Gender Gape in Science in Japan

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Women have been significantly underrepresented in the workforce in Japan. Since the 1990s, the Japanese government has recognized gender imbalance in general employment as a serious social issue (GEBCO, 2014; Kato et al., 2012), but policy actions taken thus far seem to have limited effect. This is particularly the case in the enterprise of science. According to statistics in 2010, the percentage of female academic researchers (*%female*, hereafter) in the Japanese higher education sector is 25%, which is the smallest among the G7 countries (UK: 44%, Italy: 39%, USA: 36%, Germany: 36%, France: 33%, Canada: 33%).[1]

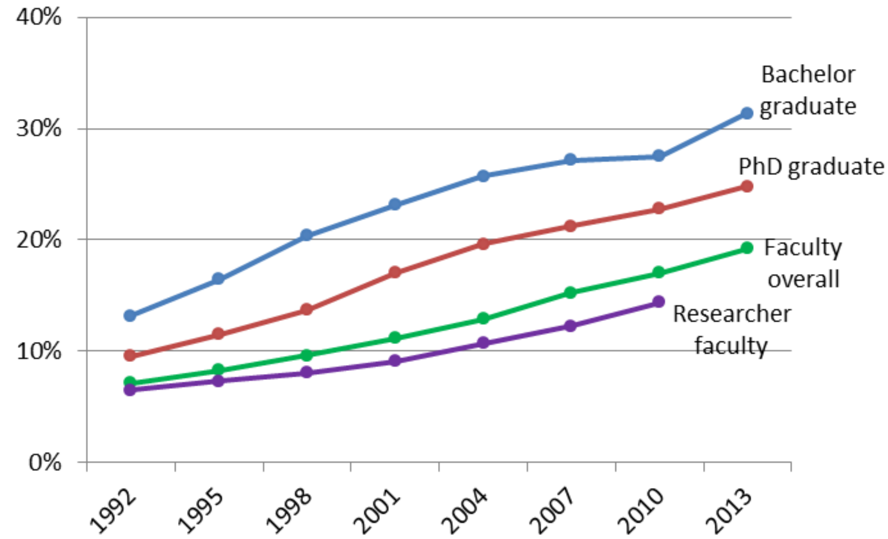
This study provides the first complete analysis of gender representation in STEM (science, technology, engineering, and math) fields in Japan, drawing on novel career data of Japanese researchers constructed from PhD dissertation and national research grant databases, with which we identified all researchers who earned PhD degrees in 1984-2004 and follow their academic career up to 2012. Our approach addresses typical limitations in previous gender analyses. First, by identifying cohorts of academics who earned PhD degrees in the same year, we examine at which career stage and in which cohort gender imbalance tends to occur. Second, we control for various confounding factors (e.g., performance, organizational prestige) that might be correlated both with gender and careers. Third, we focus on "researchers" who actually engage in scientific research, excluding academics who spend most of their time on other duties (e.g., teaching).

Snapshot statistics. Aggregate national statistics[2] of Japanese academic researchers show that %female of bachelor graduates in 2013 is nearly 50% but that of PhD graduates is 30%. While new employment in entry positions[3] in the same year is 30%, only 22% of associate and 14% of full professors in service are female.

Focusing on STEM fields (excluding social sciences and humanities), the latest statistics indicate significantly lower %female with 31% of bachelor graduates, 25% of PhD graduate and 17% of females in the overall faculty (Figure 1). When we look at %female among research-active faculty (defined as faculty members who received funding from the Grants-in-Aid (GiA) national research program) the value is consistently smaller than that of overall faculty that includes teaching staff. Compared to the 1990s, gender gap has been mitigated at all levels, which appears to be largely attributed to females' greater college attendance.[4] Nonetheless, these figures lag behind other developed countries; for example, as of 2010, %female of STEM PhD graduates was 50% in the US, 39% in the UK, and in 44% in Germany;[5] %female of overall faculty was 39% in the US.[6]

[1] Source: Eurostat for European countries, NSF Science and Engineering Indicators 2014 for the US, National Survey on Science and Technology Research for Japan, and Strengthening Canada's Research Capacity for Canada (2008-2009). The definition of researchers slightly differs between countries. Roughly speaking, it refers to people engaging in research activities in the higher-education sector. PhD students are included for Japan and Europe but not for the US and Canada.
[2] Source: School Basic Survey and School Teachers Survey, both administered by Ministry of Education, Culture, Sports, Science and Technology (MEXT).
[3] Entry positions include assistant professors, assistants, and lecturers.
[4] %Female for the four levels increased by similar factors (i.e., annual growth rates = 4.2, 4.6, 5.0, and 4.5%, respectively).
[5] Source: Eurostat. Science, Mathematics & Computing, Engineering, Manufacturing & Construction, Agriculture & Veterinary, and Health & Welfare are considered STEM.
[6] NSF Science and Engineering Indicators 2014.

Figure 1 **Trend of %Female in STEM Fields**



Source: School Basic Survey for bachelor graduates and PhD graduates, and *School Teachers Survey* for the overall faculty. Since the latter is conducted every three years (while the former every year), the data is presented with the three-year interval. The statistics do not allow breakdown by academic ranks. Both statistics distinguish 10 scientific fields, of which Science, Engineering, Agriculture, and Medicine & Healthcare are regarded as STEM while Humanities, Social Sciences, Mercantile, Family and Consumer Sciences, Education, and Art are excluded. *Researcher faculty* is defined as faculty members who received Grants-in-Aid during three years preceding each year.

Cohort analysis. We focus on four cohorts of researchers, who earned PhD degrees between 1985 and 2004 with five-year windows, and follow their research careers up to 2012 drawing on the GiA database. As GiA is the fundamental funding source of academic research in Japan (Iida, 2007: Ch.6), we regard no grant record as a sign of research inactivity.

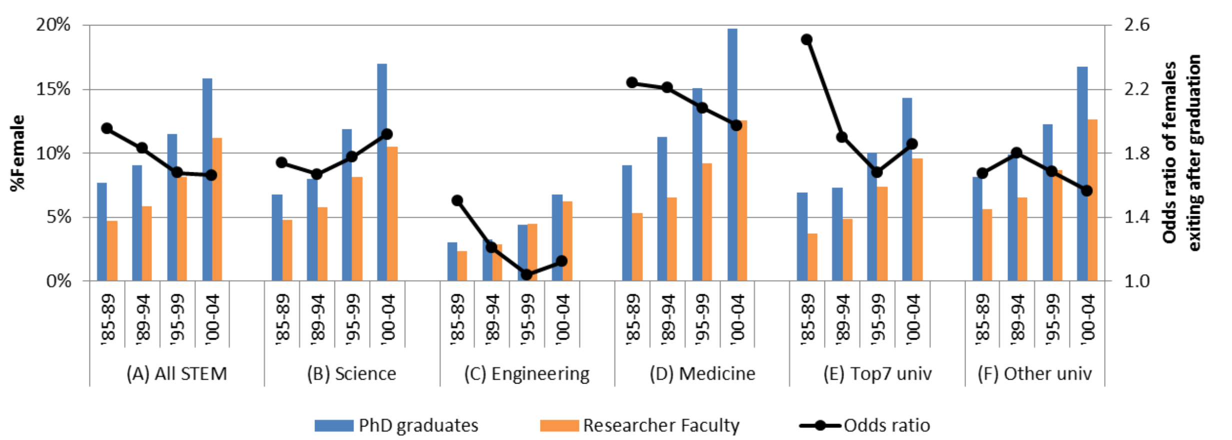
First, we examine how the extent of gender representation has changed since the 1980s by comparing the four cohorts. Figure 2 presents %female of PhD graduates and research-active faculty members (i.e., those that received at least one GiA grant) and the odds ratio of females' exiting before obtaining a faculty position, estimated by regression analyses controlling for various factors. Across all STEM fields (Figure 2A), increasing %female in both groups and a decreasing odds ratio of females' exit suggest that the gender imbalance has been mitigated over the 20 years. Nevertheless, %female of researcher faculty is consistently lower than that of PhD graduates. In contrast to the recent statistics, which did not distinguish researchers from teachers and indicated no gender bias in new employment, our result implies that female graduates are more likely to leave academia, or even if staying in academia, less likely to become independent researchers.

A field breakdown suggests that the nature of gender imbalance considerably differs between disciplines (Figures 2B-D). Medicine, the largest STEM field,[7] shows greater %female than other fields both for PhD graduates and for researcher faculty, but the odds ratio is also highest. Thus, Medicine attracts a substantial number of females, but they are less likely to continue in an academic research career. Nevertheless, the gender imbalance seems decreasing. In contrast, Engineering shows significantly smaller %female but the odds ratio has been lowest, suggesting that gender gap is largely introduced before the academic career starts. In Science, %female at both levels have more than doubled in 20 years, but the odds ratio has actually increased.

[7] Medicine, Engineering, and Science account for 35%, 29%, and 18% of all STEM PhD graduates for the 2000-2004 cohort.

Thus, employment of female researchers has increased but fallen short of the increasing female PhD graduates. Unlike Medicine and Engineering, where non-academic jobs are common, Science graduates are supposedly more susceptible to the academic employment condition. Thus, the fact that employment in Science is becoming unfavorable to females warrants much attention for future academic policy design.

Figure 2 Pre-Employment Exit by Cohort



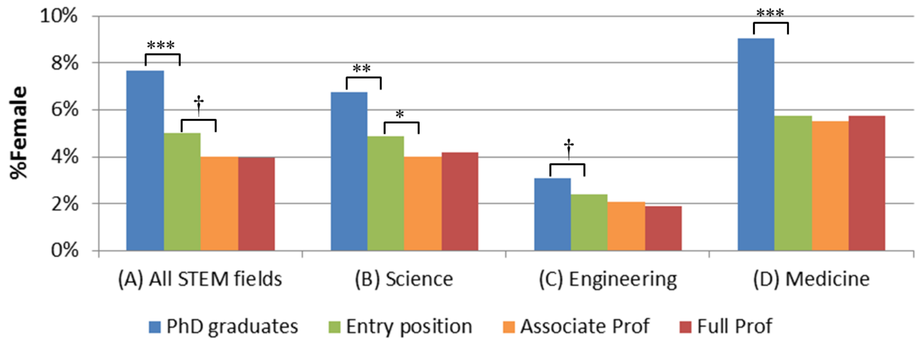
Notes: %Female of PhD graduates (blue bar) and %female of researcher faculty member (orange bar) are indicated. The latter is proxied by PhD graduates who were nationally funded at least once within eight years from graduation. In other words, we consider that PhD graduates leave academic research careers if they had never been funded within eight years. We also compute the odds ratio of females' exiting research careers without obtaining faculty positions (black line) based on regression analyses (Supplementary Document S2A). Odds-ratios greater than one suggest that females are more likely to exit than males, while odds-ratios smaller than one suggest that females are less likely to exit. We also run separate regressions for three fields and two university groups (Supplementary Document S2B/C). In this analysis, we traced career information for eight years after graduation. For sensitivity analysis, we repeated the same procedure for the cohorts of 1985-1989, 1990-1994, and 1995-1999 with following 13-year career information. As expected, this results in lower exit but the prediction of odds ratios is not significantly affected (Supplementary Document S2D).

Further, we break down PhD-granting universities into the prestigious top-seven universities and others (Figures 2E-F).[8] The top seven produce 30-40% of all PhDs and employ 40-50% of research-active faculty, but their %female has been consistently smaller at both levels compared to other universities. Also, the odds ratios have been decreasing, but they are significantly higher for the top seven 7 institutions.

Next, we focus on a single cohort of academics who graduated between 1985 and 1989 and follow their researcher career for 20 years.[9] Figure 3 illustrates %female at four career stages from PhD graduation to full professorship. Aggregating all STEM fields, we find that %female was very low (7.8%) from the beginning of the career and significantly decreased before the placement to entry positions. While the promotion to associate professor is weakly gender-biased, promotion to full professor appears unbiased. Breaking down scientific fields, we find that the placement to entry positions is the major hurdle for females in all three fields, only in Science promotion to associate is associate to further gender imbalance. Note however, the extremely small share of female associate and full professor.

[8] Top seven universities are pre-imperial national universities and have been in prestigious status.
[9] We chose this cohort to have a long enough time span to be able to follow researchers' career till full professorship.

Figure 3 **Exit by Career Stage (1985-89 cohort)**



Notes: The likelihood of exit is estimated by regression analyses with controlling for various factors, respectively at three career stages: (1) after PhD graduation and before placement to entry positions, (2) before promotion to associate professor, and (3) before promotion to full professor. For (1), we use the same regressions as for Figure 2. The setting of regression analyses for (2) and (3) is explained in Supplementary Document S3. The statistical significance of gender bias is indicated by †$p<0.1$; * $p<0.05$; ** $p<0.01$; *** $p<0.001$. The entry position includes assistant professor, lecturer, and assistant.

Figure 4 further investigates the career trajectory of the same cohort. Figure 4A indicates that promotion is slower for females than for males in general; for example, 50% of male researchers who earned entry positions took 11 years since graduation to become associate professor while females took 15 years. Females also tend to end their career in lower ranks; among those who remained as researchers after 20 years, 29% of females remained at the entry position compared to 13% of males.

Figures 4B-D break down fields. The exit slope is particularly steep in Medicine, probably because many medical PhDs eventually concentrate on clinical practices, and females are less likely to be promoted. In Engineering, the exit slope is rather flat, and exit in senior stages is not uncommon possibly because industry jobs are available. In Science, the exit slope is also flatter for both genders, but promotion is less likely for females.

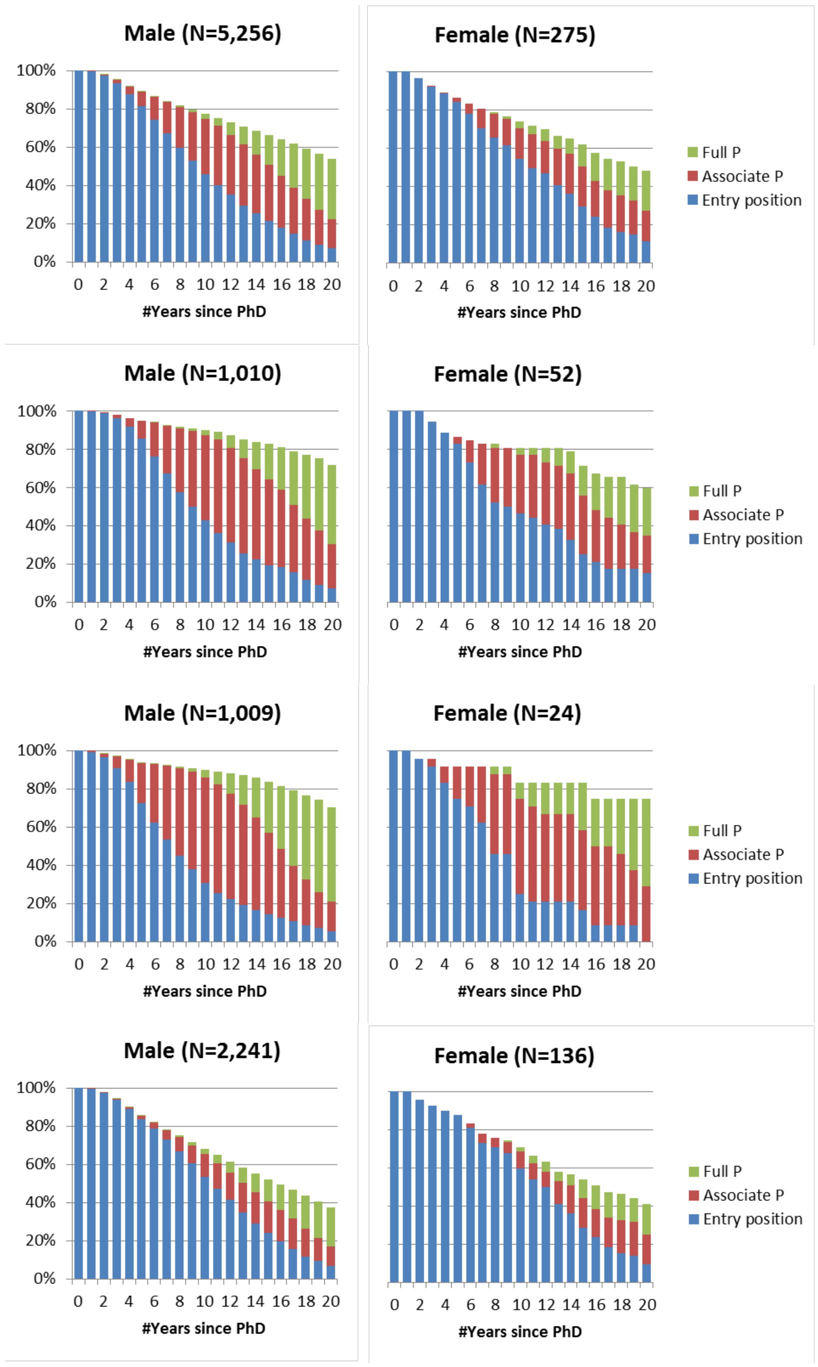
Figure 4 **Exit and Promotion**

(A) All STEM

(B) Science

(C) Engineering

(D) Medicine



Note: Academics who exited an academic research career without obtaining any faculty position are dropped from this analysis.

Conclusion. This study investigates gender representation in science in Japan by following the researcher career of cohorts of Japanese researchers in STEM fields. Our data confirm that gender imbalance is more common in STEM fields than in non-STEM fields and imply that a researcher career is more gender-biased than a teacher career. We also observe that female under-representation has been mitigated since the 1980s, probably due to females' increasing enrolment to PhD programs, but still remains higher than in other developed countries. The intertemporal trend considerably differs by fields; while Medicine has become less gender-biased, Science has become more imbalanced. Though reducing, gender bias is particularly noticeable in the top 7 imperial universities. Focusing on a single cohort who earned PhD degrees in the 1980s, we find that placement to entry positions was the major source of gender imbalance, while promotion to senior positions was less responsible. Still, female academics took longer for promotion and accounted only for 4% of full and associate professors. From the available data, we cannot fully identify how and if a gender bias is introduced; while the decisions on the side of employers might be biased, female researchers might self select out of an academic research careers. Nevertheless, our result implies a substantial gender imbalance even though recent years have seen some improvement. Considering that the improvement seems largely attributed to the increase in females' PhD enrolment, and that in Science entry odds ratios for female have actually decreased, government's effort to support female *researchers* thus seem to have had a very limited impact. Thus, further proactive policy actions are needed to achieve gender neutrality in science.

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