support for cross-cutting research to inform policymakers and other key stakeholders as they work toward gender equality.³⁷ Fraunhofer IAO, which investigates how changes in demographics affect organizations, is one of several institutions involved in the EC-funded STAGES (Structural Transformation to Achieve Gender Equality in Science) project, which supports research on building gender-aware organizational cultures and examining the impact of specific initiatives to improve equal opportunity for women in the scientific research workforce.

26 Frehill, L.M., McNeely, C.L., Pearson Jr, W., Eds. "An international perspective on advancing women in science." In: *Advancing Women in Science, An International Perspective*. London, UK: Springer; 2015.

27 *Women in STEM*, <https://www.whitehouse.gov/administration/eop/ostp/women>

28 Beede, T., Julian, T., Langdon, D., McKittrick, G., Beethida, K., Doms, M., "Women in STEM: A Gender Gap to Innovation", *ESA Issue Brief* 2011;4:11

29 United States Government Accountability Office Report to Congressional Requesters, *WOMEN IN STEM RESEARCH Better Data and Information Sharing Could Improve Oversight of Federal Grant-making and Title IX Compliance*, 2015, <http://www.gao.gov/assets/680/673987.pdf>

29 Valentine, H.A., Collins, F.S. "National Institutes of Health addresses the science of diversity." *Proc Natl Acad Sci*. 2015;112(40):12240-12242. doi:10.1073/pnas.1515612112.

30 Córdova, F.A. "Global Research Council: Commit to equity for women researchers." *Nature*. 2016;534(7608):475. doi:10.1038/534475a.

31 Stanford Gendered Innovations. <https://genderedinnovations.stanford.edu>

32 Warner, E.T., Carapinha, R., Weber, G.M., Hill, E.V., Reede, J.Y. "Considering context in academic medicine: differences in demographic and professional characteristics and in research productivity and advancement metrics across seven clinical departments." *Acad Med*. 2015;90(8):1077-1083. doi:10.1097/ACM.0000000000000717.

33 Fox, M.F., Whittington, K.B., Linkova, M. "Gender, (in)equity, and the scientific workforce." In: *Handbook of Science and Technology Studies*. U. Felt, R. Fourche, C. Miller, L. Smith-Doerr (Eds.) Cambridge, MA: MIT Press; 2016.

34 European Commission. *Strategic Engagement for Gender Equality*. 2015. https://ec.europa.eu/anti-trafficking/sites/antitrafficking/files/strategic_engagement_for_gender_equality_en.pdf

35 The Council of Europe. *Europe Gender Equality Strategy*. <https://rm.coe.int/CoERMPublicCommonSearchServices/DisplayDCTMContent?documentId=090001680590174>

36 European Commission. *Promoting Gender Equality in Research and Innovation*. <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/promoting-gender-equality-research-and-innovation#Article>

37 European Institute for Gender Equality. <http://eige.europa.eu>

Asia-Pacific Region

Gender equity is on Japan's agenda as evident through government-led initiatives such as "womenomics" and "make women shine".³⁸ The Japan Science and Technology Agency (JST) actively promotes diversity and gender equity through its Office for Diversity and Inclusion established in 2013. JST is currently instituting formal organizational policies to provide women researchers with more mentoring opportunities and flexibility in work schedules, and is pursuing initiatives that will lead to more women among leaders in high level policy positions.

Japan is also hosting the Gender Summit 10 (GS10), a program started in 2011 by the EC that has since grown worldwide. The Gender Summits are held throughout the world and provide a platform for researchers, policymakers, scholars, and other stakeholders to come together and discuss gender-based research and the impact of gender on scientific knowledge and innovation.³⁹

In Australia, the Australian National University (ANU) Gender Institute supports gender- and sex-based research and outreach, as well as the development of programs and policies to increase hiring and retention of women across the university.⁴⁰ The Institute hosted its first Women in Research Citation Awards in 2016 to specifically recognize the contributions of women researchers. On a national level, the Science in Australia Gender Equity (SAGE) program formed in 2013 within the Australian Academy of Science is currently spearheading a pilot study of the Athena SWAN program to evaluate gender equity issues in STEM.⁴¹

In the Republic of Korea, the Centre for Women in Science, Engineering and Technology (WISSET) was established in 2011 to develop policies to support women along the entire STEM research career continuum.⁴²

Viewing the Research Enterprise Through a Gender Lens

For this report, Elsevier drew on its expertise in mining the Scopus abstract and citation database of peer-reviewed literature to comprehensively evaluate two gender-based aspects of the global research enterprise: (1) the landscape of global researchers—their publication productivity, impact, and collaborations—viewed through a gender lens and (2) the scope of gender research activity. Elsevier is able to analyze these aspects of the research enterprise across twelve comparator countries and regions and over two time periods, thanks to Scopus' global coverage: over 62 million documents in more than 21,500 serials by some 5,000 publishers, inclusive across all major research fields, with 6,900 titles in the Physical Sciences, 6,400 in the Health Sciences, 4,150 in the Life Sciences, and 6,800 in the Social Sciences. More information about the Scopus database and the methodology used in this report, including the process used to identify gender research papers and the novel gender disambiguation approach, can be found in *Appendix B*.

Use of the information in the report

The data in this report may be useful to a range of stakeholder groups, including funders, policymaking bodies, government agencies, and research institutions, to help clarify the scope of gender research as well as gender-related characteristics of the STEM workforce, and how these have changed over time. This report can help inform development of evidence-based initiatives to promote diversity and specific policies to improve gender equality and build organizational structures that will support women in their pursuit of careers in STEM research.

38 Japan Ministry of Foreign Affairs, Towards a Society in which all women shine, http://www.mofa.go.jp/pc/fp/pc/page23e_000181.html

39 Gender Summits. gender-summit.eu; World Economic Forum. *Japan Gender Parity Task Force*. <https://www.weforum.org/projects/japan-gender-parity-task-force>

40 Australia National University Gender Institute. <http://genderinstitute.anu.edu.au>

41 Science in Australia Gender Equity (SAGE). <http://www.sciencegenderequity.org.au>

42 Center for Women in Science, Engineering and Technology (WISSET). <http://www.wiset.or.kr/eng/index.jsp>





CHAPTER 1
The global research
landscape through
a gender lens

Key Findings

The proportion of women among researchers and inventors has increased over time in all twelve comparator countries and regions.

SECTIONS 1.1 & 1.3

Among researchers, women tend to specialize in the biomedical fields and men in the physical sciences.

SECTION 1.1

Among researchers, compared to men, women tend to have a lower scholarly output on average, but women and men tend to have similar citation and download impacts.

SECTION 1.2

The proportion of patents with at least one woman named as an inventor tends to be higher than the proportion of women among inventors.

SECTION 1.3

1.1 Proportion of women and men among researchers

UNESCO reports that there is near gender balance among researchers at the graduate level: in 2013, women made up between 44% and 54% of graduates (ISCED level 8) for all comparator countries except Japan, where 33% of graduates were women.⁴³ The *She Figures 2015* report described a similar gender balance in the European Union in 2012, reporting that between 40% and 60% of PhD graduates were women.⁴⁴ However, it is also widely recognized that beyond the graduate level, women leave the academic track at different stages and for a number of reasons.

With the gender gap in science having been acknowledged some years ago, efforts are being made to rectify the problem. UNESCO's STEM and Gender Advancement (SAGA)⁴⁵ is a worldwide initiative with an overall aim to reduce the gender gap in STEM fields at all levels of education and research. The Million Women Mentors⁴⁶ and 1000 Girls – 1000 Futures⁴⁷ projects, as well as national and regional groups and initiatives, are pursuing similar end goals with some significant recent progress.

As a first step to understanding the global research landscape, we calculate the number of men and women researchers across our twelve comparator countries and regions in the two time periods 1996–2000 and 2011–2015. Gender balance is said to occur when women make up 40–60% of any group.⁴⁸ *Figure 1.1* shows that during the latter period in Brazil and Portugal, women constitute 49% of the researcher population, making these countries particularly noteworthy for reaching gender parity among researchers. Women comprise more than 40% of researchers in several other comparator countries and regions in the same period: the United States, the European Union, the United Kingdom, Canada, Australia, France, and Denmark. Mexico and Chile are not far behind, each with 38% women among researchers. This is an improvement on the figures in the period 1996–2000 when only Portugal had more than 40% women researchers (41%). Indeed, all countries and regions show a greater share of women among researchers in the more recent period: Denmark and Brazil see an increase of 11 percentage points, while the lowest improvements are seen in the countries with the lowest share of women researchers: Chile, Mexico, and Japan.

To understand gender in the global research landscape, we need to be able to identify trends among men and women among researchers. As a proxy for researchers, we use authors who have published articles, reviews, and conference proceedings that have been indexed in Scopus, Elsevier's indexing and abstracting database. Scopus covers 62 million documents published in more than 21,500 titles. In addition to indexing papers and other forms of scholarly output, Scopus indexes authors with an associated unique identifier (Scopus ID). Through this data structure, we can identify all the papers, affiliations, and citations of an author to form a Scopus Author Profile. Throughout the report, we use the term "researchers" when referring to indicators that are based on author profiles containing all the information we have for each author, and use "authors" to refer to the ascribed authors for each paper. To conduct any analysis of the relationships between gender of researchers/authors and various indicators of research performance, we first identify the gender of the authors in Scopus. This is done by combining Scopus data with data sources providing information on first names and gender per country (Genderize.io, NamSor sociolinguistic analysis, and Wikipedia name lists), which allow us to assign a gender to author profiles with a first name. The author's first name field is not mandatory in Scopus and therefore only author profiles with a full first name are included in the gender assignment exercise. We are able to assign a gender to a high proportion of Scopus Author Profiles for each of our twelve selected comparator countries and regions in the two time periods analyzed. For the subset of "named and gendered researchers," i.e., those researchers whose Scopus Author Profile contains a first name, and to whom we are able to assign a country of origin and gender, the proportion of gendered Scopus Author Profiles ranges across comparators from 80% to 96% for 1996–2000 and 82% to 95% for 2011–2015. (Please see *Appendix B* for more details on the methodology used).

43 UNESCO Institute for Statistics. <http://data.uis.unesco.org>.

44 European Commission. *She Figures 2015*. https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf

45 UNESCO. Gender and Science. <http://www.unesco.org/new/en/natural-sciences/priority-areas/gender-and-science/improving-measurement-of-gender-equality-in-stem/stem-and-gender-advancement-saga>

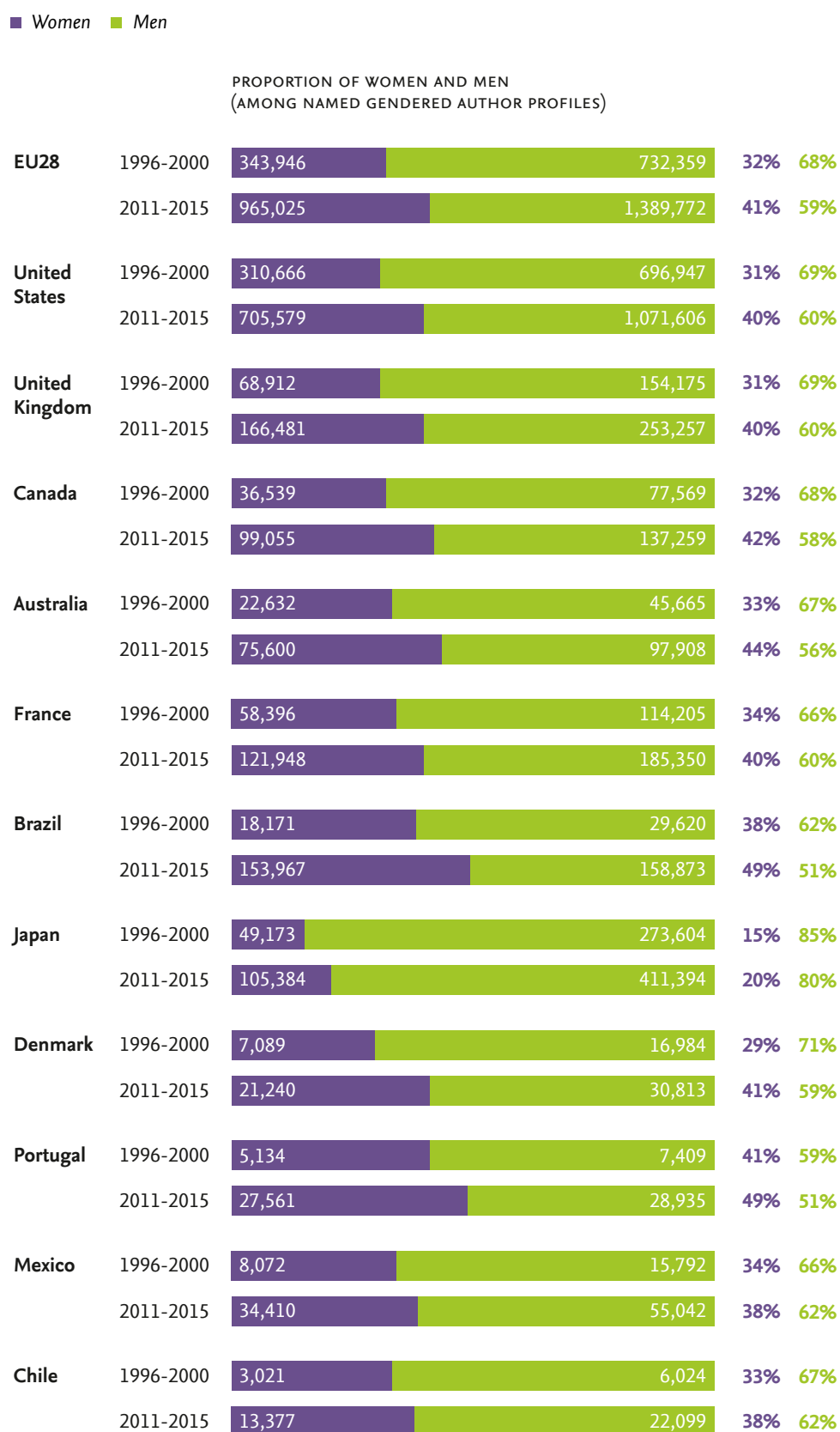
46 Million Women Mentors. <https://www.millionwomenmentors.org/about>

47 1000 Girls 1000 Futures. <http://www.1000girls1000futures.org>

48 <http://www.includegender.org/facts/gender-equality>

Figure 1.1 — Proportion and number of researchers by gender (among named and gendered author profiles) for each comparator and period, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia



Anecdotally, it is widely recognized that gender balance differs across fields of research; therefore, we drilled down behind these top-level figures to quantify gender equity by research field. In Scopus, journals are classified into 27 non-mutually exclusive subject areas (see *Appendix D*). To analyze the proportion of women and men among researchers per field, we use these journal subject areas as a proxy for fields of research and examine the authors publishing papers in these journals. If an author publishes a paper in a journal indexed in the Energy and Engineering categories, or one paper in an Engineering journal and one paper in an Energy journal, the author is counted once in each subject category, consistent with the use of our whole-counting method (see methodology in *Appendix B*).

Research specialization is “the extent to which a scholar repeatedly engages in research on the same substantive topics”, often within the context of one or more fields of research.⁴⁹ We found interesting gender differences among researchers based on subject area, as demonstrated in *Figure 1.2*. The analysis is unaffected by the absolute number of women versus men among researchers, since the distributions are relative to each gender. Although the gender differences by subject area may be more or less pronounced per comparator country or region, certain subject areas seem to show consistently greater gender specialization⁴⁹ than other subject areas across comparators.

The results show that there tend to be larger proportions of women researchers than men researchers in the Health and Life Sciences. In 2011–2015, 19% (Portugal) to 26% (Denmark) of women researchers publish in journals in the Medicine subject category, compared to 13% (France, Portugal) to 18% (Chile, Japan) of men researchers. Similarly, 10% (Chile) to 17% (Japan) of women researchers publish in journals in the Biochemistry, Genetics, & Molecular Biology category, compared to 7% (Chile) to 12% (Japan) of men researchers.

By contrast, there tend to be larger proportions of men researchers in the Physical Sciences fields. For example, in 2011–2015, 7% (Australia) to 12% (Japan) of men researchers publish in journals belonging to the Engineering subject category, compared to 3% (Chile) to 6% (Portugal) of women researchers. Likewise, 4% (Australia) to 8% (Japan) of men researchers publish in journals belonging to the Physics & Astronomy category compared to 2% (Australia) to 4% (Japan) of women researchers.

KEY FINDING

The proportion of women among researchers has increased over time in all comparator countries and regions.

“ The variation across countries is striking. It illustrates the methodological complexities of studying diversity in the scientific workforce at a global scale. At a most basic level, it is clear that multiple techniques are required just to predict the gender of authors. At a higher level, models of the scientific gender gap need to consider many interconnected factors, including population growth, migratory patterns, and international collaboration.

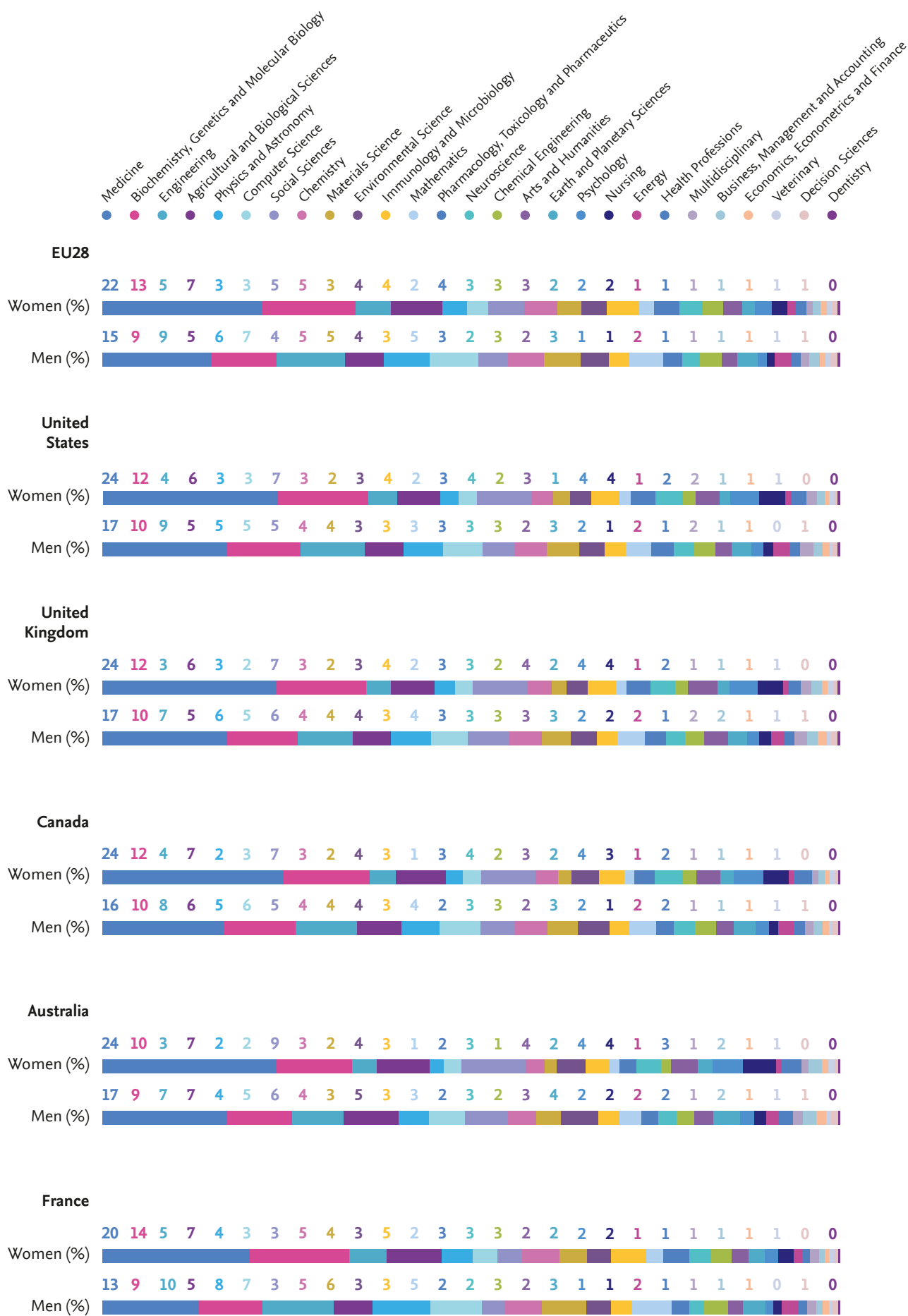
— **Griffin M. Weber**, Associate Professor of Medicine, Harvard Medical School, Harvard University and Director, Biomedical Research Informatics Core, Beth Israel Deaconess Medical Center, United States

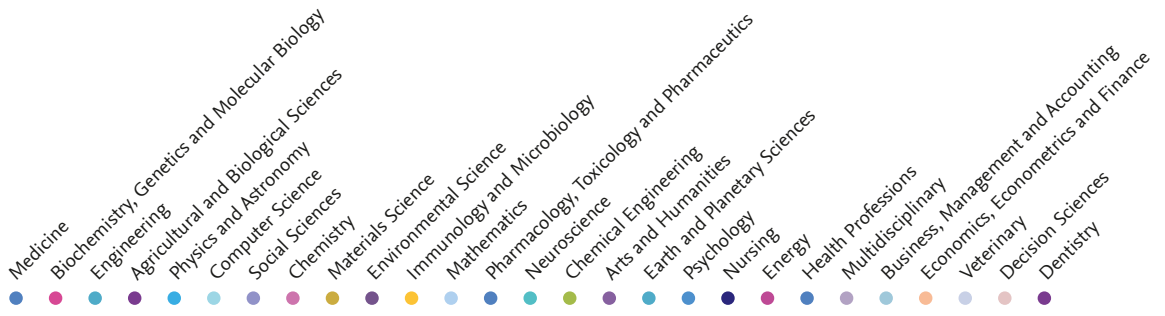
KEY FINDING

Among researchers, women tend to specialize in the biomedical fields and men in the physical sciences.

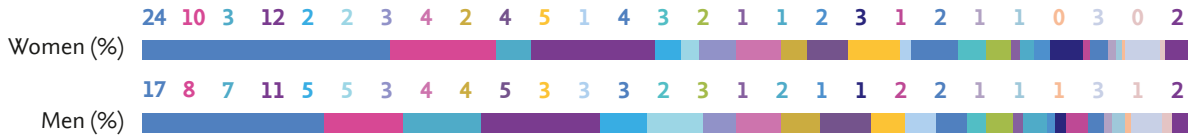
49 Leahey, E., Keith, B., Crockett, J. Specialization and promotion in an academic discipline. *Res Soc Stratif Mobil* [Internet]. 2010;28(2):135-155. doi:10.1016/j.rssm.2009.12.001.

Figure 1.2 (continues next page) — Proportion of researchers (among named and gendered author profiles) by subject area for each gender and comparator, 2011–2015. Sources: Scopus, Genderize, NamSor, and Wikipedia

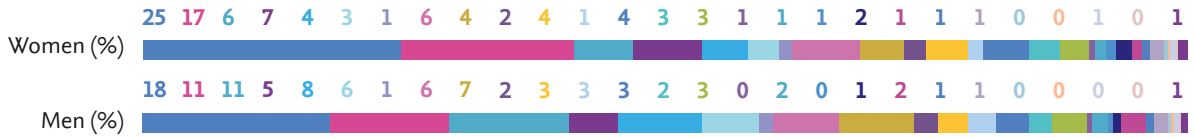




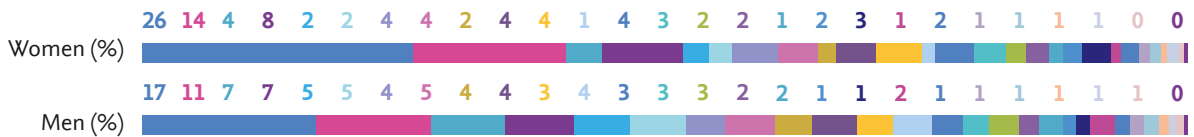
Brazil



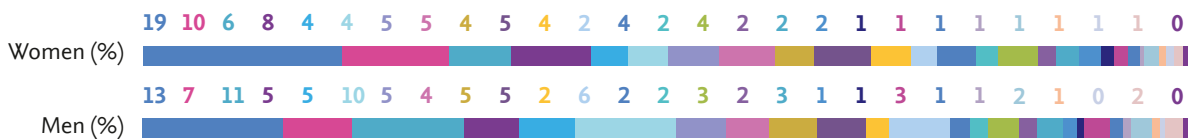
Japan



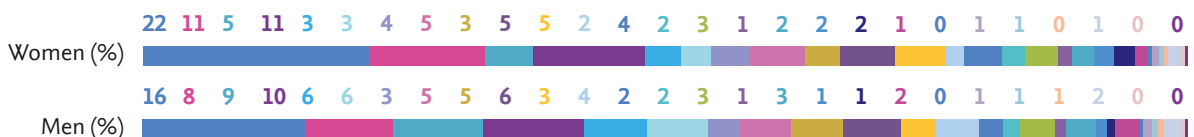
Denmark



Portugal



Mexico



Chile

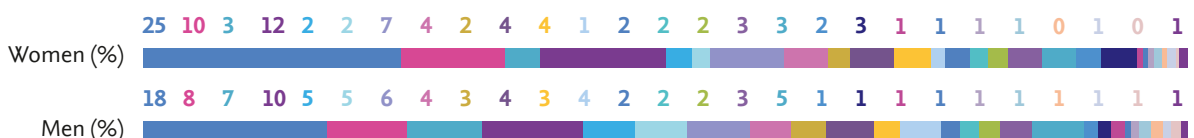


Figure 1.3 shows that the overall gender distribution patterns for each comparator country and region are mirrored in the gender distribution patterns per subject area. In other words, countries that tend to have a relatively larger proportion of women among researchers overall also tend to have a larger proportion of women among researchers per subject area, and vice versa. In line with the research specialization mentioned above, a larger proportion of women among researchers publish in the Health, Life, and Social Sciences than in the Physical Sciences.

The share of women among researchers differs across various fields of research. There are several subject areas where women represent at least 40% of researchers across the majority of our twelve countries and regions: Biochemistry, Genetics, & Molecular Biology, Immunology & Microbiology, Medicine, Nursing, and Psychology. In these subjects, all regions display increased gender balance, with the exception of Japan, where men still outnumber women to a greater extent. In Nursing, the percent of women has increased such that several countries (Australia, Brazil, Canada, Portugal, and the United States) now have more than 60% of women among researchers. This trend reflects the patterns seen among practicing nurses, where women tend to outnumber men,^{50, 51} though to a much lesser extent among researchers than among practitioners.

There are other subject areas that also have a relatively high proportion of women among researchers: in Agricultural & Biological Sciences, Neuroscience, Pharmacology, Toxicology & Pharmaceuticals, Social Sciences, and Veterinary, women represent at least 30% of researchers in all comparator countries and regions except Japan, where men outnumber women by a greater extent. To summarize in the broadest terms: the Health and Life Science fields are found to have the highest representation of women among researchers.

The Physical Sciences tell a different story. In the fields of Computer Science, Energy, Engineering, Mathematics, and Physics & Astronomy, the majority of comparator countries and regions have fewer than 25% of women among researchers. A variety of research has been conducted to better understand this gap and its underlying causes. A recent study looked at academically gifted children and compared standardized test results for boys and girls. In mathematics in the United States, for example, girls accounted for 7% of top-level scores in 1981-1985, but by 2011-2015, that number has risen to 28%.⁵² This relatively rapid change over time disputes previous suggestions of “sex differences

in general intelligence with a male advantage appearing in adolescence”⁵³ and suggests instead that the problem is social and cultural in nature. In other words, talent is not cultivated equally between boys and girls at a young age across all disciplines. A report from the American Association of University Women, *Why So Few? Women in Science, Technology, Engineering and Mathematics*, also found that “negative stereotypes about girls’ abilities in math can indeed measurably lower girls’ test performance.” When girls are told that boys and girls can achieve equally in mathematics, the difference in performance disappears.⁵⁴

Portugal’s strengths in gender balance in research at the country level are reflected across many individual subject areas. In 20 of the 27 subjects, Portugal has the highest share of women among researchers, even in subjects where women are generally underrepresented, including Physics & Astronomy (37% women), Earth & Planetary Sciences (43% women), and Environmental Science (52% women). Portugal is the only country to have more than 60% of women among researchers in fields other than Nursing and Psychology (e.g. Pharmacology, Toxicology, & Pharmaceuticals with 63% women and Immunology & Microbiology with 61% women). This may reflect the success of Portugal’s efforts to improve gender balance through policy, such as the ruling that prohibits gender discrimination in school textbooks. In 2002, Portugal was congratulated by the United Nations for its efforts to promote the equality of women.⁵⁵ Additional initiatives to promote the participation of girls and women in STEM include the Portuguese Association of Women in Science,⁵⁶ Rails Girls, Girls Lean In, Portugal Girl Geek Dinners, and Geekettes.⁵⁷ Despite these positive initiatives, criticisms remain regarding gender wage gaps, career advancement, and other aspects of gender equality in Portugal. When it comes to gender balance in research, even the bright spots could burn more brightly.

In contrast, Japan has the lowest share of women among researchers in several of the subject areas. Shares are particularly low, below 15%, in fields that are more generally dominated by men in most comparator countries and regions: Energy (9% women), Engineering (11% women), and Mathematics (11% women). This inequality reflects wider cultural, political, and economic trends in Japan. The World Economic Forum’s (WEF) *Global Gender Gap Report 2016* places Japan at 111 out of 144 countries in its global inequality rankings,⁵⁸ falling from 101st to 111th place between the WEF 2015 and 2016.⁵⁹ Efforts are being made in Japan to improve the gender balance and increase the

50 Kaiser Family Foundation. *Total Number of Professionally Active Nurses, by Gender*, 2016. <http://kff.org/other/state-indicator/total-number-of-professionally-active-nurses-by-gender>

51 NHS Employers. *Gender in NHS*. <http://www.nhsemployers.org/-/media/Employers/Publications/Gender%20in%20the%20NHS.PDF>

52 Makel, M.C., Wai, J., Peairs, K., Putallaz, M. Sex differences in the right tail of cognitive abilities: An update and cross cultural extension. *Intelligence*. 2016;59(Nov-Dec):8-15. doi:10.1016/j.intell.2016.09.003.

53 Lynn, R., Kanazawa, S. A longitudinal study of sex differences in intelligence at ages 7, 11 and 16 years. *Personality and Individual Differences*. 2011;51(3):321-324. doi:10.1016/j.paid.2011.02.028.

participation of women in science.⁶⁰ Beyond the world of research, Japan has a target to have women occupy 30% of leadership positions by 2030.

Across all comparator countries and regions in this report, the differences in the results between 1996–2000 and 2011–2015 show that the representation of women in research is generally increasing, and can increase at a rapid rate. In Portugal, only 10% of Dentistry researchers are women in 1996–2000, but in 2011–2015, this number has risen to 48%. Similarly, 27% of Nursing researchers were women in Denmark in the earlier period, and that figure is now 54%. In only a small number of comparators and subjects did the share of women researchers fall and, in the majority of cases, women already represented at least 40% of researchers in 1996–2000.

“ I was excited to see how emerging technologies can provide precise information about gender differences in existing scientific publications. Elsevier’s Scopus can be interrogated to tell who publishes what, where, and when, and this report uses the data to identify discrepancies in the publishing practices of men and women worldwide. This makes it an important resource, which will enable us to explore ideas about the causes of gender inequality in science.

— Uta Frith, Emeritus Professor, Institute of Cognitive Neuroscience and Department of Psychology, University College London and Chair, Diversity Committee, The Royal Society, United Kingdom

54 American Association of University Women. *Why So Few? Women in Science, Technology, Engineering and Mathematics*. 2010.

<https://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf>

55 United Nations. *Committee Experts Praise Portugal’s Efforts to Promote Equality of Women*.

www.un.org/press/en/2002/WOM1309.doc.htm

56 Portuguese Association of Women in Science. *Amonet*.

http://www.molinsight.net/amonet/amonet_home.htm

57 IEEE Women in Engineering. *4 Reasons to be a Tech Girl in Portugal*.

sites.ieee.org/portugal-wie/index.php/4-reasons-to-be-a-tech-girl-in-portugal

58 World Economic Forum. *The Global Gender Gap Report 2016*.

<http://reports.weforum.org/global-gender-gap-report-2016>

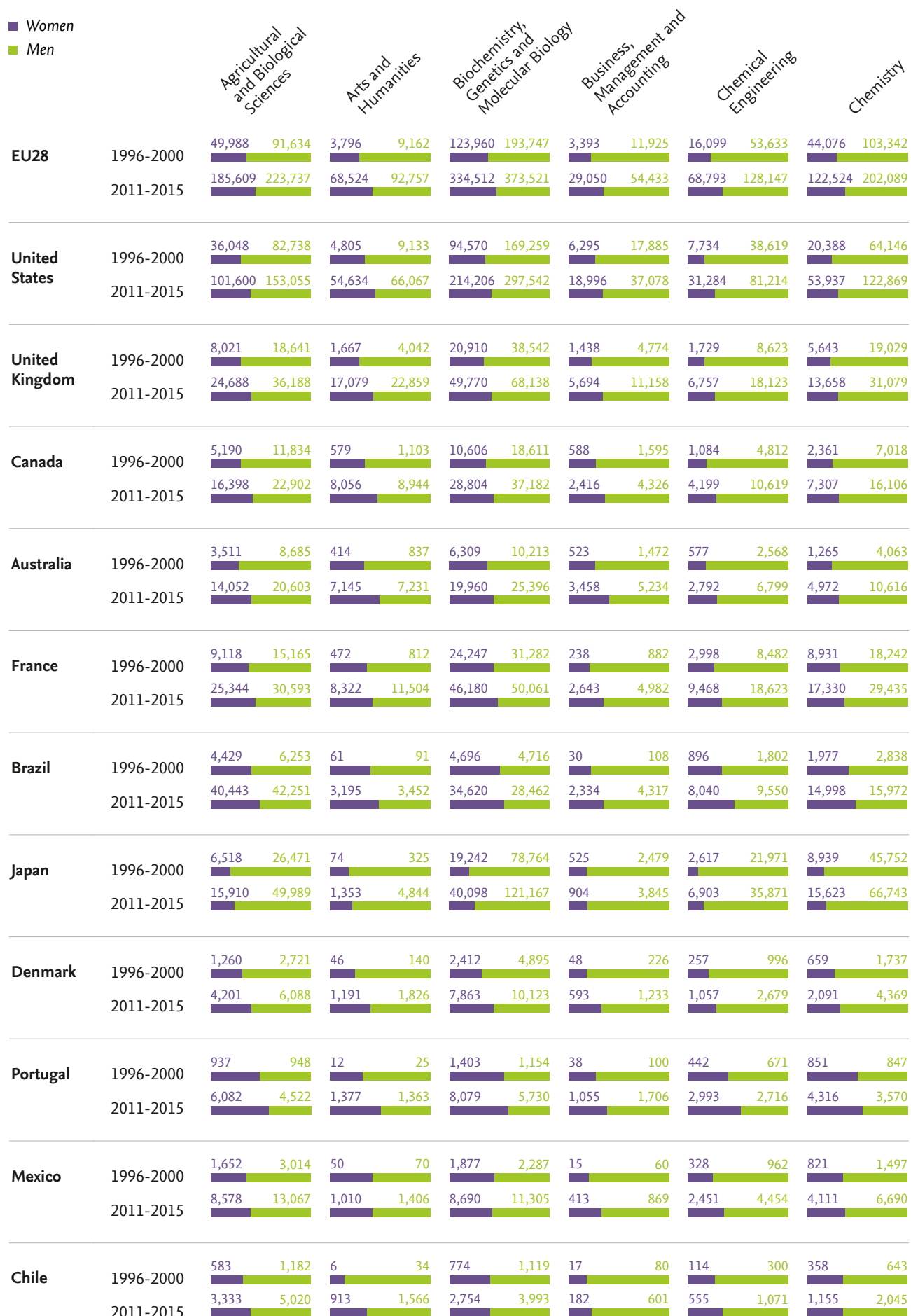
59 *The Economist*. “Japan’s efforts to make it easier for women to work are faltering.” November 26, 2016.

<http://www.economist.com/news/asia/21710849-womens-participation-workforce-high-their-status-low-japans-efforts-make-it>

60 Koshi, N. *World Economic Forum*. “How can we improve gender equality in Japan?”

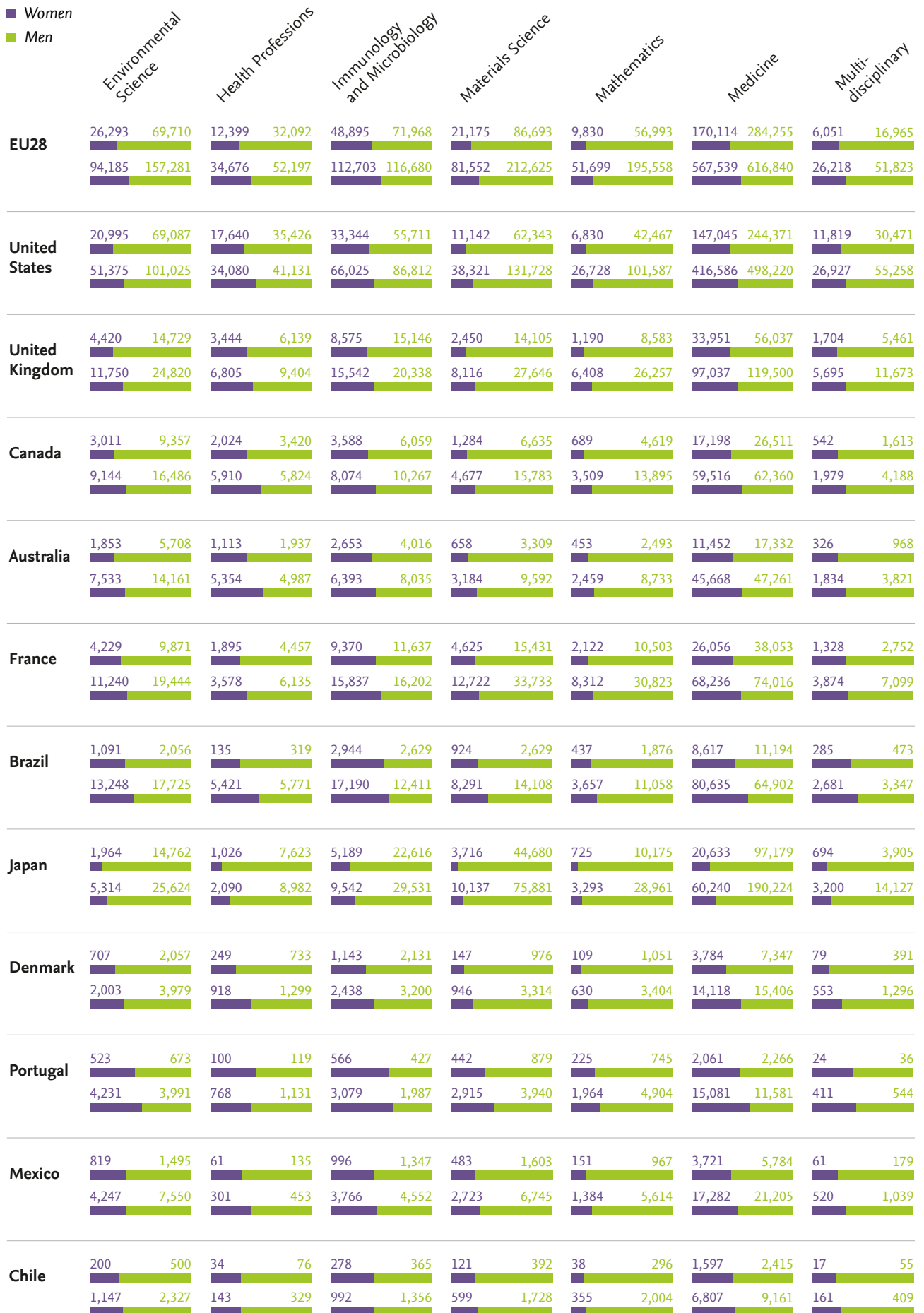
<https://www.weforum.org/agenda/2015/04/how-can-we-improve-gender-equality-in-japan>

Figure 1.3 (continues next pages) — Proportion and number of researchers by gender (among named and gendered author profiles) for each comparator and subject area, 1996–2000 vs. 2011–2015. Sources: Scopus, Genderize, NamSor, and Wikipedia



	Computer Science		Decision Sciences		Dentistry		Earth and Planetary Sciences		Economics, Econometrics and Finance		Energy		Engineering	
EU28	11,345	70,463	1,427	7,780	2,844	7,118	14,560	55,708	2,529	9,519	3,868	22,105	26,360	158,271
	78,169	272,870	13,444	38,468	9,984	14,936	46,437	110,190	18,858	38,077	27,786	92,967	123,336	388,259
United States	11,590	66,369	1,698	8,024	2,283	6,800	11,369	56,302	3,724	12,562	2,651	21,595	28,825	183,015
	44,661	155,076	6,468	18,885	4,966	9,007	25,790	79,486	9,968	24,909	14,421	64,309	68,444	258,025
United Kingdom	2,085	12,953	371	1,881	737	1,733	2,699	12,742	1,045	3,409	643	4,530	4,467	30,981
	10,051	35,177	1,888	5,822	1,534	2,504	6,531	18,386	3,399	8,447	3,141	13,014	13,729	52,020
Canada	1,141	7,019	197	968	239	611	1,644	8,195	412	1,295	299	2,287	2,567	16,194
	6,183	21,245	967	2,894	530	902	4,149	11,559	1,282	3,114	1,884	8,230	8,689	31,555
Australia	734	3,564	113	511	145	407	1,126	5,284	286	994	167	936	1,242	7,249
	4,687	13,786	866	2,480	393	666	3,855	10,459	1,664	3,617	1,407	5,101	6,485	19,837
France	2,482	12,163	237	1,058	261	699	3,083	9,910	261	845	769	3,370	6,055	28,492
	11,238	38,920	1,629	4,892	610	1,069	7,193	17,452	2,236	4,499	4,196	13,596	17,254	54,371
Brazil	509	2,107	51	193	307	461	548	1,819	36	125	194	911	993	5,176
	5,985	19,896	1,660	3,563	7,073	5,682	4,468	8,763	800	2,027	2,684	7,539	11,549	27,783
Japan	1,389	21,336	74	900	546	3,057	924	9,870	61	600	592	10,046	4,022	67,352
	7,268	58,509	329	2,571	2,156	6,263	2,650	16,164	351	2,019	2,317	24,640	13,730	121,451
Denmark	142	1,176	19	158	87	168	290	1,393	52	225	69	418	383	2,676
	1,240	4,937	225	751	181	273	721	2,163	305	860	544	2,257	1,951	6,614
Portugal	179	1,030	39	121	2	18	220	509	23	69	71	247	497	1,965
	2,992	8,215	670	1,470	329	358	1,711	2,241	549	717	1,110	2,167	4,559	9,167
Mexico	146	800	10	78	34	76	444	1,480	36	119	145	640	423	2,453
	2,333	7,833	168	557	199	272	1,722	3,902	306	771	1,037	3,192	3,638	11,806
Chile	29	195	5	59	23	41	209	826	4	75	9	74	89	591
	482	2,533	66	456	209	304	871	2,622	126	520	160	692	911	3,695

Figure 1.3 (continued from pages 24–25) — Proportion and number of researchers by gender (among named and gendered author profiles) for each comparator and subject area, 1996–2000 vs. 2011–2015. Sources: Scopus, Genderize, NamSor, and Wikipedia



	Neuroscience		Nursing		Pharmacology, Toxicology and Pharmaceuticals		Physics and Astronomy		Psychology		Social Sciences		Veterinary	
EU28	30,381	52,211	7,541	12,449	38,714	67,892	26,786	129,011	14,617	23,796	17,365	38,363	7,875	13,857
	82,736	94,464	56,070	48,578	94,227	107,837	87,027	262,883	62,478	53,490	124,113	173,275	23,499	23,371
United States	26,402	46,045	20,846	18,903	25,972	54,195	19,083	108,649	27,007	32,047	38,190	56,496	6,507	11,701
	64,376	84,799	61,869	38,651	60,290	88,534	43,800	160,710	68,911	51,512	126,598	134,813	13,177	14,374
United Kingdom	6,341	11,105	3,848	4,071	6,141	13,808	3,794	21,364	5,191	7,403	8,154	14,999	1,642	3,534
	13,951	18,346	14,417	10,956	12,675	19,767	10,836	38,844	15,469	12,007	30,530	39,773	3,235	3,686
Canada	3,596	5,678	2,154	1,665	3,058	5,892	1,771	9,635	3,373	3,685	3,799	5,838	859	1,553
	9,653	11,033	8,320	5,009	6,499	8,901	5,545	19,664	9,884	6,693	17,839	17,939	1,941	2,116
Australia	1,795	2,854	1,303	1,122	1,478	2,999	881	4,772	1,700	1,973	2,670	4,618	576	1,218
	6,285	7,093	8,675	4,707	4,563	6,188	3,612	11,712	8,016	5,105	16,929	16,538	1,726	2,147
France	5,348	7,696	622	1,222	7,119	10,946	6,438	25,557	1,552	2,340	1,845	4,041	1,056	1,674
	10,045	11,322	7,288	6,315	11,779	13,687	14,745	44,786	6,242	5,834	11,524	17,644	2,405	2,637
Brazil	1,171	1,377	386	146	1,751	1,688	1,144	4,171	221	242	450	658	768	1,484
	8,860	7,008	10,556	3,916	15,162	10,834	8,415	16,942	5,343	2,931	11,743	12,014	11,385	10,908
Japan	3,925	18,454	252	1,276	8,002	34,746	4,544	53,663	773	3,050	542	2,873	898	3,754
	7,155	22,523	3,701	8,312	10,915	34,005	10,704	85,179	2,064	4,960	3,153	13,209	1,554	4,565
Denmark	507	1,153	94	249	688	1,470	347	2,271	178	392	287	776	235	441
	1,664	2,324	1,514	1,298	2,064	2,715	1,306	4,999	980	1,008	2,360	3,461	626	629
Portugal	204	214	12	17	500	384	411	1,135	73	90	206	324	51	55
	1,680	1,376	989	619	2,896	1,737	2,828	4,688	1,672	1,044	3,804	4,140	601	409
Mexico	434	602	60	82	828	1,037	506	2,383	254	236	282	468	153	309
	1,790	2,246	1,524	1,027	2,930	3,175	2,727	8,259	1,512	1,424	2,904	4,077	1,072	2,188
Chile	112	239	10	10	251	330	136	711	54	108	100	225	96	188
	470	872	928	656	654	1,001	667	2,633	673	665	1,942	3,147	272	476

1.2 Scholarly output, impact, and usage patterns of women and men researchers

We analyze the performance of men and women among researchers by studying the scholarly output (articles, reviews, or conference proceedings; collectively referred to as “papers” in this report) associated with their Scopus Author Profiles, the citations⁶¹ their papers received in the scholarly literature, and the views and downloads their papers received on Elsevier’s full-text platform ScienceDirect.⁶²

Figure 1.4 shows scholarly output in terms of the number of scholarly papers per researcher (total number of papers for the period divided by total number of researchers for the period), by five-year period and comparator country and region. In general, we found that men publish more papers on average than women in the five-year windows of publication examined in this report, for all comparators except Japan. For all comparators except Australia, Denmark, and Chile, women publish fewer papers on average in 2011–2015 than in 1996–2000. An author is only included in this analysis if he/she publishes at least one paper in the five-year period of analysis. As a result, authors that do not publish any paper in a period are not represented in the analysis for that period. An overall career view of women and men researchers might show a detrimental effect of career breaks on the lifetime productivity of women, and career breaks may have influenced some of the gender-based differences in our analysis. Career breaks include maternity and paternity leave and absences related to ill-health and family commitments. Women take career breaks more often than men, usually for reasons related to starting a family or caring for a family member.⁶³ This gender difference may be related to a lack of choice around parental leave, societal expectations around caregiving, and gender-based differences in income (often in families with two parents, the lower income earner is designated as the caregiver by default). Although policy is evolving and pa-

rental leave may be more readily shared by parents in some countries and regions, paternity leave is not a statutory requirement placed on employers in many countries⁶⁴ and is often significantly shorter than maternity leave. Re-entry into academia after a break can also be challenging,⁶⁵ and there are more women working part-time in STEM than men, which may also impact research output.⁶⁶ Owing to the nature of the whole counting method used here, the data may overrepresent the number of women in many comparator countries and regions and subject areas, since women are typically underrepresented overall but in whole counting are given equal weight. Changes over the two time periods may also be affected by shifting demographics underlying these authorship figures, such as the effect of increasing participation of women in research over time, but at early and less prolific career stages.

“ I think the importance of data as an evidence base for policymaking has sharply grown in recent decades. This is not just true for gender equality but for many other areas of policymaking as well. Quantitative data continues to provide evidence on the persistence of social inequalities – often going up against feelings of resentment and backlashes. However, a much more profound reflection is needed on the outsourcing of political decision-making to supposedly neutral “benchmarking” practices. Data does not just provide evidence, data itself is highly political!

— **Jörg Müller**, Senior Researcher, Gender and ICT, IN3, Universitat Oberta de Catalunya, Spain; Coordinator, GenPORT, European Union

61 Citation is a formal reference to earlier work made in a paper or patent, frequently to papers in other papers. A citation is used to credit the originator of an idea or finding and is usually used to indicate that the earlier work supports the claims of the work citing it. The number of citations received by a paper from subsequently published papers is used as a proxy of the quality or importance of the reported research.

62 ScienceDirect® (www.info.sciencedirect.com) is Elsevier’s platform of authoritative, full-text scientific, technical, and health publications from over 3,800 journals and more than 35,000 book titles—over 14 million peer-reviewed publications (and growing) from Elsevier, its imprints, and its society partners. The average click-through to full-text publications per month is nearly 60 million. In this report, a download is defined as the event where a user viewed the full-text HTML of a paper or downloaded the full-text PDF of a paper from ScienceDirect. Views of an abstract alone or multiple full-text HTML views or PDF downloads of the same paper during the same user session are not included in accordance with the COUNTER Code of Practice.

63 Duncan Lawrie. *Women Taking Career Break Could Reduce Pension*. <https://www.duncanlawrie.com/insights/press/women-taking-career-break-could-reduce-pension>

64 European Parliament. *Maternity and Paternity Leave in the EU*. http://www.europarl.europa.eu/RegData/etudes/ATAG/2014/545695/EPRS_ATA%282014%29545695_REV1_EN.pdf

65 Powell, K. “Back to the bench.” *Nature*. 2011;474:115–117. <http://www.nature.com/naturejobs/science/articles/10.1038/nj7349-115a>

66 Kirkup, G., Zalevski, A., Maruyama, T., Batool, I. *Women and Men in Science, Engineering and Technology: the UK Statistics Guide 2010*. Bradford, UK: the UKRC; 2010. https://www.wisecampaign.org.uk/uploads/wise/files/archive/final_sept_15th_15.42_ukrc_statistics_guide_2010.pdf
Hill, C., Corbett, C., St. Rose, A. *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC: AAU; 2010. <https://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf>

Figure 1.4 — Scholarly output per researcher (among named and gendered author profiles), by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

■ Women ■ Men



As shown in *Figure 1.5*, we observe an increase in Field-Weighted Citation Impact (FWCI) for most comparator countries and regions between the two periods (1996–2001 and 2011–2015) for both women and men researchers. The exceptions are the United States and the United Kingdom, which both show a slight decrease in FWCI for women and a stable FWCI for men. The United States is also the only comparator with a higher FWCI for women than for men. For most comparators, the differences in FWCI in the same period for women and men among researchers are small. The most notable differences are seen in Brazil, Portugal, Mexico, and Chile, which all show higher FWCI values for men than for women among. Overall, we can say that, in the United States, the FWCI for women is higher than for men; in the United Kingdom and European Union, the FWCI is about equal for men and women. For all other comparators, the FWCI is slightly higher for men than for women, but the differences are small.

To examine scholarly impact, we use one of the most sophisticated indicators in the modern bibliometrics toolkit, the Field-Weighted Citation Impact (FWCI). FWCI is a publication-level indicator of mean citation impact that compares the actual number of citations received by a paper with the expected number of citations for papers of the same document type (article, review, or conference proceeding), publication year, and subject area. FWCI is thus a measure that normalizes for differences in citation activity by subject area, document type, and publication year, with reference to a global baseline of 1.00 (see glossary in *Appendix C* for a full definition).

Figure 1.5 — Field-Weighted Citation Impact by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

■ Women ■ Men



While citations are a widely-used proxy for scholarly impact, other use cases of research papers (e.g., by students, companies, medical practitioners, engineers, etc.) may not result in citations. Online usage can, however, give some insight into these more applied uses of research and therefore provide a proxy for impact. We count the number of downloads of a paper's PDF or the number of online views of the full-text of a paper on Elsevier's ScienceDirect platform. We then apply a similar normalization method as that used by the FWCI to the download/view counts to obtain an indicator called the Field-Weighted Download Impact (FWDI) (see glossary in *Appendix C* for more details).

Figure 1.6 shows that for most comparator countries and regions, in contrast to FWCI, FWDI values tend to be slightly higher for women than for men. Similar to FWCI, we do not observe drastic differences in FWDI between men and women, nor in trends over the two time periods.

Overall, a strong gender imbalance in scholarly impact does not emerge from our analysis of the citations or downloads of papers, with only a small advantage in FWCI to men and a small advantage in FDWI to women (but with little difference across comparator countries and regions or between time periods). In short, the present study offers no evidence that the inequalities in the representation of women researchers across countries and fields and in their scholarly output affect how their research is read or built on by others.

KEY FINDING

Among researchers, women tend to have a lower scholarly output overall than men, but women and men tend to have similar citation and download impacts.

Figure 1.6 — Field-Weighted Download Impact by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

■ Women ■ Men



1.3 Proportion of women and men among inventors and their patents

Research is crucial to innovation, which can be measured via the proxy of patents. Patents are exclusive rights granted for an invention. To be awarded a patent, information about the invention and inventors must be disclosed to the public in a patent application. To extract gender statistics from patent documents at the global level, the World Intellectual Property Organization (WIPO) developed a name dictionary to analyze approximately nine million inventors' and individual applicants' names recorded in international patent applications filed under the Patent Cooperation Treaty (PCT).⁶⁷ The name dictionary contains approximately 6.2 million names of inventors and applicants in 182 countries and economies. Using this dictionary, we can attribute gender to 96% of the names of individuals recorded in PCT applications. In our analysis, an inventor's country is understood as their country of residence and patent applications are attributed to the country of residence of the first applicant. (Please see *Appendix B* and WIPO's *Economic Research Working Paper No. 33*⁶⁸ for more details on the data sources and methodology.)

We find that, among inventors, women are generally underrepresented. However, the data also reveal that the global share of women named as inventors in PCT applications increases from 10% in 1996–2000 to 14% in 2011–2015. The percentage of patent applications that include at least one woman among inventors also increases, from 19% in 1996–2000 to 28% in 2011–2015.

We also find that the distribution of women among inventors named in patent applications is not equal across comparator countries and regions. *Figure 1.7* presents the share of women among inventors in PCT applications by country or region of residence. Again, Portugal stands out as having the highest participation of women (26%) among the comparators in 2011–2015. We also observe higher proportions of women among inventors in Brazil (19%), Chile (19%), Mexico (18%), and France (17%). On the contrary, Japan (8%), the United Kingdom (12%), and Australia (12%) have lower participation of women as inventors.

For all reported comparators, there is an improvement in gender balance between the analyzed periods. We observe the largest increase in the share of women among inventors for Portugal, Mexico, Brazil, and Chile, but these countries only have a few patent filings for the period of 1996–2000. In terms of volume, the United States and the European Union contribute the largest number of women inventors among the comparators, totaling 102,116 and 86,802 women inventors, respectively, in 2011–2015.

67 The Patent Cooperation Treaty (PCT) is an international treaty with more than 150 Contracting States. The PCT assists applicants in seeking patent protection internationally for their inventions, helps patent offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions. By filing one international patent application under the PCT, applicants can simultaneously seek protection in all contracting states.

68 Lax Martínez, G., Raffo, J., Saito, K. "Identifying the gender of PCT inventors." *WIPO Economics & Statistics Series*, No. 33. Geneva, Switzerland: WIPO; 2016.

Figure 1.7 — Proportion and number of inventors by gender (among named and gendered inventors) for each comparator, 1996–2000 vs. 2011–2015.

Source: WIPO Statistics Database, October 2016

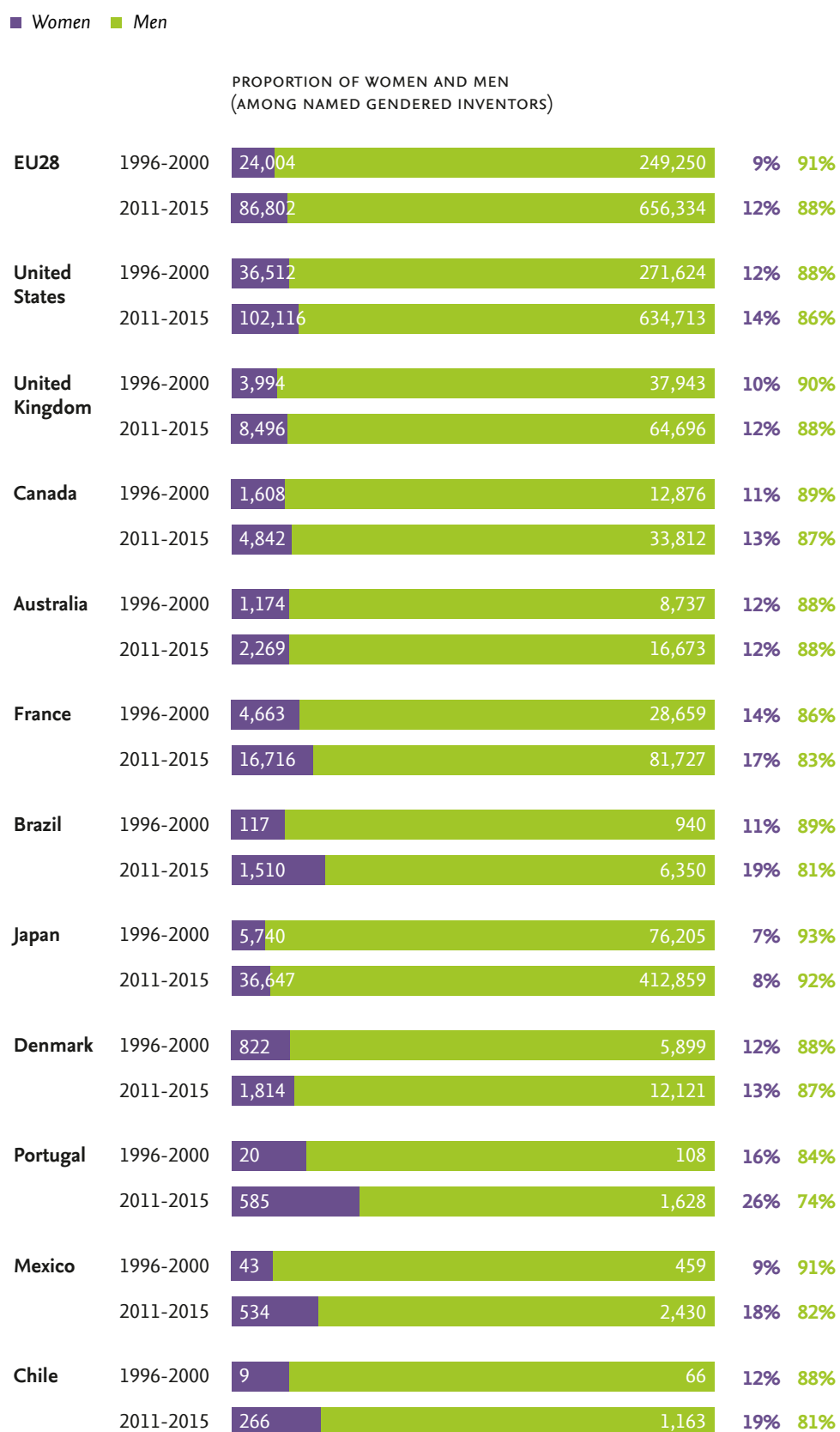


Figure 1.8 shows that the share of patent applications with at least one woman named among the inventors increases between the two periods for all comparator countries and regions, and particularly so for Brazil, Portugal, and Mexico, which all have a low number of patent applications in the earlier period. Furthermore, for most comparators with sufficient numbers of patents and inventors, the share of patents with at least one woman named among the inventors is higher than the share of women among inventors in the most recent period.

Previous research⁶⁸ also indicates that some fields of technology have seen more progress than others. In particular, fields related to the Life Sciences, such as biotechnology and pharmaceuticals, have a higher share of patent applications with at least one woman inventor. Similarly, participation of women inventors tends to be higher in the academic sector, which includes universities and public research organizations, than in the business sector. To a certain extent, the gender balance of inventors in a country depends on the country's technological specialization and share of patents from the academic sector.

These indicators also suggest women are less likely to file without inventors of the opposite gender than men. In 2011–2015, 15% of PCT applications with women named as inventors are filed by women only (up from 13% in 1996–2000), while more than three-quarters of those with men named as inventors are filed by men only (77%). In addition, women are more likely to file as part of larger groups of inventors – in 2015, the average filing group size is 4.8 for women and 4.2 for men. Women are also less likely to be the only inventor named in a patent (7% in 2015) compared to men (11%).

KEY FINDING

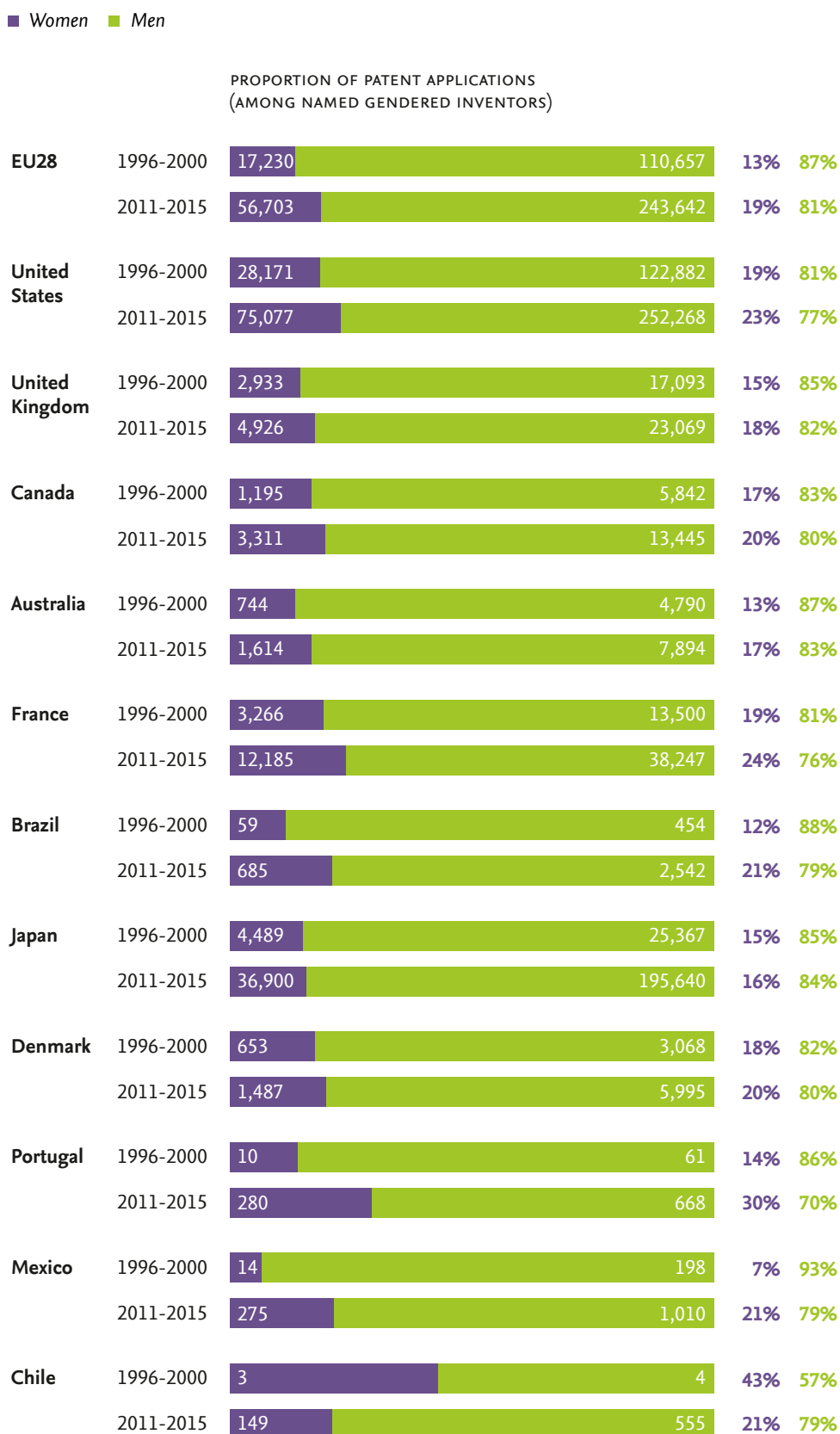
The proportion of women among inventors has increased over time in all selected comparator countries and regions.

KEY FINDING

The proportion of patents with at least one woman named as an inventor tends to be higher than the proportion of women among inventors.

68 Lax Martínez, G., Raffo, J., Saito, K. "Identifying the gender of PCT inventors." *WIPO Economics & Statistics Series*, No. 33. Geneva, Switzerland: WIPO; 2016.

Figure 1.8 — Proportion and number of patent applications with at least one woman or man named among the inventors (among named and gendered inventors), shown for each comparator, 1996–2000 vs. 2011–2015.
Source: WIPO Statistics Database, October 2016



INTERVIEW



Miyoko O. Watanabe

*Deputy Executive Director, Office for Diversity and Inclusion,
Japan Science and Technology Agency (JST), Japan*

What do you consider to be the greatest opportunities and challenges regarding diversity and gender equity in Japan and globally?

In Japan, the official act that secured equal opportunity and treatment between men and women with regard to employment was established in 1985⁶⁹ and was put into effect the following year—so 30 years ago. That was a starting point for us, in Japan. In 2016, “*The Act on Promotion of Women’s Participation and Advancement in the Workplace*” was fully enacted.⁷⁰ If we take into consideration that time gap, the young women who were hired by various companies and organizations 30 years ago are now in their 50s, and these women form the base of support for promoting female managers today.

Now is the perfect time for realizing gender equity in Japan. It would have been close to impossible to promote female managers 30 years ago because there were almost no women senior employees in universities and companies. Today it is more natural to see women represented in senior positions. Japan has worked actively to promote gender equality, for instance, with the establishment in 1999 of the “*Basic Act for Gender Equal Society*.”⁷¹ Given the Japanese ecosystem, it is now time to promote more female managers and younger scientists and engineers to higher-level positions in research.

Some people may not appreciate the value of women’s involvement in Japanese society. They may only be interested in the size of the labor force, because the Japanese labor force overall is decreasing. They are pushing for an increase in the labor force through new sources other than the male Japanese labor force; increasing the female labor force is seen as one solution. But we would like to move beyond numbers to show the qualitative value of women’s involvement in many fields in our society. This is one of our strong desires in Japan. If we look globally, Japanese women are doing better outside Japan than inside Japan in terms of the proportion of female specialists and managers. This is, in my opinion, a global challenge for women’s inclusion in the scientific workforce.

How important are data and the evidence base for policy makers and institutional leaders?

Traditionally, decision makers—the managers and senior managers—depended on their experience, their best guess and their nerve. They did not need any data and evidence because situations were simpler, and experience was the most important factor in their decision process and judgment. However, society has changed, and as situations become more complicated, we now need data and evidence to make informed decisions.

In the past, scientists may not have had to show the data and evidence to policy makers, but

now they do. Today, more decisions should be evidence-based and require access to scientific data. We cannot make decisions without data and evidence.

I would also like to point out that *data can be a new common language in the future*. There are so many languages—Japanese, English, French, and so many others—and it can be very difficult to communicate on a global scale, across languages, particularly when a situation is very complicated and the data are not so simple. If we analyze evidence through scientific data, it is much easier to understand each other. I think data is our new language.

What do you view as the key events of the past five to ten years that have had the most impact on advancing diversity and gender equity?

In Japan, a declining birth rate and a growing elderly population are key issues, along with the decreasing labor work force. We need a new type of labor force, one that fully includes women, to revitalize innovation. When we look at the world, globalization is another key factor that can help promote gender equality.

We should focus on building international communication and cooperation, and that is a common need around the world. For instance, in Japan, 76% of high school students who study abroad are girls, and 67% of the university students who go to other countries to study are girls. Even more compelling, according to the United Nations (UN), the proportion of Japanese women working in high-level positions at the UN is 60%, and 43% hold leading positions at the UN—the highest proportion of female leaders in the world. Japanese women are very good at global jobs and international jobs, so globalization is a very important key factor in promoting gender equality.

Public engagement with science is another factor. Science is becoming more and more complicated, and the relationship between science and society must be fully considered; these issues cannot be addressed only by men. Both men and women must think about this relationship, and the involvement of women is crucial.

What information in the present report do you find particularly interesting and important for policy makers and institutional leaders?

I am interested in highlighting four points.

- ▶ With regard to scholarly output per researcher, productivity was higher for women than men in Japan. This was specifically seen in Japan, and one explanation could be that women produce more papers than men because men tend to have an established senior network, in addition to their own research work, which women researchers do not have. Many decision makers are also men, so women must write more papers than men to succeed and advance in their research careers.

Another explanation could be that this is strongly related to work efficiency. Japanese men usually work longer hours than women, which is not so surprising, as women also deal with childcare and daily housekeeping, among other tasks. But while most men work many more hours, their productivity in terms of scholarly output was lower than that of women. To maintain a high productivity, female workers must work in a highly efficient manner; they have less time to accomplish the same tasks. So, the results showing that scholarly output in Japan is higher for women than men might be related to this fact. If more women join the scientific workforce and take diverse positions, I believe that Japanese productivity would be higher.

- ▶ The report also shows that women in Japan and several other countries were better than men at interdisciplinary research—this has been reported by others and is consistent with the data from the German Gender Research report.⁷² That result makes sense to me.

In my opinion, men prefer to focus on narrow research areas, whereas women prefer research that links more than one field. This is probably related to women being more inclined to think and work globally. Women are capable of working anywhere, and communicating with many people across broad fields of research. Interdisciplinary research is increasingly important nowadays, so women researchers should be admired for all of their achievements in this respect.

- ▶ With regard to the data on mobility of researchers in and out of Japan, I expect to see more women leaving Japan to work abroad, as the Japanese workplace is not as welcoming to women. As a result, many Japanese women prefer to leave Japan to work in other countries. It's actually quite difficult for women to get a good job in Japan, so female researchers tend to leave to work in other countries. It is very difficult for women to get a similar position in research in Japan as they would overseas, and this is a serious problem in Japan. We have to more actively involve women in research in Japan—we have not succeeded in keeping talented female researchers in Japan.
- ▶ Gender research has changed quite a bit over the years. For example, the concept of gendered innovations, achieved by promoting scientific research with gender analysis and considering gender as a key factor in science and engineering, is a very new concept. Most gender research in the past focused on women's participation in terms of social science, which is different from gender research as a natural science. We are very interested in this "new" gender research, but it is not as popular in Japan yet. We would definitely like to make this new gender research as popular in Japan as it is now in the United States.

Are there any connections you can make between the report data and the policies, practices, or scientific culture of a particular country or Japan?

I am working with my team, very actively, on the upcoming Tokyo Gender Summit, not only to plan the meeting but also to create a new movement in Asia, starting with Japan. We have seven working groups in which we have gathered about 100 people from Japan, from about 50 organizations including companies, national research institutes, and universities that have provided their endorsement ahead of the summit. We also aim to expand our associates and sponsors, and I am hoping to reach out to more than 50 organizations as associates and sponsors of the Summit.

We have gathered a network of colleagues in the Asia-Pacific region and we are planning on submitting a proposal to the United Nations regarding their Sustainable Development Goals (SDGs).⁷³ Gender Equality is the 5th goal of the 17 SDGs, but gender issues are also scattered throughout 10 of the other 16 SDGs. For example, SDGs related to poverty, quality education, clean water, and good health include a component related to gender equality. We are aiming to connect those SDGs that have gender perspectives. This activity will start in Japan but must expand to the rest of the world, and continue after the Tokyo Gender Summit. We are already getting a lot of support for this movement.

Thinking about the future of diversity and gender equity globally, where do you think we will be in 5-10 years' time?

The push for gender equality in Japan is timely. First, globalization is needed in our modern economy, which cannot grow further without it. We are at a turning point, I think. Second, we also have a generation gap in Japan,⁷⁴ where senior positions are dominantly held by men. If we look at younger workers, most of our active leaders are women. This new generation gap is between senior male leaders and younger female leaders. This gap is huge. We have to change this structure by increasing the number of senior female leaders as well as young male leaders, otherwise this situation will continue.

Another issue is connecting the various problems in the workforce; as I said before, gender equality can be an adhesive that connects many issues. Japanese people are usually good at providing solutions for segmented issues. What is needed now is integration among each issue and its solutions, and connectivity between the many gender-related issues.

So, if we promote true gender equality, meaning inclusion on an equal basis in terms of both quality and quantity of gender equality, our life will be brighter and many more young men and women will have jobs with opportunities for advancement, while raising children and attaining a better work-life balance. Unfortunately, achieving gender equality has not been easy in Japan, and maybe that is also true in other places in the world. All people should be concerned about making this decisive change towards a new society.

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- 70 *The Act on Promotion of Women's Participation and Advancement in the Workplace*. 2016. http://www.gender.go.jp/english_contents/pr_act/pub/pamphlet/women-and-men16/pdf/2-3.pdf
- 71 *The Basic Act for Gender Equal Society*. 1999. http://www.gender.go.jp/english_contents/pr_act/pub/pamphlet/women-and-men16/pdf/2-2.pdf
- 72 Elsevier, *Mapping Gender in the German Research Arena*, 2015.
- 73 United Nations. *Sustainable Development Goals*. 2016. <http://www.un.org/sustainabledevelopment/sustainable-development-goals>
- 74 For further reading, see "Japan: Women in the workforce." *Financial Times*. (2015). <https://www.ft.com/content/60729d68-20bb-11e5-aa5a-398b2169cf79>

INTERVIEW



James Stirling

Provost, Imperial College, United Kingdom

What do you consider to be the greatest opportunities and challenges regarding diversity and gender equity in the United Kingdom and globally?

We face two main challenges at Imperial College. First, we don't have enough women students coming into our STEM programmes. At the student level, only 35% of our incoming undergraduates are women. Second, for those who do enter into STEM and pursue academic careers, we still aren't supporting them adequately enough throughout their careers. When we track the percentage of women at various career stages, from undergraduate through postgraduate, postdoc, lecturer, senior lecturer, reader, and professor levels, we can clearly see the "leaky pipeline" in action—the proportion of women decreases at each career stage. At the professor level, the percentage of women has fallen to just 15%. So, it's really a two-fold problem we're facing: not enough women are coming in to STEM subjects and when they do come in they're not reaching the highest ranks in the profession.

But the situation is by no means hopeless, and in fact, I think there is a lot more we could and should do. But we must first ask ourselves: why would we want to do this? Why is it important that we have more women in STEM? To me the answer is quite simple: with this level of gender imbalance, we are not properly exploiting the UK scientific talent base. If we want more high-quality scientists, I am absolutely convinced that we will find them amongst the female population, and that is why encouraging more young women into STEM and supporting them properly is so vitally important. How do we do it? One thing I have learned from being involved in this for many years is that there is no single "magic bullet," no one simple solution that we can pull out of a hat and then suddenly everything is solved. Rather, there are lots of small things we can do, that taken together will ultimately help us achieve our goals.

In looking for reasons why there are not enough women getting into STEM in the first place, one should go right back to when very young children start playing with toys that have implicit, built-in gender bias. We recently did something interesting to address this—some of my Imperial colleagues started a science toy awards competition where awards are given to manufacturers that produce toys that are both scientifically interesting and gender neutral. I believe that gender bias towards or against STEM really does start in young children, and programmes like the science toy awards can make a difference. It is also unfortunately very easy for these initial gender biases to be reinforced and amplified as children progress through primary and secondary schools. Our target should be to have women representing 50% of undergraduates who enter into STEM programmes at our universities. It can be done: countries like Malaysia have achieved gender balance in students in science programmes, and in the UK in recent years, there have been more women joining medical schools than men. So, getting to that 50% in STEM—that's the first part of the solution.

The second part is improved career support and development for women already in STEM. In my experience, men and women do approach their career development differently. For example, men are more likely to apply for jobs for which they are not obviously qualified, adopting a “scattershot” approach to job applications. Women tend to be more thoughtful and careful about the jobs for which they apply. Then there are all the issues around career breaks and work-life balance: maternity support, returning to work, childcare responsibilities, and so on. Again, there is no single magic bullet, just many things we can and should do to support women as they develop their careers. That’s the journey we’re on at Imperial College.

I would love to get to the point one day when gender inequality in STEM is no longer an issue in the UK, but we’re still pretty far from that point. In the meantime, we can learn a lot from other countries. Your data show very clearly that there are countries that have either better or worse gender balances in their STEM research workforces compared to the UK. In Europe, Portugal and some of the Mediterranean countries like Greece and Italy have a better gender balance, whereas in other countries the situation is worse than it is here in the UK. I would like to see more dialogue between different countries on this issue, since ultimately it is a global problem.

What do you view as the key events of the past 5-10 years that have had the most impact on advancing diversity and gender equity?

In the context of STEM and particularly universities involved in STEM research and education, the introduction of the Athena SWAN Charter and awards programme has had an incredibly positive impact. I am aware that Athena SWAN has been criticized as being little more than a “tick-box exercise,” but having worked intimately with the programme over many years, I would strongly refute that – I am a huge fan of Athena SWAN.

First of all, it not only focused attention on the problem of gender inequality in STEM subjects in universities, but encouraged a methodological, scientific approach to addressing it. Certainly, in the universities that I have worked in, I would attribute most of the advances that we’ve made in gender equality to involvement in Athena SWAN. One very positive feature about Athena SWAN is that you can never rest on your laurels—you have to demonstrate progress against an action plan just to maintain an award at a particular level. And the bar for achieving a gold award is extraordinarily high. Very few university departments have an award at that level—we have one so far at Imperial.

Alongside programmes like Athena SWAN, there has been another significant development: an increased awareness of unconscious bias. Nowadays, we put a lot of effort into unconscious gender bias training, at all levels of the organization, and yet I’m still surprised at how many men are skeptical about such programs and would swear that they don’t have a biased bone in their body! But in my experience, after they have been through the training, many of them will admit that in fact they could in certain circumstances be biased against women without even realizing it. All of these efforts to combat unconscious bias are directly relevant to the selection and promotion of women in STEM, to make sure that the way we recruit, promote, and develop our staff is completely gender neutral.

Two more things come to mind. This discussion has so far been about gender, but your question was about diversity as well. Unfortunately, I don’t have much to say about diversity. I say “unfortunately” because I think there is still a lot of work to do around diversity more generally, in building a community that is fully representative in terms of ethnic minorities and other underrepresented groups. That’s why I am supportive of broadening the Athena SWAN charter to embrace diversity in the more general sense. It’s certainly very high on our agenda here at Imperial.


What information in the present report do you find particularly interesting and important for policy makers and institutional leaders?

First, I think the primary value of the data is that it enables us to benchmark ourselves, not only with other UK institutions, but also, and just as importantly, with other comparable international institutions. The data are particularly interesting because while we generally have our own internal key performance indicators and targets, it's important to know how we compare with other institutions; to see to what extent we're ahead of, or in some cases lagging behind, other institutions. Second, when I read through the report, there were several sets of data that I found particularly interesting because they were providing quantitative confirmation of my perception of the issues; for example, the imbalance in the proportion of female authors and subjects was consistent with my own understanding. Then again, where the data showed no gender differences, for example for citations per author, this is something I would have expected to see, and in fact to me it demonstrates the reliability of the analysis. Other data sets for which there were gender differences, for example the number of outputs per author, made me want to explore further to understand the underlying reasons.

Recently, we were sent data by the Research Councils UK on the success rates of applications for research grants by gender. While the aggregated data did suggest an interesting—and worrying—headline, that women were apparently less successful at applying for research grants than men, they also triggered a lot of work to analyse the data in more detail to try to understand the contributing factors. The conclusion of this work was that the headline conclusion was in fact misleading; the reality is more subtle than that. The analysis revealed that success rate for grant applications varies according to “career age,” with more senior researchers tending to be more successful. Since there are fewer women at the top of the career ladder—the “leaky pipeline” concept—this may well be the explanation for the gender differences that were seen in the aggregate figures. In fact, our work showed that when researchers at the same career stage are compared, there is no difference in grant success rates between men and women. This illustrates the importance of drilling down to establish what other factors may be responsible for apparent gender differences.

Can you describe what the impact of gender inequality on research is globally?

I think that, in a way, we are disenfranchising a major component of the global population. The evidence clearly shows that there is absolutely no difference between the quality of research performed by men and women scientists. So, it stands to reason that if we want to increase the quality of science globally, we need to have more women involved in STEM research. It is as simple as that. I would even go further and say that we're not trying to pretend that men and women are equal in all respects; in fact, I think that the subtle differences in perspectives, attitudes, and attributes that men and women bring to research make the overall research enterprise stronger. Much scientific research nowadays is done in teams and, in my experience; the most effective teams are those with a good gender balance. The large experimental collaborations working at the CERN Large Hadron Collider are good examples of this.



CHAPTER 2
Gender and research
leadership, collaboration,
interdisciplinarity,
and mobility

Key Findings

In Engineering, men tend to appear as first or corresponding authors on a larger proportion of their scholarly output than women. In Nursing, the reverse is true for most comparators.

SECTION 2.1

Women are less likely than men to collaborate internationally on research papers.

SECTION 2.2

Women are slightly less likely than men to collaborate across the academic and corporate sectors on research papers.

SECTION 2.3

In general, highly interdisciplinary research represents a slightly larger share of women's scholarly output than men's.

SECTION 2.4

Among researchers, women are generally less internationally mobile than men.

SECTION 2.5

2.1 First and corresponding authorship

Earning credit for scientific research is important to researchers for academic, social, and financial reasons. With levels of co-authorship on the rise,⁷⁵ there is greater discussion around how credit for a paper should be shared among authors and even more deliberation on how authorship should be presented on a paper to ensure credit is attributed correctly.⁷⁶ Several leading societies address this issue for their field of interest by offering guidance on author sequence in the bylines of research papers. For example, the American Mathematical Society (founded in 1888 and with 30,000 individual members) has stated that “joint research is a sharing of ideas and skills that cannot be attributed to the individuals separately,”⁷⁷ and mathematicians typically list authors alphabetically on their papers. However, in many other fields it is common to list the most senior author in either the first or last position. If a researcher is listed as a first/last or corresponding author on a paper, it is likely that his or her role was central to the research project in terms of contribution.

Because author order convention differs by field, we focus on two fields in which the first or corresponding author position may be reliably associated with contribution level: Engineering and Nursing. The Institute of Electrical and Electronics Engineers (IEEE) is the world’s largest technical professional organization with over 420,000 members. Their author guidelines⁷⁸ state that “typically, the first author listed is the person who has taken the most responsibility for the work... Sometimes, the senior author

is the head of department and is listed last.” In Nursing, the journal *Applied Nursing Research* guidelines state that “Within nursing... the individual who has made the most significant contribution to the research is listed as the first author.”⁷⁹ Although the level to which these rules are applied may vary, we can analyze one aspect of leadership by identifying papers on which researchers are first and/or corresponding authors, and compare the breakdown by gender.⁸⁰

Engineering is a field of science where women researchers are generally significantly outnumbered by men researchers. In our analysis, women represent no more than 35% of researchers in any of the twelve comparator countries or regions in 2011–2015 (see *Section 1.1*). The present analysis shows that when men appear as authors in Engineering papers, they are more likely to take the first or corresponding author position than when women publish in the same field (see *Figure 2.1*). The gender difference is most pronounced in Japan, where the share of men taking a first or corresponding author position on their papers is 34 percentage points higher than that of women researchers. Notably, Japan also has the lowest proportion of women among researchers in Engineering (10% in 2011–2015, see *Figure 1.3*) of all twelve comparator countries and regions. The gender difference in first/corresponding authorship in Engineering is least pronounced in Australia, Denmark, and Portugal, each with only nine percentage points between women and men.

“ The report is a fascinating use of Scopus bibliometric data to uncover differences between men and women who publish scientific articles. The report’s deep dive into gender differences includes detailed analyses in several areas: leadership as first or corresponding author; mobility, which is associated with differences in citations; and extent of interdisciplinary collaborations. The gender contrast in leadership roles between engineering, a field where men comprise the majority of researchers, and nursing, a field in which women comprise the majority, suggests the value of further pursuing the causal links between gender preponderance within a particular field and the activity of researchers by gender in that field.

— **Richard B. Freeman**, Herbert Ascherman Professor of Economics; and Co-Director, Labor and Worklife Program at Harvard Law School, Harvard University, United States

75 Plume, A., van Weijen, D. “Publish or perish? The rise of the fractional author.” *Research Trends*. 2014;38(Sept). <http://www.researchtrends.com/issue-38-september-2014/publish-or-perish-the-rise-of-the-fractional-author>

76 Casrai. CRediT Program Committee. <http://casrai.org/credit>

77 American Mathematical Society. *The Culture of Research and Scholarship in Mathematics: Joint Research and Its Publication*. 2004. <http://www.ams.org/profession/leaders/culture/CultureStatement04.pdf>

78 IEEE. *How to Write for Technical Periodicals & Conferences*.

http://www.ieee.org/publications_standards/publications/authors/author_guide_interactive.pdf

79 Fitzpatrick, J.J. Authorship guidelines for *Applied Nursing Research*. *Appl Nurs Res*. 2005;18(3):129. doi:10.1016/j.apnr.2005.04.002

80 We are not able to include last authorship in our analysis due to technical limitations.

Figure 2.1 — Share of total scholarly output in Engineering in which the author byline includes at least one woman and a woman is first and/or corresponding author or the author byline includes at least one man and a man is first and/or corresponding author, shown for each comparator, 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

■ Women ■ Men

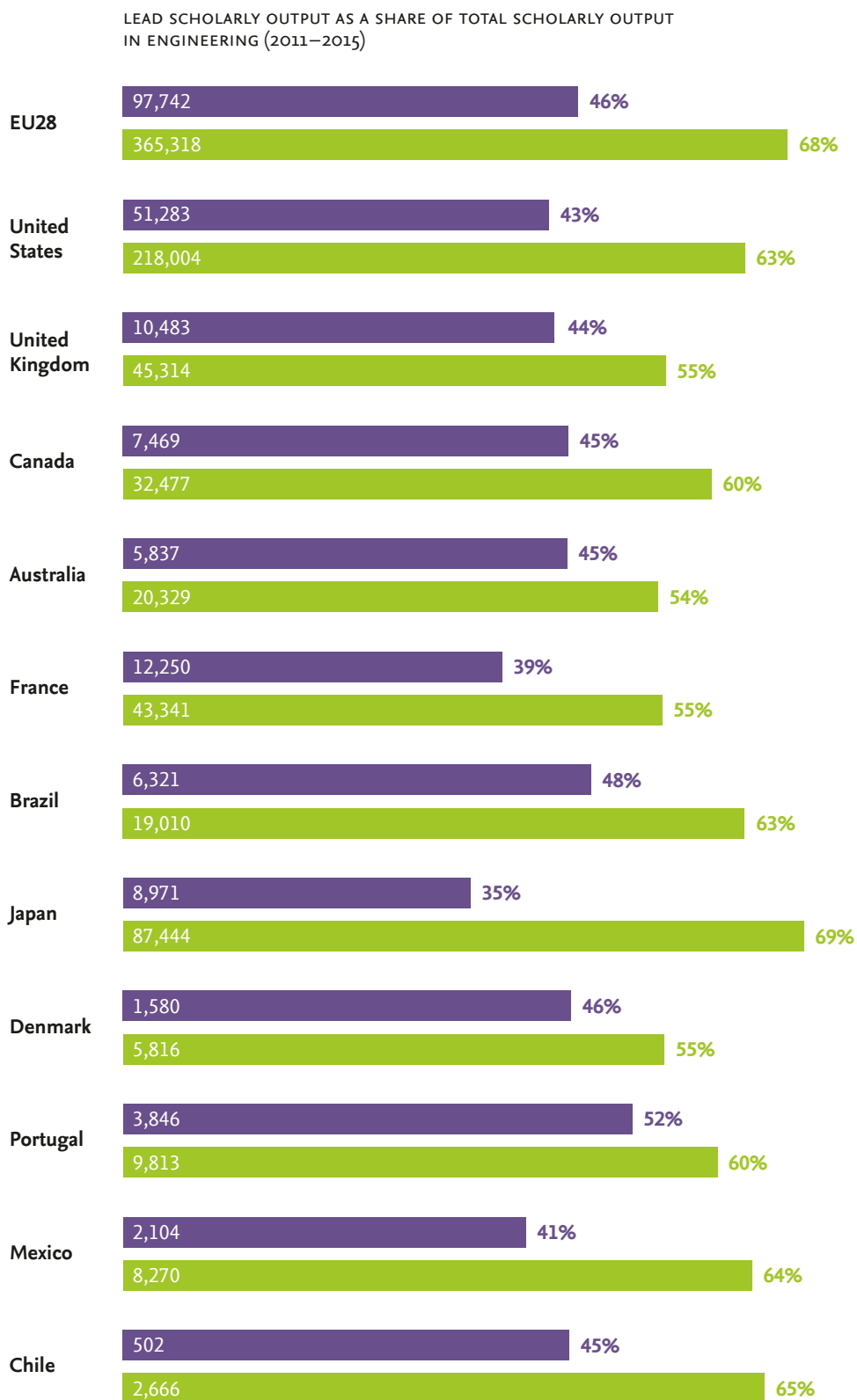
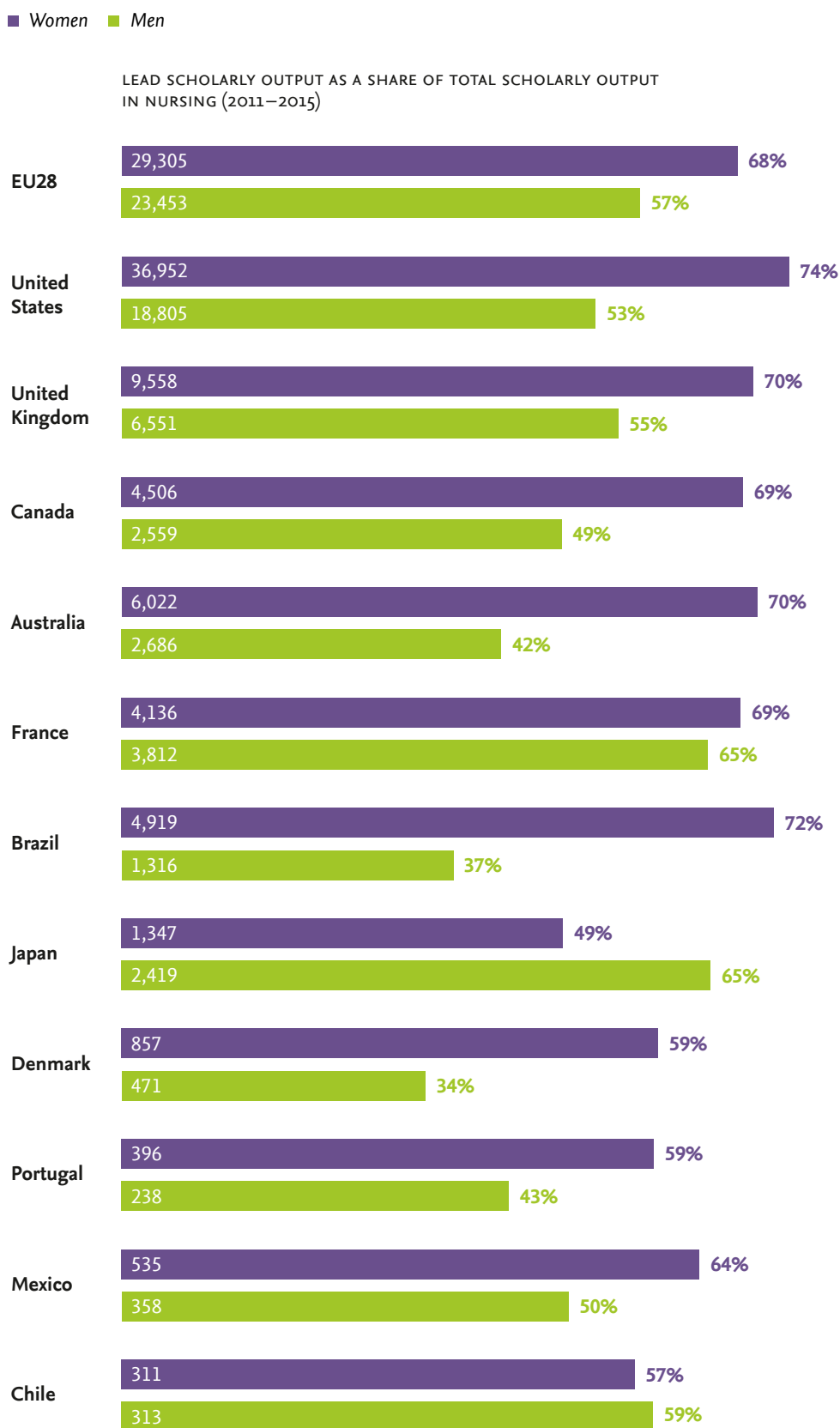


Figure 2.2 — Share of total scholarly output in Nursing in which the author byline includes at least one woman and a woman is first and/or corresponding author or the author byline includes at least one man and a man is first and/or corresponding author, shown for each comparator, 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia



In terms of representation of women among researchers, the Nursing field is very different from Engineering. In most of the twelve comparator countries and regions, women represent more than half of Nursing researchers, and up to 73% in Brazil, though most comparators are between 50% and 65%. Japan is the exception, with only 31% of women among researchers in Nursing (see *Section 1.1*). As such, we expected to see the opposite trends with regard to first and corresponding authorship in Nursing to what is seen in Engineering. Indeed, in all regions except Japan and Chile, women are more likely to take the first or corresponding author position on their Nursing papers than men are on theirs (see *Figure 2.2*). Chile is therefore an exception to the general trend that women are more likely to take the lead position on a paper if they are better represented in a field overall.

Despite the fact that women are less likely than men to appear as first or corresponding author on Engineering papers, the results show that women are relatively overrepresented in the first or corresponding author position in Engineering: that is, the share of papers on which women are lead author is greater than the share of women among researchers in the field. Nursing, which is generally a more gender-balanced field in terms of researchers (following the guide that 40-60% of women in a group means it is a gender-balanced group), has less overrepresentation of women researchers than the overrepresentation of men researchers in Engineering. As such, the results for first/corresponding author in Nursing are much closer to expectations: the shares of women among researchers in Nursing and the shares of women in first or corresponding authorship positions are very similar for most of the twelve comparator countries and regions. In further support of this finding, in Japan, where the proportion of women among researchers in Nursing is lower than other comparators, women again have a relatively high share of first or corresponding author positions (49%).

Research has shown that gender does have an influence on tasks associated with authorship: women are more likely to perform experiments than men, who tend to have other roles⁸¹. Our results may suggest that women's contribution to the creation and publication of research results is high, even in fields in which they are underrepresented. The analysis presented here highlights that women in Engineering, where they are greatly outnumbered by men, are less likely to be in the first or corresponding author position on their papers than men are on theirs. The pattern observed in Engineering and Nursing is that underrepresentation overall in a field is

As with other analyses in this report, the results between 1996–2000 and 2011–2015 have been compared; however, for most comparator countries and regions, there is a decline in first/corresponding author scholarly output as share of total scholarly output from the earlier to the later period. This general trend is probably primarily caused by an increase in the number of authors per paper, which means that authors are more likely to be first or corresponding authors on earlier than on later papers. Because this can obscure other observations, the 1996–2000 data have been removed from the charts and excluded from the analysis.

associated with reduced likelihood to occupy lead author positions in a research paper. However, in Engineering, despite their low representation in the field, women hold a fairly high share of first/corresponding authorships in this field.

Further research into first and last author position, traditionally held by the most senior researcher, is needed to better understand the dynamics of contribution and leadership by gender.

KEY FINDING

In Engineering, men appear as first or corresponding authors on a larger proportion of their scholarly output than women for all comparator countries and regions. In Nursing, the reverse is true for most comparators.

81 Macaluso, B., Larivière, V., Sugimoto, T., Sugimoto, C.R. "Is Science Built on the Shoulders of Women? A Study of Gender Differences in Contributorship." *Academic Medicine*. 2016;91(8):1136-1142. doi: 10.1097/ACM.0000000000001261

2.2 International collaboration

In many fields, collaboration is as essential to research as developing and testing hypotheses and publishing findings.⁸² It enables innovation⁸³ and facilitates the exchange of ideas, and tends to result in higher impact research than that which did not include some form of collaboration. This is particularly the case for international collaboration.^{84, 85} Collaboration between researchers broadens networks and facilitates the exchange of ideas. Therefore, if women collaborate internationally to a lesser extent than men or if women have a greater presence in fields with lower levels of international collaboration, this may have implications for the citation impact of their scholarly output.

Our analysis clearly shows that women collaborate less than men at an international level (see *Figure 2.3*). This is the case for all twelve comparator countries and regions examined, with men's share of scholarly output reflecting higher proportions of international collaboration. This is most extreme in Chile (46% for women; 56% for men), although the differences are quite similar across the 12 comparator countries and regions: for the European Union, Japan, and Portugal, the difference is only 4%. This did not change notably between 1996–2000 and 2011–2015, despite an overall increase in international collaboration for both men and women in line with global patterns⁸⁶ for all comparators except Brazil. There is also variation in the levels of international collaboration across comparators. Japan has relatively low shares of papers reflecting international collaboration for both men and women (18% for women; 22% for men); in contrast, the United Kingdom (43% for women; 49% for men), Denmark (48% for women; 55% for men), and Chile (46% for women; 56% for men) have relatively high rates of international collaboration.

Co-authorship of research papers between researchers based in different countries is widely used as a proxy for collaboration, and international collaborations can be assessed by taking into account the countries listed in the authors' affiliations in each published paper. In this analysis, whole rather than fractional counting is applied, which means that a paper written by authors with affiliations in several countries is counted once in each country's total, but deduplicated at aggregated levels (for example, across the European Union). In our analysis, international collaboration for the European Union means collaboration between one or more researcher(s) with a European Union affiliation co-authoring with one or more researcher(s) outside the European Union.

82 Prathap, G. "Second order indicators for evaluating international scientific collaboration" *Scientometrics*, 2013;95(2):563-570. doi:10.1007/s11192-012-0804-8.

83 Nielsen. *How Collaboration Drives Innovation Success*. 2015.

<http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2015-reports/how-collaboration-drives-innovation-success-march-2015.pdf>

84 Franceschet, M., Costantini, A., "The effect of scholar collaboration on impact and quality of academic papers". *J Informetrics*. 2010;4(4):540-553. doi:10.1016/j.joi.2010.06.003.

85 Elsevier. *Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility*. <https://www.elsevier.com/research-intelligence/research-initiatives/science-europe>

86 Adams, J. "Collaborations: The fourth age of research." *Nature*. 2013;497(7451): 557-560. doi:10.1038/497557a.

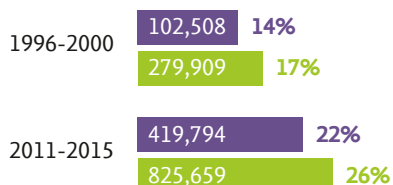
Figure 2.3 — Scholarly output resulting from international collaboration as share of total scholarly output by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

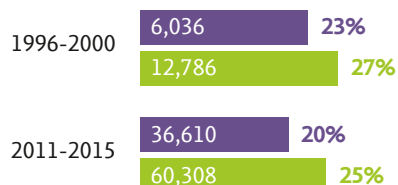
■ Women ■ Men

SCHOLARLY OUTPUT RESULTING FROM INTERNATIONAL COLLABORATION AS A SHARE OF TOTAL SCHOLARLY OUTPUT

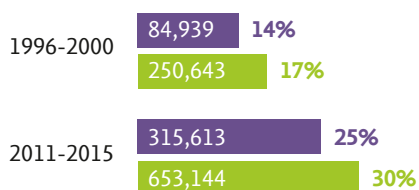
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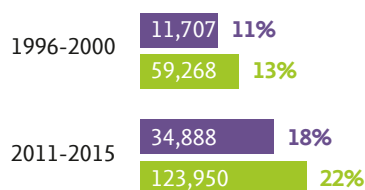
Brazil



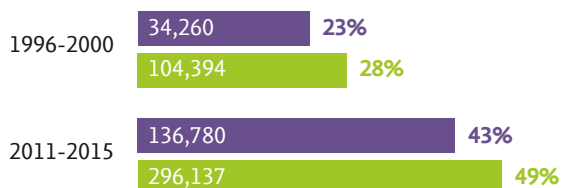
United States



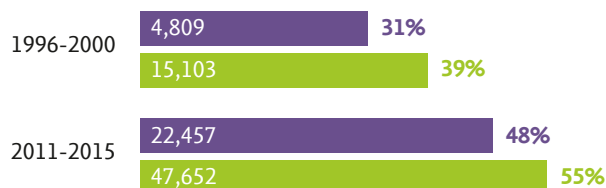
Japan



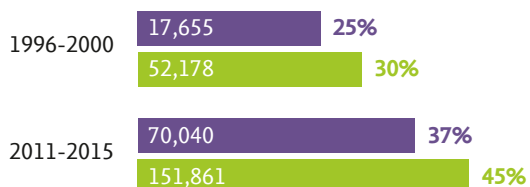
United Kingdom



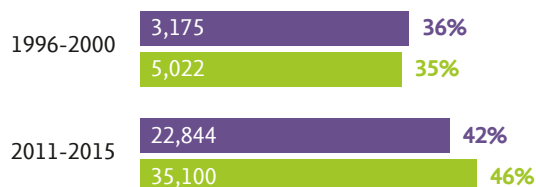
Denmark



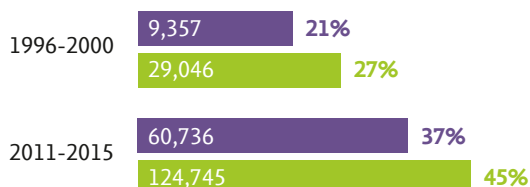
Canada



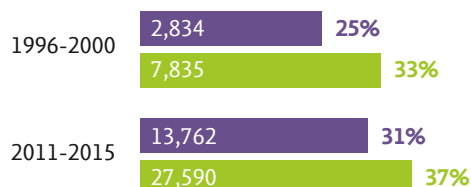
Portugal



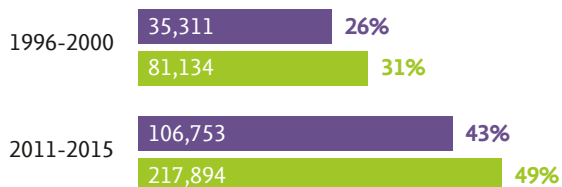
Australia



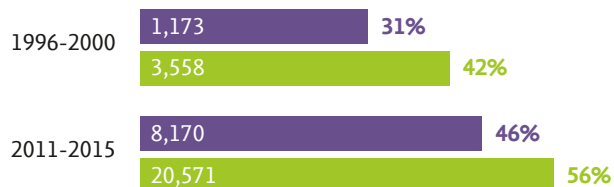
Mexico



France



Chile



In Chapter 1, we report that women publish fewer papers than men but there is no notable difference in the impact of women's and men's research. Similarly, despite women exhibiting lower rates of international collaboration, we do not observe a detrimental effect on their research in terms of how it is cited or how much it is downloaded. Given our understanding of the effect of international collaboration on citation impact in particular, this is an unexpected finding. More research is therefore needed to understand these observations and their relationship(s). Research has also found another apparent contradiction to our findings: women are attracted to collaboration, more so than men.⁸⁷ Our findings therefore arguably add weight to the concept of a "glass fence" around women: a barrier that prevents women from engaging in international collaboration. Though having children has been found to negatively affect women researchers' ability to collaborate, having a partner with a full-time job matters more.⁸⁸ Further, as bias remains in the funding review process,⁸⁹ it may be that less success in receiving funding has a detrimental effect on women's opportunities to collaborate.

KEY FINDING

Women are less likely than men to collaborate internationally on research papers.

87 Kuhn, P.J., Villeval, M.-C. "Are women more attracted to cooperation than men?" *National Bureau of Economic Research Working Paper No. 19277*; 2013. <http://www.nber.org/papers/w19277>

88 Uhly, K.M., Visser, L.M., Zippel, K.S. "Gendered patterns in international research collaborations in academia." *Studies in Higher Education*. 2015;1-23. doi:10.1080/03075079.2015.1072151.

89 Kaatz, A., Lee, Y.-G., Potvien, A., et al. "Analysis of NIH R01 application critiques, impact and criteria scores: Does the sex of the principal investigator make a difference?" *Acad Med*. 2016;91(8):1080-1088. doi:10.1097/ACM.0000000000001272.

2.3 Academic-corporate collaboration

Scholarly output that reflects collaborative work between sectors can spur innovation and tends to have higher citation impact than that which does not.⁹⁰ If women collaborate across the academic and corporate sectors to a lesser extent than men, due to their field specialization or other factors, it may have implications for the impact of their scholarly output.

The pattern of academic-corporate collaboration is similar to the international collaboration pattern in that men consistently collaborate more than women across sectors, although the differences between genders are very small. *Figure 2.4* shows that there is variation in cross-sector collaboration percentage between comparator countries and regions, ranging from about 1% to 8% in the 2011–2015 period. For all comparators in both periods, the proportion of scholarly output resulting from academic-corporate collaboration is slightly lower for women than for men. For most comparators (the United Kingdom, Australia, France, Brazil, Denmark, Portugal, and Chile), the proportion of cross-sector collaboration increases between periods for both men and women. In the European Union, it increases only for men, in Mexico, it increases only for women, and in the rest (the United States, Canada, and Japan) it decreases for both genders.

KEY FINDING

Women are slightly less likely than men to collaborate across the academic and corporate sectors on research papers.

We capture the affiliation sector type (corporate or academic) of authors on published papers and use this as a measure of academic-corporate collaboration—a widely used proxy for this indicator (see *Appendix B*). We use whole rather than fractional counting, which means that a paper produced in collaboration between authors in different sector types is counted once in each sector's total, but is deduplicated at aggregated levels.

⁹⁰ Elsevier. *International Comparative study of the Netherlands' Research Performance in the Top Sectors - 2014*. <https://www.elsevier.com/research-intelligence/resource-library/international-comparative-study-of-the-netherlands-research-performance-in-the-top-sectors>

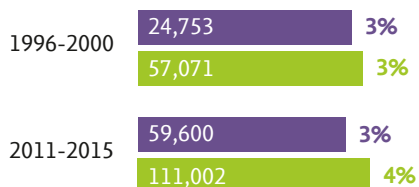
Figure 2.4 — Scholarly output resulting from academic-corporate collaboration as share of total scholarly output by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

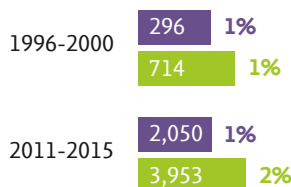
■ Women ■ Men

SCHOLARLY OUTPUT RESULTING FROM ACADEMIC-CORPORATE COLLABORATION AS A SHARE OF TOTAL SCHOLARLY OUTPUT

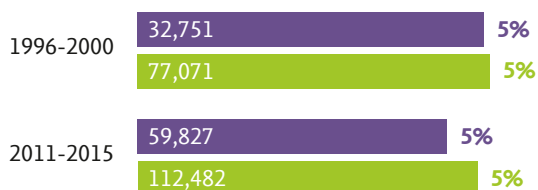
EU28



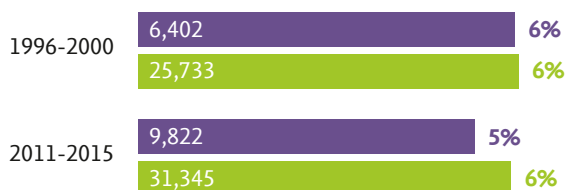
Brazil



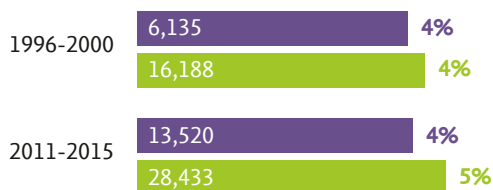
United States



Japan



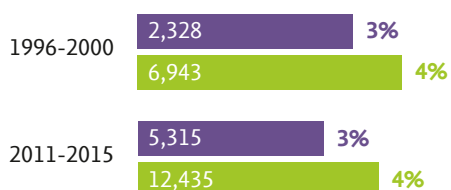
United Kingdom



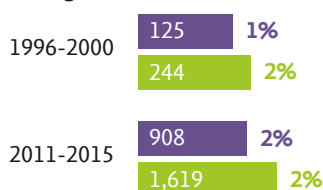
Denmark



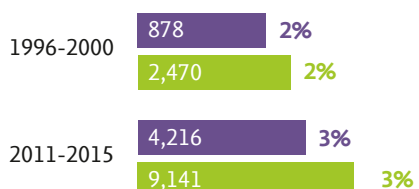
Canada



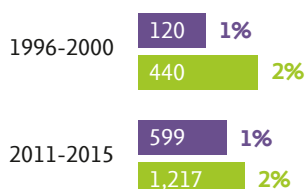
Portugal



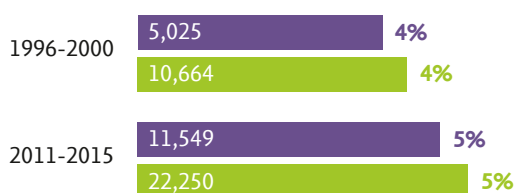
Australia



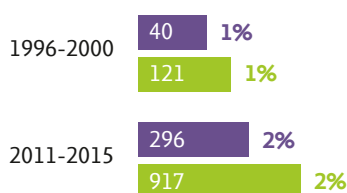
Mexico



France



Chile



2.4 Interdisciplinary research

Some research questions may require approaches that span across disciplinary boundaries, and interdisciplinary research has been encouraged in many countries. Interdisciplinary scholarly output does however tend to have lower citation impact than disciplinary output.⁹¹ If women are less likely than men to engage in research that is more interdisciplinary, it may have implications for the citation impact of their scholarly output.

Figure 2.5 shows that there is little variation in the proportion of interdisciplinary papers across comparator countries and regions, ranging from about 6% to 10% in the 2011–2015 period. The differences across gender are also somewhat limited; however, for most comparators, women tend to have a slightly higher share than men of the top 10% of interdisciplinary scholarly output relative to their total scholarly output. In most comparators, the proportion decreases for women (except in the United States, Brazil, Portugal, and Mexico) and increases for men (except in France, Japan, Denmark, and Chile) between 1996–2000 and 2011–2015.

We use a citation-based approach to measure the interdisciplinarity of published papers. The basic principle behind this approach is that, if a paper cites others that are “far away” from it in terms of their position in the overall citation network, the paper is likely to be drawing on diverse disciplinary sources and so reflects some level of interdisciplinarity. We use this methodology to assign an interdisciplinary score to each paper, and then focus on the 10% of papers with the highest interdisciplinary scores.

KEY FINDING

In general, highly interdisciplinary research represents a slightly larger share of women’s scholarly output than of men’s.

“ The Athena SWAN program has had a big impact and encouraged everyone in research to think hard about gender inequality and the dominance of particular groups in their fields. We still need more research and a better understanding of all the subtle ways that gender is “done” in academia. This work by Elsevier gives an incredibly useful picture of regional differences and trends across disciplinary fields that will provide very valuable material for improving outcomes further.

— **Fiona Jenkins**, Associate Professor, School of Philosophy; Convenor (2013–2015), ANU Gender Institute, Australian National University (ANU), Australia

⁹¹ Elsevier. *A Review of the UK’s Interdisciplinary Research using a Citation-based Approach*. <https://www.elsevier.com/research-intelligence/research-initiatives/uk-interdisciplinary-research>

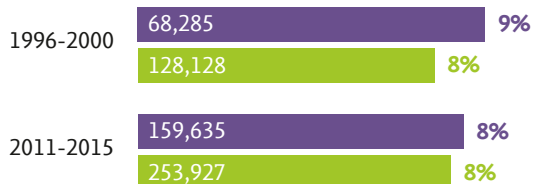
Figure 2.5 — Top 10% of interdisciplinary scholarly output as share of total scholarly output by gender for each comparator, 1996–2000 vs. 2011–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

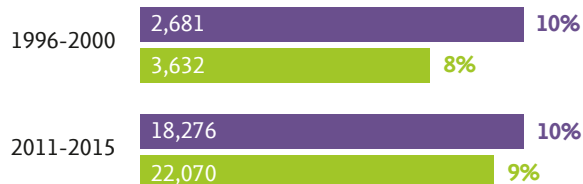
■ Women ■ Men

TOP 10% INTERDISCIPLINARY SCHOLARLY OUTPUT AS A SHARE OF TOTAL SCHOLARLY OUTPUT

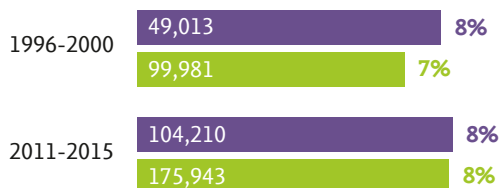
EU28



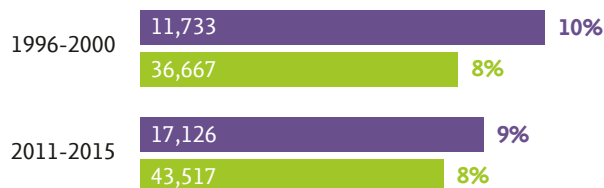
Brazil



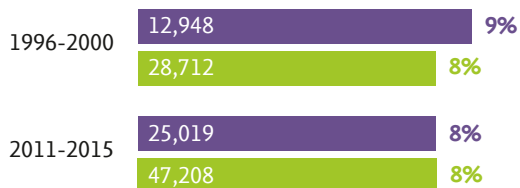
United States



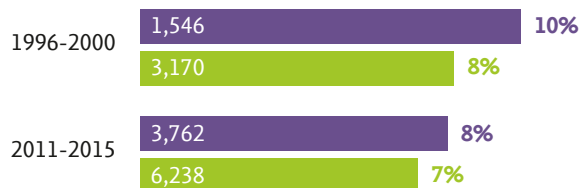
Japan



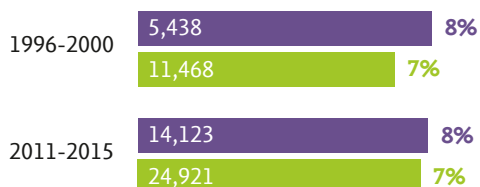
United Kingdom



Denmark



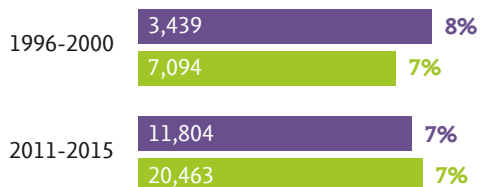
Canada



Portugal



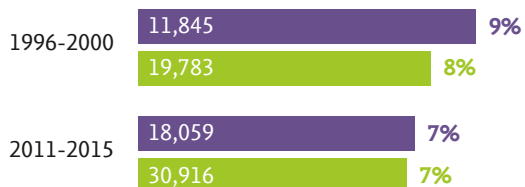
Australia



Mexico



France



Chile



2.5 International mobility

Internationally mobile researchers tend to have higher citation impact than those who are not.⁹² If women are less mobile than men, it may have implications for the impact of their scholarly output.

Figures 2.6, 2.7, 2.8, and 2.9 present mobility analyses for the United Kingdom, Canada, Brazil, and Japan, respectively. Overall, the United Kingdom and Canada both have higher shares of mobile researchers (more than 70%) than Brazil and Japan (less than 40%), where it is more common to be a non-migratory researcher.

In the present analysis, among researchers women are generally less mobile than men. In the United Kingdom, Canada, and Brazil, the proportion of women researchers classified as migratory (in any one of the three classes: outflow, transitory, or inflow) is lower than the share of active women researchers overall. In all three countries, the share of non-migratory women researchers is higher than the share of women researchers overall: this indicates that women researchers may be less internationally mobile than men researchers. We can hypothesize that the findings around international collaboration and mobility are linked: if women are less internationally mobile, it may also restrict their network and international collaboration opportunities. If international collaboration occurs less frequently for women than men, their networks may remain small and this may negatively affect opportunities for career progression and mobility.

We measure international mobility by tracking changes over time in the country affiliation that appears for each researcher on Scopus-indexed papers. If the affiliation of a researcher changes, it is likely that they have physically relocated in the intervening period. Researchers are considered residents of a country if they publish at least one paper in the period with an affiliation in that country. Active researchers are those exceeding a threshold count of papers in the period (see *Appendix B* for details on the definition of an active researcher). Researchers who publish under an affiliation in another country for two years or more are considered migratory and divided into outflow (researchers that leave the country) and inflow (researchers that come into the country). Researchers who publish under an affiliation in another country for less than two years are deemed transitory. Non-migratory researchers are those whose affiliation(s) remain in the same country throughout the whole period. To better understand the composition of each mobility group, three aggregate indicators are calculated to represent the productivity and seniority of the researchers and the impact of their papers. Relative Productivity is measured as the number of papers per year since the first appearance of each researcher as an author during the period, relative to all researchers in the same country during the same period. Relative Seniority is measured in terms of the years since the first appearance of each researcher as an author during the period, relative to all researchers in the same country during the same period. Field-Weighted Citation Impact (FWCI) compares the actual number of citations received by a paper with the expected number of citations for papers of the same document type (article, review, or conference proceeding), publication year, and subject area, and is calculated for all papers in each mobility class. All three indicators are calculated for each author's entire output in the period (i.e., not just those papers listing a country in the author's address). (Please see *Appendix B* for more details on the methodology used for this analysis.)

92 Elsevier. *Comparative Benchmarking of European and US Research Collaboration and Researcher Mobility*. <https://www.elsevier.com/research-intelligence/research-initiatives/science-europe>

In Japan, however, the differences between men and women are very small. Japan also stands out as the only country with a relatively high proportion of women researchers leaving the country (outflow)—no other country demonstrates this trend. In all four comparator countries and regions, the number of women researchers entering the country (inflow) is relatively low; this combination of trends in Japan may contribute to the low representation of women among researchers in this country.

Consistently across these four countries, the highest impact research comes from the transitory group. Although research from the outflow group has a lower impact than that of all active researchers, the FWCI is lowest for the non-migratory researchers, which also has higher than expected shares of women researchers. The Relative Seniority and Relative Productivity are also lowest in this non-migratory category: the lower relative seniority indicates that this group contains a greater share of early career researchers. The lower levels of experience and exposure may contribute to the lower impact of their research.

KEY FINDING

Among researchers, women are generally less internationally mobile than men.

“ It is very exciting to see gender differences in the pattern of international mobility unveiled. Elsevier’s innovative approach to using Scopus to track researchers opens new research possibilities to examine the role of gender differences in the international “brain drain” and “brain circulation” patterns.

— **Sifan Zhou**, Postdoctoral Fellow, Center of Mathematical Sciences and Applications and Research Associate, Labor and Worklife Program at Harvard Law School, Harvard University, United States

Figures 2.6–2.9 (continues next page) — International mobility of researchers (among named and gendered author profiles) for the United Kingdom, Canada, Brazil, and Japan, 1996–2015.

Sources: Scopus, Genderize, NamSor, and Wikipedia

Relative Productivity, Relative Seniority, and FWCI: ■ < 0.50 ■ 0.50–0.75 ■ 0.75–1.25 ■ 1.25–1.75 ■ > 1.75

United Kingdom

332,642 ACTIVE RESEARCHERS

Of whom women: 31%

FWCI: 1.98

Inflow

Researchers: 9%
Of whom women: 28%
Relative Productivity: ■ 1.04
Relative Seniority: ■ 1.12
FWCI: ■ 2.22

Transitory

Researchers: 49%
Of whom women: 29%
Relative Productivity: ■ 1.24
Relative Seniority: ■ 1.06
FWCI: ■ 2.02

Outflow

Researchers: 13%
Of whom women: 26%
Relative Productivity: ■ 0.92
Relative Seniority: ■ 1.12
FWCI: ■ 1.87

Non-migratory

Researchers: 29%
Of whom women: 37%
Relative Productivity: ■ 0.49
Relative Seniority: ■ 0.80
FWCI: ■ 1.67

Canada

176,718 ACTIVE RESEARCHERS

Of whom women: 31%

FWCI: 1.93

Inflow

Researchers: 11%
Of whom women: 28%
Relative Productivity: ■ 0.89
Relative Seniority: ■ 1.14
FWCI: ■ 1.96

Transitory

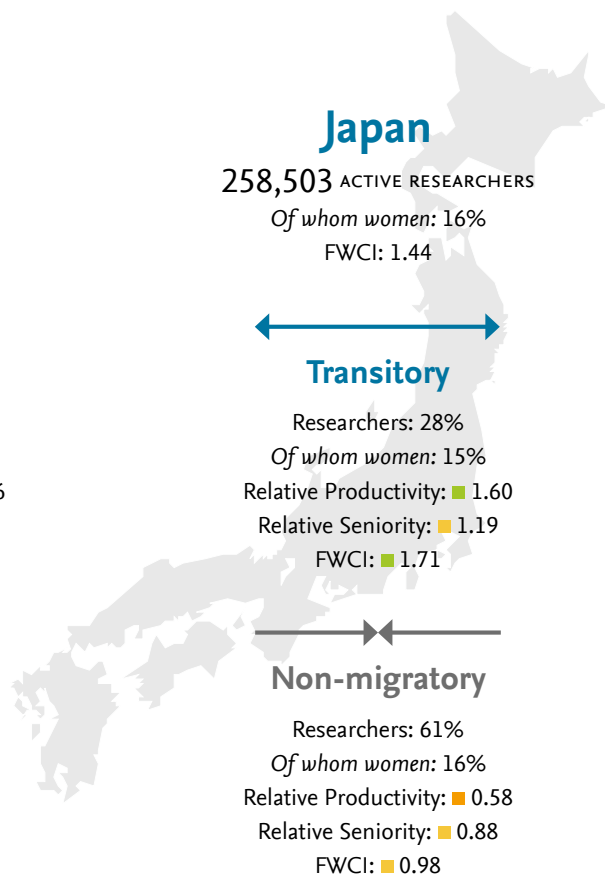
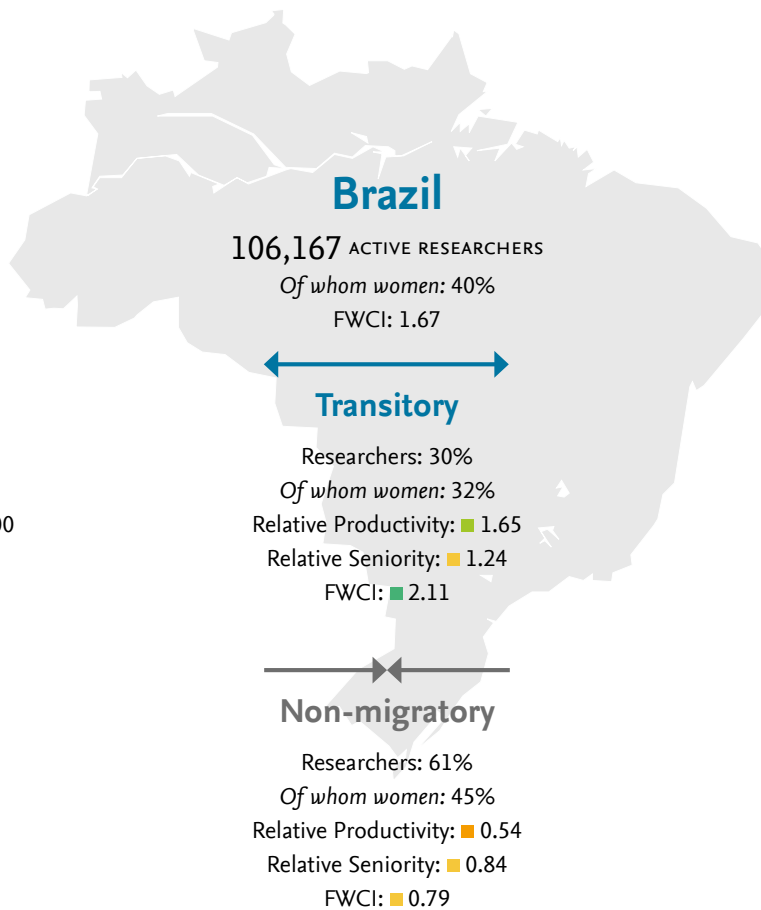
Researchers: 49%
Of whom women: 28%
Relative Productivity: ■ 1.28
Relative Seniority: ■ 1.07
FWCI: ■ 2.02

Outflow

Researchers: 13%
Of whom women: 26%
Relative Productivity: ■ 0.92
Relative Seniority: ■ 1.11
FWCI: ■ 1.73

Non-migratory

Researchers: 28%
Of whom women: 41%
Relative Productivity: ■ 0.42
Relative Seniority: ■ 0.77
FWCI: ■ 1.46



INTERVIEW



Vladimir Šucha

*Director-General, Joint Research Centre
European Commission, European Union*

What do you consider to be the greatest opportunities and challenges regarding diversity and gender equity in Europe and globally?

As for the opportunities, we see that there are more and more highly educated women all around the world. In the context of our globalized world and the mobility of highly skilled people, we can expect that there will be a stronger demand for gender equity as well as ethnic diversity in research organizations. There is clearly growing awareness and evidence about the benefits of diversity and gender equity. The challenge is that these processes will most likely be slower than they should be.

Already more girls and women are pursuing their interest in technical subjects and getting involved in science. The old idea of there being typical “male” subject areas is falling and we can see improvement in the numbers of female scientists in those areas over the last few decades. This is also the case in the Joint Research Centre (JRC), where we have seen a steady increase of female scientists taking up research positions, both temporary and permanent. Women are also increasingly occupying important management positions in the JRC.

Another opportunity I see is to go beyond “let’s have more women in XYZ” and towards “let’s make these places attractive to people with a family,” especially for those with young children.

Female representation among graduate and doctoral students is also growing. This is an increasing and promising basis for achieving equal representation of both genders in science. The system of peer review further promotes the non-discriminatory and merit-based evaluation of researchers. However, female representation is still lagging behind in scientific bodies where membership depends on invitation or voting. I believe that stronger network building can help change this.

How important are data and an evidence base for policymakers and institutional leaders?

As the Director-General of an organization whose mission is providing data and evidence for policymakers, you would of course expect me to say “very important.” I think most scientists and policymakers would give the same response: scientists want their work to be taken into account and policymakers like to say that their policies are evidence-based. It is much more complicated to say whether this is the case in practice. We are working with a growing number of partners internationally to better understand how evidence and policy interact and how scientists can become more effective in helping policymakers take evidence into account. There is a lot of work to be done to understand how evidence and values can

be reconciled in a positive way in political decision-making. Evidence and values are deeply entangled and cannot easily be disentangled into a clear separation of the roles of scientist and policymaker. With all the complex problems policymakers face, they will surely need evidence. But they will also need a new understanding of how evidence and policy interact.

I see great potential for data analysis in identifying biases, including gender bias, in our organizations and in how we evaluate research. Your report is an important step towards obtaining this evidence.

What do you view as the key events of the past 5-10 years that have had the most impact on advancing diversity and gender equity?

There have been many reports documenting that diversity tends to be good for business; these ideas start to become common knowledge, which is good because there is a lot of common sense there. So we could say that we are moving progressively towards more equality. Unfortunately, it is not that straightforward.

Female participation in higher education is a real motivating factor. Reaching a critical mass in specific areas is an enabler of diversity in science. Concerning geographic diversity, free access to academic journals and the introduction of open access articles are the biggest enablers.

Diversity and gender equity are increasingly on the agenda of global forums and these issues have been given increased visibility. The argument for diversity and gender equality comes from an economic perspective, in terms of competitiveness, labor force participation, and value added, and the performance of companies with more diverse high-level management. There is still an imbalance at the decision-making level. Progress has been very slow when diversity is left to develop “naturally” in society, in contrast to countries that have introduced quotas, e.g., for political representation. Discussions on the introductions of quotas have helped to expose this problem.

What information in the present report do you find particularly interesting and important for policy makers and institutional leaders?

I was struck by the data on interdisciplinarity. Here in the JRC, we talk a lot about the need to promote interdisciplinarity and we see that based on your indicators, women are doing slightly better than men on this front. However, we have a problem there. As you rightly point out, interdisciplinary output tends to have a lower citation impact; this means that it may not be very beneficial for researchers' careers to engage in interdisciplinarity. It seems that women may be hit harder by this half-way appraisal of interdisciplinarity.

The number of publications between men and women are quite equal. And across all scientific fields there is an increase in female authors. However, we also need to understand better whether women are equally (or proportionately) represented among lead authors, team and project leaders, or department chairs.

Are there any connections you can make between the data and the policies, practices, scientific culture in the European Union or in a particular country?

As I already mentioned, perhaps more consequential promotion of interdisciplinarity could have a positive impact on women researchers in particular.

There are many connections which can be made, but drawing from my experience, I would say that those countries with strong and long-standing social policies that allow and encourage the population to find a well-balanced private and professional life, are also the ones

where you find a scientifically productive female community. Women there are also able to continue their careers and reach influential positions in management or academia.

Thinking about the future of diversity and gender equity globally, where do you think we will be in 5-10 years' time?

Again, as I already said, we should not take the achievements of today for granted.

There are some exciting developments in the area of behavioral insights that can help identify and rectify biases. When facilitated by progress in digital technologies, there could be some interesting developments towards less biased recruiting and peer-review systems that could make research, as well as other areas, less discriminatory and more merit-based.

We will be performing better than we are now, but concerning leadership positions in science (and elsewhere) we will still not have achieved gender balance.



CHAPTER 3

The gender research landscape

Key Findings

Gender research is split between biomedical and social sciences. The topics included in the latter area are more diverse than a decade earlier and there is now more research explicitly bridging the two areas.

SECTION 3.1

Gender research is growing, relatively quickly, over time. Though the United States previously dominated gender research, it is now distributed more evenly between the United States and the European Union.

SECTION 3.2

The citation impact of gender research papers is converging over time between countries and regions as international collaboration grows.

SECTION 3.2

3.1 Identifying and mapping gender research

To visualize changes to gender research over time, the two maps presented show papers from the 1996–2000 period, from which 449 terms are extracted (*Figure 3.1*) and from the 2011–2015 period, from which 1,297 terms are extracted (*Figure 3.2*). To appear in either map, terms must have occurred in a minimum of 40 papers within each of the two time periods. The size of a node representing a single term indicates the number of papers in which the term occurs. The distance between two terms reflects their relatedness, measured by the frequency with which the terms occur together in papers. In general, the stronger the relationship between two terms, the closer to each other they will be located on the map. The colors in the map represent clusters, i.e., groups of related nodes.

Both maps show two main groups of term clusters, one with a focus on biomedicine (on the right) and the other on social science (on the left). These cluster groups are well defined, suggesting that there is little overlap in term use between the papers that use them. The methodology used to identify gender research papers does not distinguish social science literature from other literature using the word “gender,” for example, biomedical research with a gender perspective. Therefore, all research is presented, but our particular interest lies in the dynamics of papers focused on gender research within the social science group.

In the 1996–2000 map, terms in the social sciences group on the left show topics such as gender economics, gender equality, and women in STEM. These papers include topics around education, employment, gender identity, and gender-related policies. The intermingled clusters show that these subjects are closely linked and the terms are used together relatively frequently.

The 2011–2015 map includes more terms and is therefore more densely populated, reflecting the growth in gender research that is analyzed later in this chapter. While gender research has grown in terms of the number of papers, the overall network of terms has not changed dramatically: the two main groups of term clusters seen in the earlier map are still present. There are some more subtle changes within those groups, though. In the social sciences group, terms relating to gender economics, gender equality, and women in STEM are still present, but there are now also more terms around feminism, representation and gender stereotyping, gender wage gaps, and technology. As in the earlier map, these clusters intermingle, showing that there is overlap in term use between these topics.

In addition to the expansion of the social science group, there are also more terms bridging the social science and

To analyze gender research, we used VOSviewer software developed at the Centre for Science and Technology Studies (CWTS), which uses text mining functionality to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature. In this case, the body of scholarly literature is papers (articles, reviews, and conference proceedings) indexed in Scopus with “gender” in the title. Identifying gender research in this way has advantages but also limitations. It is not easy to define gender research and identify all relevant papers. Our approach favors accuracy over recall and we are likely to have missed papers that are on topic but do not feature “gender” in the title. Other language may be used, for example, for research on women’s and feminist studies and research on men’s and queer studies, which can all be classed as gender research but would not be included in our analysis. This approach may also mean that we are tracking the preference of the term “gender” in relation to these studies: if the word “gender” is more popular in 2011–2015 than in 1996–2000, then the growth we measure could be inflated. Nevertheless, our approach allows the identification of a corpus of papers on the topic of gender research that is amenable to further analysis. VOSviewer uses natural language processing techniques to extract important, publication-specific keywords or noun phrases from the titles and abstracts of the papers identified by the title-only search. The tool measures the co-occurrences of all keywords and creates a term co-occurrence map in which the structure of the research is represented and visualized. (See *Appendix B* for more details on the methods used.)

biomedical terms. In particular, a smaller cluster of terms appears in the later map which is not present in the earlier one: this smaller cluster is focused on image processing for gender classification or identification. This cluster forms an arch comprising technologically focused terms surmounted by an apparently distinct topic related to gender classification. This new topic in the 2011–2015 map appears related to the burgeoning area of gender classification. Gender classification technology is important for human-computer interaction, but there are also potential applications in law enforcement, security, and demographic studies. The lower, pink colored cluster also includes more terms relating to gender identity disorder and dysphoria and intimate partner violence and there is an even more defined cluster of terms focused on health, especially substance abuse and related socio-economic status and risks.

It is clear from this analysis that gender research is complex. Not only are there two main areas of biomedicine and social, cultural and political gender studies, but the latter group is made up of many topics. Themes emerge around gender economics, equality, politics, and women in STEM in 1996–2000 and they tend to intermingle, suggesting that the topics are pervasive. This has not changed over time. Rather, more themes have appeared in 2011–2015, suggesting that either they are newly formed subtopics or simply that they have sufficiently grown in size to show up in our analysis. Included in these new topics are feminism, representation and gender stereotyping, gender wage gaps, and technology, plus entirely new subtopics focused on gender classification and identification.

Overall then, these maps of gender research reflect the growth in the volume of research over time, but also its developments: the overall structure has not changed radically between the two time periods studied here, but there appears to be an increased number of subfields within gender research. The close association of terms reflected in the groups of clusters on the left of the map may be a reflection of the complex and pervasive nature of gender issues. It is likely that multi- and/or interdisciplinary approaches are prevalent here.

“Scientific activity occurs in a larger context of gender, as well as race and ethnicity, geopolitical positions, and other inequalities. Understanding how inequality translates into differential outcomes involves accounting for the complexity of the collaborative research work process, life course career dynamics, and institutional and regional influences on science labor markets and activity. All too often the focus is on US academic science, in single disciplines and fields. This report leverages hard-to-obtain data to provide a much needed portrait of global scientific activity in a comparative context, providing an evidence base for future research agendas that can address how to empower social groups proactively and broadly across countries and societies.

— **Kjersten Bunker Whittington**, Associate Professor of Sociology, Reed College, United States

KEY FINDING

Gender research is split between biomedical and social sciences. The topics included in the latter area are more diverse than a decade earlier and there is now more research explicitly bridging the two areas.

3.2 Gender research scholarly output and impact

As mentioned in the previous section, we define gender research as scholarly papers (articles, reviews, and conference proceedings) with “gender” in their title. In this section, we report on the scholarly output and impact of gender research, identified as the corpus of scholarly papers indexed in Scopus that include the term “gender” in their title, comparing two time periods (1996–2000 and 2011–2015) across twelve comparator countries and regions. It should be noted that these twelve comparators do not reflect all of the countries and regions with the largest contributions to gender research, nor the greatest growth.

We use Field-Weighted Citation Impact (FWCI), one of the most sophisticated indicators in the modern bibliometric toolkit, as a proxy measure for scholarly impact. FWCI captures mean citation impact by comparing the actual number of citations received by a paper with the expected number of citations for documents of the same type (article, review, or conference proceeding), publication year, and subject area. FWCI therefore normalizes for differences in citation activity by subject area, document type, and publication year, with reference to a global baseline of 1.00.

Overall, there has been strong growth in the volume of scholarly literature over time, which more than doubled between 1996–2000 and 2011–2015. Gender research is no exception and, indeed, grew in volume at a rate slightly higher than that of all scholarly literature. Between 2011 and 2015, there are over 23,000 gender research papers, more than two and a half times (2.7 factor of growth) the number of papers published between 1996 and 2000. Examining the output of gender research of each comparator, shown in absolute terms in *Table 3.1* and as a share of the global output in *Figure 3.3*, provides further insight into the global distribution of gender research and its evolution through time. All twelve comparators show growth in output of gender research papers between the two time periods.

Gender research is localized primarily in the United States in 1996–2000, accounting for half (50%) of the literature in this period, or over 4,000 papers. The output in the United States nearly doubles in absolute numbers by 2011–2015, but in relative terms drops in share to just over a third (34%) due to stronger growth in other countries and regions. The relatively lower growth rate in gender research in the United States is consistent with a relatively low growth rate in all scholarly output (1.8 factor of growth). In

KEY FINDING

Gender research is growing, relatively quickly, over time. Though the United States previously dominated gender research, it is now distributed more evenly between the United States and the European Union.

fact, the United States is the only comparator whose growth in scholarly output is inferior to the overall world average for this period (2.1 factor of growth).⁹³ They do, however, remain the country with the highest scholarly output of research among those studied in this report.

Gender research is growing at a relatively fast pace. Though the growth rate varies, very few comparators dramatically increase their share of papers. The exception is the European Union. Gender research in the European Union grows strongly: their output more than quadruples (4.3 factor of growth) between the two time periods. Accordingly, the European Union’s output share of gender research grows from 21% (1996–2000) to 35% (2011–2015), thereby exceeding that of the United States. The growth of gender research is also significantly stronger than the rate at which research as a whole grew in the European Union (2.1 factor of growth), suggesting that gender research is growing quickly in the region.

“ We appear to be witnessing two trends in tension with one another. First, there is a proliferation of discussion and policy regarding gender equity in the public and private spheres, and second, there is evidence of a “backlash,” with the persistence of deeply rooted sexism. Increasing the proportion of women in public life is more important than ever, and so too is creating the evidence base that keeps decision-makers on their toes when they make appointments and justify funding decisions.

— **Kim Rubenstein**, Professor, ANU College of Law and Public Policy Fellow; Inaugural Convenor (2011–2012), ANU Gender Institute, Australian National University (ANU), Australia

⁹³ This is also observed in several of our other comparative reports, such as *International Comparative Performance of the UK Research Base – 2013* and *International Comparative Performance of India’s Research Base (2009–2014): A Bibliometric Analysis*.

Although some of the other comparator countries and regions show a dramatic increase in the amount of gender research published, the numbers of papers published in 1996–2000 is low for Portugal (6 papers), Chile (9 papers), Mexico (25 papers), and Brazil (39 papers).

In summary, though gender research is centered in the United States in the earlier period, gender research is now shared more evenly among the United States and the European Union.

Table 3.1 and Figure 3.3 show FWCI and its changes over time for gender research. In 1996–2000, the gender research literature has an overall FWCI of 1.14, meaning that the papers receive 14% more citations than the global average. This FWCI falls to 1.03 in 2011–2015. The trend in decreasing FWCI is seen in the European Union, Australia, Denmark, and Portugal, while many other comparator countries and regions see very little change at all. This may not, however, simply mean that gender research has become less impactful over time. The convergence of FWCI towards 1.00 across comparators may be related to a global increase in overall international collaboration. A whole counting method is applied to these sets of papers, so the full credit of each paper is attributed to every author's affiliated country. Therefore, as international collaboration increases, there is a greater overlap in the sets of papers analyzed for each country and so a convergence in metric scores is to be expected.

Gender research with the highest impact is published by the United States (1.35 FWCI), United Kingdom (1.34 FWCI), and Denmark (1.31 FWCI). This fits with the overall profile of these countries: the United States and the United Kingdom in particular are research-intensive and all three countries produce high-impact research across all domains of research. The lower FWCI values tend to come from relative newcomers to the gender research area: that is, those

comparator countries and regions with only a few research papers in 1996–2000 and high growth rates, including Brazil, Portugal, Mexico, and Chile. With the exception of Portugal, the impact in gender research from these countries also reflects the below average FWCI of these countries overall. While Japan is also considered research-intensive overall, the FWCI of its gender research is lower than the overall global average

In summary, gender research as a whole receives 3% more citations than the overall global average. The highest impact research comes from the United States, United Kingdom, and Denmark. These observations are in keeping with the overall impact profiles of these countries, with research leaders (in terms of impact) also showing strong impact in gender research. Meanwhile, lower impact content comes from countries and regions with only a growing but small amount of gender research.

KEY FINDING

The citation impact of gender research papers is converging over time between countries and regions as international collaboration grows.

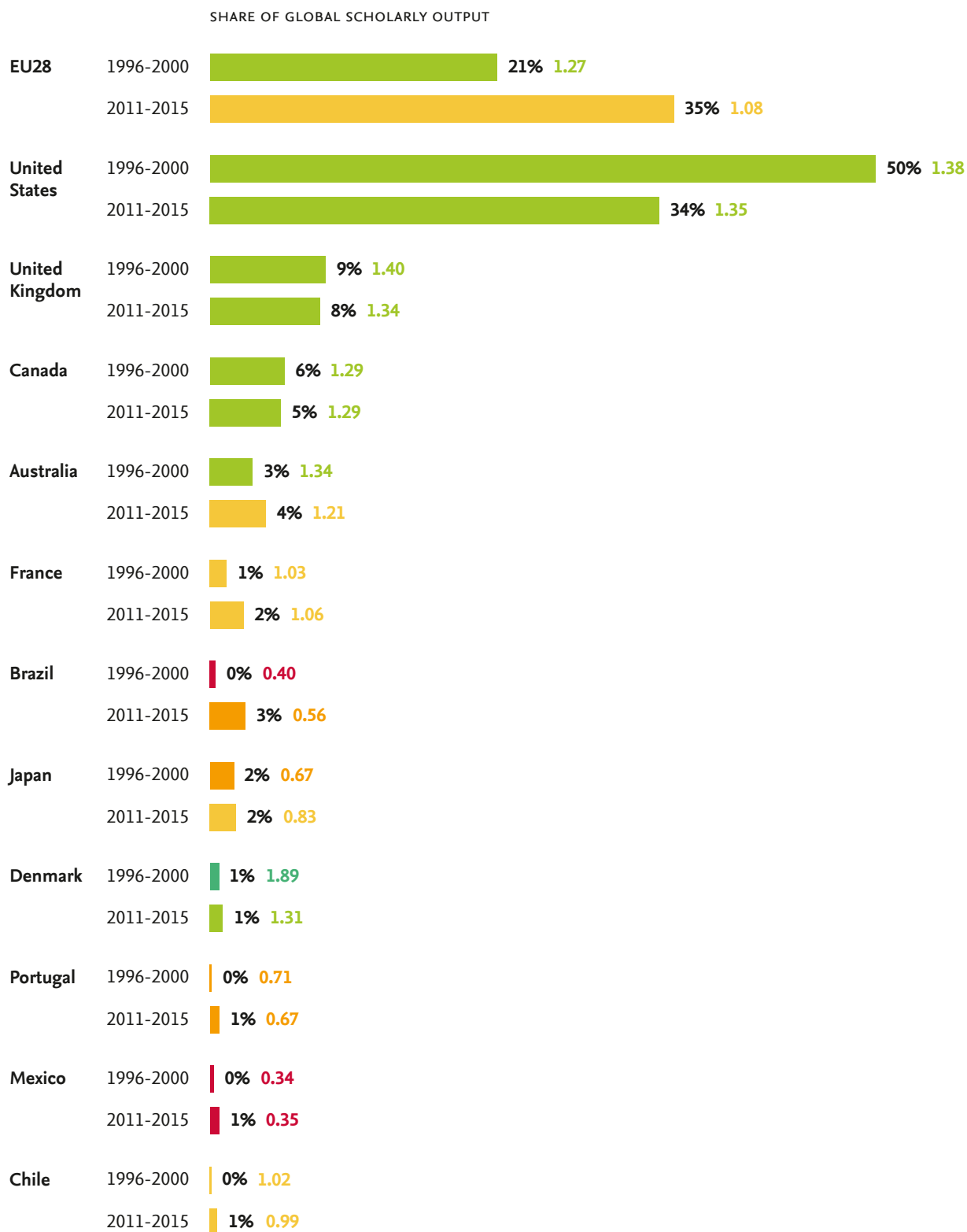
Table 3.1 — Scholarly output and FWCI of gender research for selected comparators, 1996–2000 vs. 2011–2015.

Comparator	Scholarly output			FWCI			FWCI: ■ > 1.75 ■ 1.25–1.75 ■ 0.75–1.25 ■ 0.50–0.75 ■ < 0.50 Change ↑ > 5.0 ↗ 1.0–5.0 → 1.0 ↘ 0–1.0 ↓ < 0
	1996–2000	2011–2015	Change factor	1996–2000	2011–2015	Change factor	
World	8,631	23,063	↗ 2.7	■ 1.21	■ 1.02	↘ 0.8	
United States	4,281	7,743	↗ 1.8	■ 1.38	■ 1.35	→ 1.0	
EU28	1,847	7,973	↗ 4.3	■ 1.27	■ 1.08	↘ 0.9	
United Kingdom	740	1,907	↗ 2.6	■ 1.40	■ 1.34	→ 1.0	
Canada	482	1,212	↗ 2.5	■ 1.29	■ 1.29	→ 1.0	
Australia	282	973	↗ 3.5	■ 1.34	■ 1.21	→ 0.9	
France	107	567	↑ 5.3	■ 1.03	■ 1.06	→ 1.0	
Brazil	39	611	↑ 15.7	■ 0.40	■ 0.56	↗ 1.4	
Japan	156	454	↗ 2.9	■ 0.67	■ 0.83	↗ 1.2	
Denmark	57	239	↗ 4.2	■ 1.89	■ 1.31	↘ 0.7	
Portugal	6	169	↑ 28.2	■ 0.71	■ 0.67	→ 0.9	
Mexico	25	148	↑ 5.9	■ 0.34	■ 0.35	→ 1.0	
Chile	9	116	↑ 12.9	■ 1.02	■ 0.99	→ 1.0	

Source: Scopus

Figure 3.3 — Scholarly output as global publication share (number in black at end of bar) and FWCI (number in color at end of bar) of gender research for each comparator, 1996–2000 vs. 2011–2015.
Source: Scopus

FWCI: ■ < 0.50 ■ 0.50–0.75 ■ 0.75–1.25 ■ 1.25–1.75 ■ > 1.75



INTERVIEW



Londa Schiebinger

The John L. Hinds Professor of History of Science and Director, Gendered Innovations in Science, Health & Medicine, Engineering, and Environment, Stanford University, United States

What do you view as the key events of the past 5-10 years that have had the most impact on advancing diversity and gender equity?

The funding agencies, such as the National Science Foundation (NSF) in the United States and the European Commission (EC), have been remarkably important to advancing inclusion and gender equity, and I think that granting agencies are standardizing their policies now. We see similar policies across the United States, Canada, and Europe, and now also in Asia. Certainly South Korea is thinking about gender equality more and to some extent so are Japan and Taiwan. Most importantly, the funding agencies understand that integrating sex and gender analyses into research is about the quality of the research. It's not just about women and inclusion; it's about the quality of science and engineering. It's about producing excellent science. And by excellent, I mean sustainable science that supports both men and women in society and helps meet global grand challenges.

Over the past several decades, governments, universities, and increasingly, corporations, have taken three strategic approaches to gender equality:

- ▶ *“Fix the Numbers of Women”* has focused on tapping into the underused talents of women and underrepresented minorities. Efforts in this area began in the 1980s when government agencies both gathered statistics on women in the scientific and engineering workforce and provided programs to jump-start women's careers—by increasing funding to women's research, teaching women how to negotiate, setting up mentor networks, and the like.
- ▶ *“Fix the Institutions”* has promoted gender equality in careers through structural change in research organizations. Since the 2000s, programs such as NSF ADVANCE have worked to reduce implicit gender bias in hiring and promotion and to support numerous family-friendly policies, such as family leave, work-life balance, mobility, and dual-career hiring (the latter is particularly important; women often won't take jobs if their partners can't find appropriate positions nearby).
- ▶ *“Fix the Knowledge”* or *“gendered innovations”* stimulates excellence in science and technology by integrating sex- and gender-based analysis into research. This is the newest approach and the most important for the future of science and engineering. Here the Canadian Institutes of Health Research (CIHR) led the way in 2010 by asking that both sex and gender analysis be included in research, where applicable. The European Commission (EC) followed in 2013 with its emphasis on the “gender dimension” in research, and in 2016, the National Institutes of Health (NIH) in the United States required that sex be included as a biological variable in all agency-funded research. We expect the NIH to expand its policy to include gender. A Stanford-led team is currently developing an

instrument to measure gender variables in health research. We also expect the NSF to develop policies to integrate sex and gender analysis into research.

In new developments on this front, a growing number of peer-reviewed journals have implemented editorial policies requiring sex- or gender-specific reporting. For example, the International Committee of Medical Journal Editors (ICMJE) advocates that researchers “aim for inclusive representative populations in all study types” for “such variables as age, sex, or ethnicity” or “at a minimum provide descriptive data for these and other relevant demographic variables.” In addition, the European Association of Science Editors has developed a set of recommendations for reporting sex and gender in study design, data analyses, results, and interpretation of findings. Standards for transparent reporting of sex and gender will reinforce granting agency policies for the inclusion of sex- and gender-based analysis in research.

We don’t necessarily expect to see a “gender dimension” in fields like theoretical physics, but for any field of science or engineering with a human endpoint—including biomedicine, mechanical engineering, computer hardware and architecture, nanotechnology, etc. (the EC has identified some 130 areas of science and technology where gender analysis could benefit research)—it’s important that sex and/or gender be considered in the research design. Considering sex and gender when designing research will be one important factor to ensure that research serves all segments of the population equally.

Thinking about the future of diversity and gender equity globally, where do you think we will be in 10 years’ time? What societal or cultural issues do you think will influence gender research priorities and applications in the future?

Even though a lot of funding agencies have policies that consider the “gender dimension,” or how sex and gender are integrated into research, most researchers don’t know how to carry out this type of research in sophisticated ways. These methods are not at the heart of university curricula.

What granting agencies need to do now is to support training for researchers. How do we do this? The CIHR and the NIH have some nice online training for biomedical and health researchers. Similar trainings are needed for engineers. The EC is training its program officers and, to a certain extent, researchers, on how to evaluate whether researchers have properly integrated sex and gender analysis in their grant proposals.

I think the granting agencies now need to support more of these trainings, and it would be wonderful if they could also support a wave of university curricular change that integrates sex or gender analysis directly into the core STEM curriculum. At the moment, at many research institutions, students can take a course on diversity in the humanities, and sometimes these courses count as a general education requirement, but such analytics should be incorporated directly into basic science or engineering. Engineering schools across much of the world teach many of the same things. We need to develop a curriculum on the gender dimension in research and then share it broadly to create a huge change in how the world functions. If we want to support gender equality, we need to make sure that every product is safe and works effectively for people of different sizes and shapes, different biological sex, and different ethnic backgrounds. If we’re thinking about engineering and product design, we need to design the world so it’s an equitable world. We can’t create gender equality simply by having diverse bodies in the room. We must actually transform the world to work in an equally wonderful way for people of diverse backgrounds.

How important are data and an evidence base for policymakers and institutional leaders?

Policymakers want evidence. As you probably know, the EC supported the Gendered Innovations Project. I had already started Gendered Innovations; they saw the value of it and used our data as evidence for their policies. In Gendered Innovations, we demonstrate how research can harness the creative power of sex and gender analysis for innovation and discovery. Importantly, we created 26 evidence-based case studies that show, in very concrete ways, how taking sex and/or gender into account has improved science.

I think that the NSF is waiting for more data in order to ask for sex and gender analysis in research. They're still hovering at that turning point, but I think it's something that will happen soon. The NIH just adopted their policy in January 2016, and that's huge. Their decision was based on literature developed over the past 20 years, in which top medical researchers have shown that sex analysis makes a difference in health outcomes.

All the other aspects of gender equality policy—increasing the number of women, fixing the institution—are also based on data. The NSF started collecting data on the number of women in research institutions in 1980, and the EC started not so long ago. These data will provide ongoing evidence of what policies are needed and what policies are working. Those data, like this report, are important evidence.

What information in the present report do you find particularly interesting and important for policy makers and institutional leaders?

I hope Elsevier will further investigate gender differences in the choice of research topics. Since men and women are socialized differently, we have slightly different interests and tend to ask slightly different questions. I think that you'll find that women bring a huge amount of creativity to the academy—once they have sufficient funding—that influences the kinds of questions that are asked. We know that in my field, history, as more women have entered the field over the past 30 years, there's been a sea change of topics. We now have women's history, gender history, history of the household, history of birthing, history of marriage; we have new avenues of research into the histories of all kinds of human endeavors.

As another example, we know that since more women have gotten into technology, menstrual hygiene products have gone through a huge revolution. Men might not like to think about menstrual hygiene products, but women engineers have produced novel materials so that women have new options and new freedoms when dealing with this basic biological function. This has been important in Western countries for athletes as well as ordinary women, and it's perhaps even more important in places like rural India. Girls often stop going to school when they start menstruating. Making available convenient, low-cost, and often locally produced menstrual hygiene products is a gendered innovation. Thinx, for instance, is a new kind of underwear that absorbs menstrual fluid; you just wear the underwear, and it's washable, and so it's also sustainable. This research area probably wouldn't be pursued by men, so it's really important that women are in institutions, well-funded, and free to ask the questions they want to ask.

Other areas where gender analysis will be important are: creating safe seatbelts for pregnant women, assistive technology to free people from domestic work (such as unloading the dishwasher or folding the laundry), and, one of the newest areas, developing and optimizing algorithms and automated systems that guarantee gender (and ethnic) fairness in job applications. So, I think that topic choice for men and women researchers is an important area for further investigation. At the same time, everyone—men and women—need to be trained in gender analysis. Men and women can contribute to gendered innovations.

Conclusion

Gender issues influence most aspects of our lives and societies. Their relevance to the world of research has been increasingly recognized via global, regional, and local initiatives aiming to foster better gender representation in Science, Technology, Engineering, and Mathematics (STEM).

(Introduction p10 and Chapter 1 p15)

This report reveals that some progress has been made towards gender equity in research: all of the comparator countries and regions included in the analysis show a greater share of women among researchers (*Figure 1.1 p18*) and inventors (*Figure 1.7 p35*) in 2011–2015 compared to 1996–2000. While in the earlier period, only one of the twelve comparators has 40% of women among researchers, by the later period, this proportion has risen to nine. The data also show that in 2011–2015, men publish more papers on average than women for eleven out of the twelve comparators (*Figure 1.4 p29*). This imbalance in scholarly output is not reflected in the number of citations or downloads that those papers receive, with only a small advantage in citations to men and a small advantage in downloads to women (*Figures 1.5 & 1.6 p31 & p33*). In terms of innovation, for most comparators, the share of patents with at least one woman named among the inventors is considerably higher than the share of women among inventors (*Figure 1.8 p37*).

The report also finds differences in gender representation between fields of research, with women better represented in the Health and Life Sciences, and underrepresented in the Physical Sciences (*Figure 1.2 p20*). In several subject areas, women represent at least 40% of researchers across the majority of the twelve comparator countries and regions: Biochemistry, Immunology & Microbiology, Medicine, Nursing, and Psychology. In Agricultural & Biological Sciences, Neuroscience, Pharmacology, Toxicology & Pharmaceuticals, Social Science, and Veterinary, women represent at least 30% of researchers in eleven of the twelve comparators. However, in Computer Science, Energy, Engineering, Mathematics, and Physics & Astron-

“ In 5-10 years, research will not be limited to the ivory towers of academia but will be more firmly rooted in society. That’s the moment when more women will be interested in research.

— **Martina Schraudner**, Head, Fraunhofer Center for Responsible Research and Innovation, Fraunhofer IAO, Germany

omy, women represent less than 25% of researchers in the majority of comparators (*Figure 1.3 p24*).

In Engineering, in which women are greatly outnumbered by men among researchers, women are less likely to be first or corresponding author on their papers than men are on theirs (*Figure 2.1 p48*). Conversely, in Nursing, in which women tend to outnumber men among researchers, women are more likely to be first or corresponding author on their papers than men are on theirs (*Figure 2.2 p49*). The pattern observed in these two fields suggests that underrepresentation in a field is associated with reduced likelihood to occupy lead author positions on a research paper in that field.

Interdisciplinary approaches may be warranted to answer certain research questions, yet interdisciplinarity has been linked to lower impact of the research in terms of citations. The data from this report show that women tend to have a slightly higher share of the most interdisciplinary scholarly output relative to their total scholarly output than men (*Figure 2.5 p57*).

Collaboration between researchers broadens networks and facilitates the exchange of ideas, and collaboration across national borders or institutional sectors in particular tends to be associated with greater citation impact of scholarly output. The analysis shows that among researchers, women collaborate less than men at an international level: the share of their scholarly output resulting from international collaboration tends to be smaller than the men's in all twelve comparator countries and regions (*Figure 2.3 p52*). A similar pattern is observed in academic-corporate collaboration, but with smaller differences between genders (*Figure 2.4 p55*).

International mobility can help researchers expand their network and propagate their ideas, and publications by researchers who move across national borders are generally cited more than those by non-migratory researchers. The case studies across four countries highlighted in this report show an overrepresentation of women in the non-migratory researcher class, meaning that among researchers, women tend to be less internationally mobile than men (*Figures 2.6, 2.7, 2.8, 2.9 p60*).

We hypothesize that the findings around gender differences in international collaboration and mobility are linked: if international collaboration or mobility occur less for women than men among researchers, their networks may suffer and thereafter opportunities for career progression and further international collaboration and mobility.

While this analysis finds that among researchers, women exhibit lower rates of international (*Figure 2.3 p52*) and academic-corporate (*Figure 2.4 p55*) collaboration, and publish a relatively higher proportion of the most interdisciplinary output (*Figure 2.5 p57*), it also finds little difference in the citation and download impact of men and women among researchers (*Figures 1.5 & 1.6 p31 & p33*). This suggests that either there is no detrimental effect from these collaborative patterns of work on their research impact in terms of how it is cited and downloaded, or that any detrimental effect is compensated for in some way. More research is needed to understand these observations and their relationships.

Gender issues are ubiquitous and complex, as demonstrated by the topics and themes tackled by gender research. The topics within gender research tend to cluster in either biomedicine or a more diverse area encompassing social, cultural, and political gender studies. In the latter social science area, gender economics, equality, politics, and women in STEM topics already established in 1996–2000 are joined in 2011–2015 by topics including feminism, representation and gender stereotyping, gender wage gaps, and technology, as well as gender classification and identification. These research areas may be entirely new, or may have experienced growth in scholarly output over time such that they show up in the later time period of the analysis (*Figures 3.1 & 3.2 p68 & p69*).

Gender research is growing relatively fast in terms of scholarly output, reflecting the increasing importance of the issue globally. While the majority of publications originated from the United States in 1996–2000, by 2011–2015 there is a more even contribution from the United States and the European Union. The scholarly impact of the research is highest in the countries with a high citation impact overall (*Table 3.1 & Figure 3.3 p72 & p73*).

Overall, this report provides an analytical framework for understanding gender in the research landscape, and a baseline for monitoring the future progress of this important dimension of gender equality.

Appendices

APPENDIX A	Project team, Subject experts, and Acknowledgements	80
	Core project team	80
	Other contributors	81
	Acknowledgements	81
	Subject experts	82
APPENDIX B	Methodology and Data Sources	84
	Methodology and rationale	84
	Document types	84
	Counting	84
	Name and gender disambiguation for researchers	84
	Gender disambiguation for inventors	85
	Comparator selection	85
	Measuring international researcher mobility	86
	Measuring paper downloads	86
	Identifying relevant gender research papers	86
	Data sources	87
APPENDIX C	Glossary of Terms	88
APPENDIX D	Subject Classification	90
	Background on classification system	90
	Scopus 27 subject classification	90

Appendix A

Project team, Subject experts, and Acknowledgements

This project would not have been possible without the hard work and expertise of many at Elsevier and beyond. We are truly grateful for all the insights and valuable contributions we received, as well as the relentless enthusiasm, dedication, and professionalism of each and everyone involved. We list here the key contributors to the report in alphabetical order, while acknowledging the support of many others.

Core project team – in alphabetical order



Ludivine Allagnat

Senior Academic Relations Manager, Elsevier
Project Management, Engagements, Communications



Stephane Berghmans

Vice President, Academic and Research Relations, Elsevier
Engagements



Holly J. Falk-Krzesinski

Vice President, Strategic Alliances, Global Academic Relations, Elsevier
Author, Project Management, Engagements



Shereen Hanafi

Head of Marketing, Research Management, Elsevier
Communications



Rachel Herbert

Senior Market Intelligence Manager, Elsevier
Analyst, Author



Sarah Huggett

Analytical Services Product Manager Research Intelligence, Elsevier
Analyst, Author



Stacey Tobin

Writer and Editor, The Tobin Touch, Inc.
Author

Other contributors – *in alphabetical order*

Jeroen Baas	Eleonora Palmaro
Dante Cid	Lei Pan
Kelsey Grentzer	Andrew Plume
Bamini Jayabalasingham	Ylann Schemm
Anton Jumelet	Taylor Stang
Elizabeth Kalinaki	Kana Takasaka
Judith Kamalski	Lesley Thompson
Anders Karlsson	John Walker
Sophia Katrenko	

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Londa Schiebinger

The John L. Hinds Professor of History of Science, Director, Gendered Innovations in Science, Health & Medicine, Engineering, and Environment, Stanford University, United States;

James Stirling

Provost Imperial College, United Kingdom;

Vladimir Šucha

Director-General, Joint Research Center (JRC), European Commission, European Union;

Miyoko O. Watanabe

Deputy Executive Director, Office for Diversity and Inclusion, Japan Science and Technology Agency (JST), Japan.

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Subject experts – in alphabetical order



Pernille Brandt

Human Resources Project Manager, Joint Research Center (JRC)
European Commission, European Union



Kjersten Bunker Whittington

Associate Professor of Sociology
Reed College, United States



Richard B. Freeman

The Herbert Ascherman Professor of Economics; and Co-Director, Labor and Worklife Program
Harvard Law School, Harvard University, United States



Uta Frith

Emeritus Professor, Institute of Cognitive Neuroscience and
Department of Psychology, University College London (UCL);
Chair, Diversity Committee, The Royal Society, United Kingdom



Fiona Jenkins

Associate Professor, School of Philosophy; Convenor (2013–2015) ANU Gender Institute
Australian National University (ANU), Australia



Pamela Kennedy

Senior Expert at the Institute for Environment and Sustainability, Joint Research Center (JRC)
European Commission, European Union



Gema Lax Martínez

PhD candidate, Department of Economics and Econometrics, University of Lausanne
Formerly Individual Contractor, World Intellectual Property Organization (WIPO), Switzerland
Author (see Section 1.3)



Jörg Müller

Senior Researcher, Gender and ICT, IN3, Universitat Oberta de Catalunya, Spain
Coordinator, GenPORT, European Union



Julio D. Raffo

Senior Economic Officer, Economics & Statistics Division
World Intellectual Property Organization (WIPO), Switzerland
Author (see Section 1.3)



Kim Rubenstein

Professor, ANU College of Law and Public Policy Fellow; Inaugural Convenor (2011–2012)
ANU Gender Institute, Australian National University (ANU), Australia



Kaori Saito

Gender and Diversity Specialist, Human Resources Management Department
World Intellectual Property Organization (WIPO), Switzerland
Author (see Section 1.3)



Londa Schiebinger

The John L. Hinds Professor of History of Science and Director, Gendered Innovations in
Science, Health & Medicine, Engineering, and Environment
Stanford University, United States



Martina Schraudner

Head, Fraunhofer Center for Responsible Research and Innovation
Fraunhofer Institut für Arbeitswirtschaft und Organisation (IAO), Germany



Katerina Svickova

Scientific Officer, Joint Research Center (JRC)
European Commission, European Union



Alice Szczepanikova

Scientific Officer, Joint Research Center (JRC)
European Commission, European Union



Katalin Toth

Scientific Officer, Joint Research Center (JRC)
European Commission, European Union



Miyoko O. Watanabe

Deputy Executive Director, Office for Diversity and Inclusion
Japan Science and Technology Agency (JST), Japan



Griffin M. Weber

Associate Professor of Medicine, Harvard Medical School, Harvard University and Director,
Biomedical Research Informatics Core, Beth Israel Deaconess Medical Center, United States



Sifan Zhou

Postdoctoral Fellow, Center of Mathematical Sciences and Applications and Research
Associate, Labor and Worklife Program
Harvard Law School, Harvard University, United States

Appendix B

Methodology and Data Sources

Methodology and rationale

Our methodology is based on the theoretical principles and best practices developed in the field of quantitative science and technology studies, particularly in science and technology indicators research. The *Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems* (Moed, Glänzel, & Schmoch, 2004)⁹⁴ gives a good overview of this field and is based on the pioneering work of Derek de Solla Price (1978),⁹⁵ Eugene Garfield (1979)⁹⁶, and Francis Narin (1976)⁹⁷ in the United States; Christopher Freeman, Ben Martin, and John Irvine in the United Kingdom (1987)⁹⁸; and several European institutions including the Centre for Science and Technology Studies at Leiden University, the Netherlands, and the Library of the Academy of Sciences in Budapest, Hungary.

The analyses of bibliometric data in this report are based on recognized advanced indicators (e.g., the concept of relative citation impact rates). Our base assumption is that such indicators are useful and valid measures, though imperfect and partial, in the sense that their numerical values are determined by research performance and related concepts, but also by other influencing factors that may cause systematic biases. In the past decade, the field of indicators research has developed a set of best practices that state how indicator results should be interpreted and which influencing factors should be considered. Our methodology builds on these practices.

A body of literature is available on the limitations and caveats in the use of such “bibliometric” data, such as the accumulation of citations over time, the skewed distribution of citations across papers, and differences in publication and citation practices between fields of research, different languages, and applicability to social sciences and humanities research. In the social sciences and humanities, the bibliometric indicators presented in this report must be interpreted with caution because a reasonable proportion of research output in these fields take the form of books, monographs, and non-textual media. As such, analyses of journal publications, their usage, and citation, provides a less comprehensive view of the social sciences and humanities than other fields, where journals comprise the vast majority of research output.

Document types

For all analyses, the following document types (collectively termed “papers”) are considered:

- ▶ Article (AR)
- ▶ Review (RE)
- ▶ Conference Proceeding (CP)

Counting

Analyses of researchers and research performance make use of

whole counting rather than fractional counting. For example, if a paper has been co-authored by one author from the United States and one author from the United Kingdom, then that paper counts towards both the paper count of the United States, as well as the paper count of the United Kingdom. Total counts for each country represent unique counts of papers. The same methodology applies to papers that appear in multiple subject categories or that are co-authored by women and men. Throughout the report, we use “researchers” when referring to indicators that are based on author profiles containing all the information we have for each author, and use “authors” to refer to the ascribed authors for each paper. We use “inventors” to refer to applicants in international patent applications filed under the Patent Cooperation Treaty (PCT). Inventor country is understood as the country of residence. Patent applications are attributed to the country of residence of the first applicant.

Name and gender disambiguation for researchers

Scopus uses a sophisticated author-matching algorithm to precisely identify documents published by the same author. The Scopus Author Identifier gives each author a unique ID and groups together all the documents published by that author, matching alternate spellings and variations of the author’s last name and distinguishing between authors with the same surname by differentiating on data elements associated with the paper (such as affiliation, subject area, co-authors, and so on). This is enriched with manual, author-supplied feedback, both directly through Scopus and via Scopus’ direct links with ORCID (Open Researcher & Contributor ID).

To analyze the relationship between the gender of researchers and various indicators of research performance, we need to identify the gender of the authors in Scopus (at an aggregate level). We combine Scopus data with various data sources described below that provide information on first names and gender per country. As the author’s first name field is not mandatory in Scopus, only author profiles with a full first name are included in the gender disambiguation analysis.

We define an author’s country of origin as the country in which his or her first paper is published. We gather each author’s list of papers in his or her first year of publication in Scopus, and then derive the country of origin based on the affiliations listed in the papers. In some cases, authors have published papers in more than one country in their first year of publication in Scopus. In these cases, we assign the country with the largest number of papers as the author’s country of origin. Authors with equal numbers of papers in two or more countries are excluded from the gender disambiguation analysis. We then use three data sources to assign genders to the corpus of author profiles with a first name and a country of origin.

On social media platforms, most users provide their first name and country of origin in their profile. Our first source, Genderize.io⁹⁹, uses these data to provide lists of first names, and the number of people with this first name that are women or men. We use these lists to calculate the probability that each

author's first name is a feminine or masculine name in the country of origin. An author's name needs to have appeared at least five times in the Genderize.io data and the probability that the name is a feminine name or a masculine name needs to be at least 85% for us to use it to assign a gender to the author. The corpus of Scopus author profiles is matched to these data according to authors' country of origin and first name. Some authors have multiple given names (e.g., "Rose Mary"). In these cases, we first attempt to match a gender to the full given name (e.g., "Rose Mary"). If the full given name does not match to a gender, we then attempt to match a gender to the first given name (e.g., "Rose").

Sociolinguistic features of the authors' first names can also provide information on gender. For example, the name "Andrea" is understood as a feminine name in most languages, but in a few others (Italian, Albanian, Romansh, Istrian), it is considered to be a masculine name. We utilize a second data source, NamSor™ Applied Onomastics¹⁰⁰, which uses sociolinguistic characteristics to mine Big Data sources with its name recognition software, and assigns a quasi-probability that the bearer of a given name is a man (-1) or a woman (+1) depending on the individual's location. We match the likely gender of frequent names (5 or more occurrences) with a quasi-probability of less than -0.7 for masculine names and greater than +0.7 for feminine names to the remainder of the Scopus author profiles (with first name and country of origin) for which we are unable to match using Genderize.io.

The use of Genderize.io and NamSor tends to work well for authors from Western countries and for certain names, in particular, Latin or Anglophone names. However, these methodologies are not sufficient for robustly determining the gender of names of authors of African, Arabic, or Asian descent. For most countries in these regions, we are unable to assign genders to significantly representative proportions of author profiles, and are therefore unable to include them in our analyses. Because we aim to conduct a global analysis, we use a third source for gender disambiguation of author names from Japan: a set of the most common masculine and feminine names from Wikipedia; this set is also used by Larivière et al. in their 2013 publication.¹⁰¹ Dr. Cassidy Sugimoto shared additional lists of names and genders that resulted from that Nature article, but they did not help us further enhance our disambiguation results, so we did not ultimately incorporate them into the report methodology.

Gender disambiguation for inventors

The World Intellectual Property Organization (WIPO) has compiled a world gender-name dictionary (WGND) from 13 different sources, covering 182 different countries. Most of the sources are national public institutions. They also rely on lists compiled by previous gender studies and make use of popular name lists by country available through Wikipedia. Finally, WIPO uses information extracted from the publicly available list of participants in the Assemblies of the Member States of WIPO. In addition to these public sources, WIPO also makes use of an ad-hoc list, created by Chinese, Indian, Japanese, and Korean WIPO staff native speakers. The final version of the WGND contains 6,247,039 unique pairs of names and countries and can be found on the WIPO website.¹⁰² We match the PCT applicants' names to the names and genders from the WGND, using the country of residence and the nationality in order to obtain 96% attribution in our PCT data. For more details on the methodology, please see WIPO's *Economic Research Working Paper No. 33*.¹⁰³

It should be noted that the success of our gender disambiguation methodology depends on the accuracy of the sources on which we draw, and that these sources do not account for changes in naming conventions across genders through time.

Comparator selection

Bearing in mind the above-mentioned limitations, we select comparator countries and regions from most major geographies to ensure our analyses are as global as possible. Our selection of comparators is also influenced by the total scholarly output of each comparator, as well as the proportions of researchers from each whose gender we are able to identify (at least 80% of author profiles with a first name for 1996–2015), to ensure that the analyses are robust and representative. Unfortunately, we are unable to reach this threshold for the entire world as well as several countries with large research programs (e.g., China, India, Russian Federation, South Africa), and these are not included in our analyses.

The set of comparator countries and regions is refined to the following twelve comparators:

- ▶ Australia (AUS)
- ▶ Brazil (BRA)
- ▶ Canada (CAN)
- ▶ Chile (CHL)
- ▶ France (FRA)
- ▶ Denmark (DNK)
- ▶ European Union (EU28)
- ▶ Japan (JPN)
- ▶ Mexico (MEX)
- ▶ Portugal (PRT)
- ▶ United Kingdom (UK)
- ▶ United States (USA)

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Measuring international researcher mobility

We use Scopus author profile data to derive a history of active author affiliations recorded in published papers and assign them to mobility classes defined by the type and duration of observed moves.

What is a “researcher” from a given country/region?

To define the initial population for study, researchers are identified as those authors who list an affiliation in a comparator country or region on at least one paper (articles, reviews, and conference proceedings) published across the sources included in Scopus during the period 1996–2015.

What is an ‘active researcher’?

We identify a large proportion of authors with relatively few papers published over the entire 20-year period of analysis. As such, it is assumed that these are not likely to represent career researchers, but individuals who have left the research system. A productivity filter is therefore implemented to restrict the analysis to authors who are active researchers, defined as those with at least one paper published in the five-year period 2011–2015 and at least ten papers published in the entire twenty-year period 1996–2015, or those with fewer than ten papers published in 1996–2015 but at least four papers published in 2011–2015. After applying the productivity filter, a set of active researchers is defined and forms the basis of our analysis.

How are mobility classes defined?

The measurement of international researcher mobility by co-authorship in the published literature is complicated by the difficulties involved in teasing out long-term mobility from short-term mobility (e.g., doctoral research visits, sabbaticals, secondments, etc.), which might be deemed instead to reflect a form of collaboration. In this study, stays abroad of two years or more are considered migratory. Stays abroad of less than two years are deemed transitory. Since author nationality is not captured in publication or author data, authors are assumed to be from the country where they first publish (for migratory mobility) or from the country where they publish the majority of their papers (for transitory mobility). In individual cases, these criteria may result in authors being assigned migratory patterns that do not accurately reflect the real situation, but such errors are assumed to be evenly distributed across the groups, so that the overall pattern remains valid. Researchers without any apparent mobility based on their published affiliations are considered non-migratory.

MIGRATORY *Outflow*: active researchers whose Scopus author data for the period 1996–2015 indicate that they have migrated from their first country to another country (or countries) for at least two years without returning to their original country of publication. *Inflow*: active researchers whose Scopus author data for the period 1996–2015 indicate that they have migrated to the country from another country (or countries) for at least two years without leaving the new country.

TRANSITORY Active researchers whose Scopus author data for the period 1996–2015 indicate that they have been based

in the country for less than two years at a time.

NON-MIGRATORY Active researchers whose Scopus author data for the period 1996–2015 indicate that they have not published outside their country of origin.

What indicators are used to characterize each mobility group?

To better understand the composition of each mobility group, three aggregate indicators are calculated to represent the productivity and seniority of the researchers included in each group, and the Field-Weighted Citation Impact (FWCI) of their published papers. Relative Productivity is measured as papers published per year since the first appearance of a researcher as an author during the period 1996–2015, relative to all researchers from the same country/region in the same period. Relative Seniority is calculated as years since the first appearance of a researcher as an author during the period 1996–2015, relative to all researchers in the same country/region and period. FWCI is calculated for all papers in each mobility class. All three indicators are calculated for each author’s entire output in the period (i.e., not just those papers listing a specific country address for that author).

Measuring paper downloads

Citation impact is, by definition, a lagging indicator: newly published papers need to be read, after which they might influence studies that will be carried out, which are then written up in manuscript form, peer-reviewed, published, and finally included in a citation index such as Scopus. Only after these steps are completed can citations to the earlier paper be systematically counted. For this reason, investigating downloads has become an appealing alternative, since it is possible to start counting downloads of full-text papers immediately upon online publication and to derive robust indicators over windows of months rather than years.

While there is a considerable body of literature on the meaning of citations and indicators derived from them,¹⁰⁴ the relatively recent advent of download-derived indicators means that there is no clear consensus on the nature of the phenomenon that is measured by download counts.¹⁰⁵ A small body of research has concluded, however, that download counts may be a weak predictor of subsequent citation counts at the publication level.¹⁰⁶

In this report, a download is defined as the event by which a user views the full-text HTML of a paper or downloads the full-text PDF of paper from ScienceDirect, Elsevier’s full-text publication platform. Views of an abstract alone or multiple full-text HTML views or PDF downloads of the same paper during the same user session are not included in accordance with the COUNTER Code of Practice. ScienceDirect provides download data for approximately 16% of the papers indexed in Scopus; it is assumed that user downloading behavior across countries does not systematically differ between online platforms. Field-Weighted Download Impact (FWDI) is calculated from these data using the same principles applied to the calculation of FWCI, described above.

Identifying relevant gender research papers

We identify papers relevant to gender specifically as those with

the word “gender” in the title. This is a broad search for any relevant content, regardless of the nature of the research. This approach favors accuracy over recall, as searching for “gender” in the title plus abstract and/or keywords of papers retrieves too many papers whose focus on gender is peripheral rather than central.

To analyze topics in the field of gender research, we use VOSviewer software developed at the Centre for Science and Technology Studies (CWTS), which uses text mining functionality to construct and visualize co-occurrence networks of important terms extracted from a body of scientific literature.¹⁰⁷ VOSviewer uses natural language processing techniques to extract the important, publication-specific keywords or noun phrases from the titles and abstracts of the papers. The tool measures the co-occurrences of all of the keywords and creates a term map in which the structure of the research field is represented and visualized. Binary counting is used, meaning that only the presence or absence of a term matters—the number of occurrences in a paper does not matter. For all terms, a relevance score is calculated and based on that score, only the most relevant terms will be selected. The default choice is 60%. Clustering resolution (i.e., number of clusters) is increased in the most recent map to account for the greater count of papers. A small tidy up of the terms in the map has been undertaken and terms that are related to the publication of the papers have been removed. This includes publisher names and the terms “author” and “paper.”

It should be noted that while the datasets are assessed for overall construct validity, we do not examine each paper returned by the searches to confirm whether they specifically concerned gender research.

For the analyses of scholarly output and impact in gender research, Solr™ queries are performed on the title field of a May 2016 Scopus dataset that is customized for analytics. These queries are based on keyword searches where Solr takes into account language, grammar, and stemming within texts. Please note that Scopus search results will not be identical to those used in this study because we use a Solr search of a customized Scopus snapshot dated May 2016. Therefore, our search results would be different from those retrieved with an advanced search in Scopus.com. The Solr datasets are then refined to include only articles, reviews, and conference proceedings, which are then used to calculate the metrics reported in this study.

Data sources

ScienceDirect is Elsevier’s full-text publication platform. With an incomparable customer base, ScienceDirect.com provides a comprehensive and invaluable resource for evaluating various

performance metrics of scientific research. ScienceDirect.com is used by more than 12,000 institutes worldwide, with more than 11 million active users and over 700 million full-text document downloads in 2012. The average click through to full-text documents per month is nearly 60 million. More information about ScienceDirect can be found on www.info.sciencedirect.com.

Scopus is Elsevier’s abstract and citation database of peer-reviewed literature, covering 62 million documents published in over 21,500 journals, book series, and conference proceedings by over 5,000 publishers.

Scopus coverage is multilingual and global: approximately 21% of titles in Scopus are published in languages other than English (or published in both English and another language). In addition, more than half of Scopus content originates from outside North America, representing many countries in Europe, Latin America, Africa, and the Asia-Pacific region.

Scopus coverage is also inclusive across all major research fields, with 6,900 titles in the Physical Sciences, 6,400 in the Health Sciences, 4,150 in the Life Sciences, and 6,800 in the Social Sciences (the latter including some 4,000 Arts & Humanities related titles). Included titles are predominantly serial publications (journals, trade journals, book series, and conference material), but considerable numbers of conference papers are also included as stand-alone proceedings volumes (a major dissemination mechanism, particularly in the computer sciences). Acknowledging that a great deal of important literature in all fields (but especially in the Social Sciences and Arts & Humanities) is published in books, Scopus has begun to increase book coverage in 2013, covering more than 120,000 books in 2016.

For most of the analyses in this report (excluding the analysis of key topics in the field of gender research), a static version of the Scopus database covering the period 1996–2016 inclusive is aggregated by country, region, and subject. Subjects are defined by All Science Journal Classification (ASJC) subject areas (see *Appendix D* for more details). When aggregating paper and citation counts, an integer counting method is employed.

The **World Intellectual Property Organization (WIPO)** is the global forum for intellectual property services, policy, information, and cooperation. WIPO is a self-funding agency of the United Nations, with 189 member states. Its mission is to lead the development of a balanced and effective international intellectual property (IP) system that enables innovation and creativity for the benefit of all. WIPO’s mandate, governing bodies, and procedures are set out in the WIPO Convention, which established WIPO in 1967.

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Appendix C

Glossary of Terms

Academic-corporate collaboration	In Scopus, institutions are classified into one of four main sectors (<i>Corporate, Academic, Government, and Medical</i> sectors). In this report, academic-corporate collaboration is analyzed via the proxy of papers whose authors' affiliations belong to both the academic and corporate sectors.
Author	An Author refers to an individual included in the authorship byline for each paper indexed in Scopus.
Citation	A citation is a formal reference to earlier work made in a paper or patent, frequently to other papers. A citation is used to credit the originator of an idea or finding and is typically used to indicate that the earlier work supports the claims of the work citing it. The number of citations received by a paper from subsequently published papers can be used as a proxy of the quality or importance of the reported research.
Download	Downloads are defined as either downloads of a PDF of a paper on ScienceDirect, Elsevier's full-text platform, or a view of the full-text online on ScienceDirect without downloading the actual PDF. Views of abstracts are not included in this definition. Multiple views or downloads of the same paper in the same format during a user session are filtered out, in accordance with the COUNTER Code of Practice ¹⁰⁸ .
Field-Weighted Citation Impact (FWCI)	Field-Weighted Citation Impact (FWCI) is an indicator of mean citation impact, and compares the actual number of citations received by a paper with the expected number of citations for papers of the same document type (article, review, or conference proceeding), publication year, and subject area. Where the paper is classified in two or more subject areas, the harmonic mean of the actual and expected citation rates is used. The indicator is therefore always defined with reference to a global baseline of 1.0 and intrinsically accounts for differences in citation accrual over time, differences in citation rates for different document types (e.g., reviews typically attract more citations than research articles), as well as subject-specific differences in citation frequencies overall and over time and document types. It is one of the most sophisticated indicators in the modern bibliometric toolkit.
Field-Weighted Download Impact (FWDI)	Field-Weighted Download Impact (FWDI) is a similar indicator to FWCI that uses downloads rather than citations.
Interdisciplinary research	Interdisciplinary research combines two or more academic disciplines into one activity (e.g., a research project). We use a citation-based approach to measure interdisciplinarity. The basic principle behind our approach is that, if a paper cites others that are "far away" from it in terms of topic and hence position in the overall citation network, it is likely to be interdisciplinary. We use this methodology to assign an interdisciplinary score to each paper, and then focus on the top 10% of papers with the highest interdisciplinary scores.
International collaboration	International collaboration in this report is indicated by papers with at least two different countries listed in the authorship byline.
Inventor	An inventor refers to an applicant in international patent applications filed under the Patent Cooperation Treaty (PCT). Inventor country is understood as the country of residence.

108 <http://projectcounter.org/>
<http://usagereports.elsevier.com/asp/main.aspx>

Journal	A journal refers to a peer-reviewed periodical in which scholarship relating to a particular research field is published, and is the primary mode of dissemination of knowledge in many fields.
Leadership	Traditionally, in some fields, if a researcher is a first or corresponding author on a paper, it is likely that his or her role is central to the research project in terms of execution, guidance, or funding. We can therefore analyze one aspect of leadership in research by identifying papers on which researchers are listed as first or corresponding authors.
Output or scholarly output	Output or scholarly output for a country is the count of papers with at least one author from that country (according to the affiliation listed in the authorship byline). All analyses make use of “whole” rather than “fractional” counting: a paper representing international collaboration (with at least two different countries listed in the authorship byline) is counted once each for every country listed.
Paper	A paper (unless otherwise indicated) refers collectively to the three main types of peer-reviewed documents published in journals: articles, reviews, and conference proceedings.
Patent	A patent is an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem. To get a patent, technical information about the invention must be disclosed to the public in a patent application.
Researcher	Throughout the report, we use “researchers” when referring to indicators that are based on author profiles containing all the information we have for each author, and use “authors” to refer to the ascribed authors for each paper.
Scholarly output share	Scholarly output share is the global share of papers for a specific country or region expressed as a percentage of the total global output. Using a global share in addition to absolute numbers of papers provides insight by normalizing for increases in world publication growth and expansion of the field in question or the whole Scopus database.

Appendix D

Subject Classification

Background on classification system

Titles in Scopus are classified under four broad subject clusters (Life Sciences, Physical Sciences, Health Sciences, and Social Sciences & Humanities), which are further divided into 27 major subject areas (ASJC, All Subject Journal Categories), and 300+ minor subject areas. Titles may belong to more than one subject area. In this report, we focus on the 27 ASJC level to ensure the analyses include enough papers to be robust.

Scopus 27 subject classification

<i>ASJC 27 subject classification</i>	<i>Broad cluster</i>
Multidisciplinary (journals like <i>Nature</i> and <i>Science</i>)	All
Agricultural & Biological Sciences	Life Sciences
Arts & Humanities	Social Sciences
Biochemistry, Genetics, & Molecular Biology	Life Sciences
Business, Management, & Accounting	Social Sciences
Chemical Engineering	Physical Sciences
Chemistry	Physical Sciences
Computer Science	Physical Sciences
Decision Sciences	Social Sciences
Dentistry	Health Sciences
Earth & Planetary Sciences	Physical Sciences
Economics, Econometrics, & Finance	Social Sciences
Energy	Physical Sciences
Engineering	Physical Sciences
Environmental Science	Physical Sciences
Health Professions	Health Sciences
Immunology & Microbiology	Life Sciences
Materials Science	Physical Sciences
Mathematics	Physical Sciences
Medicine	Health Sciences
Neuroscience	Life Sciences
Nursing	Health Sciences
Pharmacology, Toxicology, & Pharmaceuticals	Life Sciences
Physics & Astronomy	Physical Sciences
Psychology	Social Sciences
Social Sciences	Social Sciences
Veterinary	Health Sciences

