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Unveiling gender imbalances among PhD students: early inequalities in productivity and impact influenced by supervisor-student gender combinations

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Introduction: Gender imbalances in academia are found globally. Even though women earn the same rate of PhD degrees, the gender imbalance becomes increasingly prominent at higher academic levels. Several reasons have been proposed for these differences, including family responsibilities, disparities in the number and size of grants awarded, invitations to present at conferences, and differences in promotions and grant allocations, all favoring men. However, these factors should be less pronounced or even absent at the PhD student level.

Method: This paper investigates whether a gender imbalance exists in scientific production and research impact, measured by the number of publications, citations, and overall publication impact, among a cohort of Swedish medical and health science PhD students. It also explores whether this possible difference is further influenced by the gender of the PI.

Results: The results show significant differences in PhD student productivity depending on both the gender of the student and the PI, evident even at this early career stage.

Discussion: The results suggest a consistent gender pattern where female PhD students with female PIs are less productive and have a lower research impact, and PhD students with female PIs receive fewer citations.

KEYWORDS

gender equality, higher education, doctoral studies, supervision, PhD student

1 Introduction

It is widely established that there is a global gender imbalance in the ratio of full professors in favor of men. Despite many initiatives to address this gender imbalance, it persists and contributes to inequalities in hiring, earnings, funding opportunities, job satisfaction, and patenting (Larivière et al., 2013). Another way this imbalance is reflected is through looking at research productivity. Many papers have focused on productivity among male and female academics overall, where a consistent gender productivity gap has been observed (van Arensbergen et al., 2012; Larivière et al., 2013; West et al., 2013;

Cameron et al., 2016; Raj et al., 2016; Astegiano et al., 2019; Huang et al., 2020; Staniscuaski et al., 2021). However, it has been suggested that women's lower productivity rate is offset by higher citation counts, but there is no consensus on this matter (Larivière et al., 2013) and different citation patterns have been seen in different countries (Thelwall, 2018).

Several reasons have been proposed for this productivity gender gap. Among the suggested reasons are family choices, the fact that women obtain fewer and smaller grants, and that they are less frequently invited to give keynote talks, attend workshops, participate in strategic research proposals, or write comments in high-profile journals (Filipsson, 2011; Thompson et al., 2011). In line with these explanations overall differences have also been associated with the cumulative advantages of the Matthew effect or disadvantages of the Matilda effect (Merton, 1968; Rossiter, 1993).

These reasons occur less frequently at the PhD student level. Even so, differences have been observed at this early level as well. Several papers have noted that female PhD student publish less frequently than their male counterparts (Roksa et al., 2022). In a study comprising PhD students in chemistry it was suggested that female student who worked with female PIs were more productive (Gaule and Piacentini, 2018). In a similar study it was seen that female PhD student with male PIs were less productive than PhD students with same gender PIs (Rossello et al., 2023). Another study observed a lower productivity rate among female PhD students; however, this pattern did not persist when examining first-authorship contributions (Roksa et al., 2022). Even in awardees of the same grant (NSF Graduate Research Fellowship Program) female PhD students were seen to publish less papers, despite grants being meritocratically awarded (Graddy-Reed et al., 2019). Results around this subject are not always in agreement and seem to be somewhat context dependent. In a larger study it was found that the most productive PhD students had a mid-career female PI that herself was highly productive (Corsini et al., 2022). These gender differences have in turn been attributed to differences in collaborative and PI behavior (Lindahl et al., 2021). Another paper studying natural science and liberal arts PhD students in Israel, however, did not find any differences that could be attributed to the PIs, even though a gender gap was found, but only persistent in single-author papers (Yair, 2009).

This paper explores the impact of gender imbalance on research productivity, citation counts, and publication impact among PhD students and their principal investigators. It extends the current knowledge around this productivity gender gap of PhD students and investigates the combined effect of the PhD student-PI gender combination. While previous studies have primarily focused on productivity in terms of publication count, utilizing a sample of Swedish PhD students in medical and health sciences, this paper also extends the analysis to include citation counts and impact factor. The results suggest a consistent gender pattern: female PhD students with female PIs are less productive and have lower impact, and PhD students with female PIs receive fewer citations.

2 Materials and methods

To answer the research questions, a quantitative study of PhD students at a Swedish university was performed.

2.1 Sample

Gender, as inferred from the first names of 367 PhD students and their PIs, was analyzed manually in relation to doctoral dissertations. This method has been successfully used in prior research (Gaule and Piacentini, 2018). Any name that could not be assigned to a specific gender was omitted. Only a handful of people could not be specified using this method. From this cohort, 222 doctoral dissertations were randomly selected and further studied to investigate the productivity and impact of their research within their fellow research community of each PhD student during their PhD studies. Their publication information can be accessed in DiVA, a Swedish repository for research publications and reports (DiVA - Digitala Vetenskapliga Arkivet, 2016).

PhD theses were chosen as study subjects because the PhD defense represents a common career milestone for all students. Later in the academic career, it is harder to find such a time point. Even though a certain number of years may have passed since the defense, some individuals may have taken leave while others did not, leading to differences in their time in academia. This is also a period when several proposed factors contributing to lower scientific output among women have not yet taken effect. Previous research has identified collaboration and co-authoring with the supervisor as key factors influencing PhD student productivity (Lindahl et al., 2021).

2.2 Productivity

To investigate the productivity of each PhD student during their studies, the total number of research or review papers, the number of first-author papers, and the number of co-authorships has been analyzed. All papers listed in the thesis as primary or supplementary articles have been included in this study. To find additional articles not listed in the thesis, a search was conducted for each student's and supervisor's publications in ISI Web of Knowledge (Web of Science, n. d.). All articles published during the PhD studies have been included. Publications listed as submitted manuscripts in the thesis were also included if they had been published by the time of data collection in 2016, even if they were published after the PhD defense.

The total number of research and review articles serves as a measure of the PhD student's productivity. The number of first authorship articles also indicates the productivity of the PhD student, as these are the papers where the student has contributed the most (Lapidow and Scudder, 2019). Additionally, shared first-author papers, as indicated in the theses, were counted as first-author contributions, regardless of the student's position in the author list. The number of papers in which the PhD student is listed as a co-author indicates the extent of their involvement in collaborative projects. Previous research has shown a correlation between the degree of collaboration and the productivity of a PhD student (Lindahl et al., 2021).

In this study, only research articles and review articles were included, while book chapters and conference abstracts produced by the PhD students were not. This is because these publication types are less significant in the field of medical and health sciences. This is also confirmed by the fact that none of the theses were based on such publications. Publications clearly linked to research conducted before the PhD studies, based on their topics and co-authors, were omitted from this analysis.

2.3 Research impact

The research impact on the academic community has been investigated by collecting data on the number of citations each publication had accumulated by the time of data acquisition. The number of citations has previously been used as a proxy for the impact of a researcher's work (Broström, 2019). This measure has some inherent limitations, for example, a paper might not always be cited because it is valuable (Aksnes et al., 2019). However, as citation numbers are still used to evaluate individual researchers' performance, e.g., allocation of funding or position (Hicks et al., 2015), it is still of interest to compare. The citation data were collected through a search of each published article in the common database of ISI Web of Knowledge (Web of Science, n. d.). Self-citations are included in the citation counts. All articles that can be found in the database also include citation data. The total number of citations for each PhD student was calculated, along with the number of citations for first-author papers only.

Citation data are gaining increasing importance in the evaluation of researchers and scientific research as a whole, as indicated for example, by a researcher's h-index or a journal's impact factor. Several different ways of normalizing the counts to equalize the citation patterns within different fields have been proposed (Waltman, 2016). This study focuses on basic citation counts, including both total citations (a size-dependent measure) and average citations per paper (a size-independent measure). The data have not been normalized for several reasons. First, research has shown that differences between academic fields are greater than differences within subfields (Rørstad and Aksnes, 2015). This paper investigates the publication patterns within a medical faculty and is thus only comparing data within a single field. Second, research has shown that normalization methods can yield vastly different results, and there is no consensus on the best approach (Thelwall, 2018). Third, unnormalized citation counts are frequently used to compare individuals, e.g., when assessing applications for positions or grants based on an applicant's h-index or total citations (Hicks et al., 2015). Although this approach has been criticized as unfair, comparing raw citation counts remains valuable, as potential gender differences in these metrics may still influence career outcomes.

2.4 Impact factor

Information on the impact factor of each journal was collected from the Journal Citation Reports (Journal Citation Reports, 2016) for 2014, which was the most recent report available before data collection. If the information was unavailable, it was collected from ResearchGate (Researchgate, 2016). The impact factor of non-indexed journals was set to zero. After determining the impact factor for each published paper, the values were summed into a total called 'impact points,' including all papers published by each student. A similar calculation was performed, considering only first-author articles.

The impact factor is a somewhat controversial metric (Aksnes et al., 2019). However, like citation counts, it is frequently used in decisions related to funding allocation and the awarding of bonuses to researchers who publish in high-impact journals (Hicks et al., 2015). For this reason, and despite the fact that some medical subfields more easily publish in high-impact journals, I find it relevant to examine individual differences in publication patterns with respect to impact factor.

2.5 Descriptive statistics

Descriptive data for the independent variables are collected in Tables 1, 2. For visual comparison this data are also plotted and visualized in Supplementary Figures 1-3.

2.6 Data analysis

To analyze the data regression analysis was used. Such econometric methods are widely used in studies examining complex relationships between variables such as research productivity, citation counts, and academic impact, especially when dealing with cross-sectional or panel data. The data in this study, which involves multiple observations of PhD students and their respective PIs, fits naturally with econometric approaches that can handle hierarchical and clustered data effectively.

One of the key strengths of econometric techniques, particularly regression analysis, is their ability to simultaneously assess the impact of multiple variables and their interactions. This study, aimed to explore the combined effect of gender imbalances between PhD students and PIs on research outcomes. Econometric methods allows to account for these intricate interactions, providing a clearer understanding of how these factors jointly influence research productivity, citations, and impact.

SPSS was used to analyze the data and GraphPad Prism was used to visualize the results. Count data was analyzed by Poisson or binomial negative regression where appropriate. Continuous data was analyzed by gamma regression. Three different dependent variable types were studies, productivity, research impact and impact factor.

The effect of two independent variables, gender of the PhD student and the PI, and the interaction of these, was investigated. In case of cross-over interaction I also include the interaction term alone. The independent variables were coded as dummy variables where male = 0 and female = 1 in both cases.

A chi-square test, where differences between two distributions were compared, was also performed. Alpha levels used are 0.05 (*), 0.01 (**), and 0.001 (***).

2.7 Research ethics

This study has no ethical implications. No human subjects were directly involved in this study. No data can be related back to any person, and the collected data are all from public sources.

TABLE 1 Descriptors for the independent variables sorted in groups of students and PIs including means and standard deviations within parentheses.

	Male students	Female students	Male PI	Female PI
Productivity				
Total no of papers	5.51 (2.13)	5.00 (1.84)	5.38 (2.01)	5.03 (1.97)
First author papers	3.39 (1.54)	3.17 (1.22)	3.20 (1.35)	3.35 (1.4)
Co-author papers	2.12 (1.98)	1.83 (1.67)	2.17 (1.81)	1.68 (1.79)
Scientific impact				
Total no of citations	135.61 (213.77)	129.42 (120.49)	146.03 (197.33)	113.26 (114.38)
Average citations per paper	23.61 (39.84)	25.75 (21.62)	26.91 (21.95)	21.95 (21.07)
Total no of citations first author papers	52.74 (42.71)	61.19 (49.81)	59.57 (50.70)	54.60 (41.25)
Average citations per first author papers	16.12 (13.63)	20.83 (20.39)	19.99 (20.41)	17.07 (13.52)
Impact factor				
Total impact factor	22.57 (17.95)	20.77 (15.38)	23.05 (17.01)	19.54 (15.76)
Impact factor first authorships	11.86 (7.77)	11.24 (8.32)	11.92 (8.09)	10.97 (8.05)

TABLE 2 Descriptors for the independent variables sorted in groups of student-PI pairs including means and standard deviations within parentheses.

	Male student male PI	Male student female PI	Female student male PI	Female student female PI
Productivity				
Total no of papers	5.43 (2.15)	5.66 (2.13)	5.32 (1.89)	4.66 (1.74)
First author papers	3.33 (1.37)	3.49 (1.84)	3.08 (1.33)	3.27 (1.1)
Co-author papers	2.10 (1.91)	2.17 (2.11)	2.25 (1.71)	1.39 (1.52)
Scientific impact				
Total no of citations	143.38 (248.83)	121.63 (130.99)	148.60 (131.44)	108.29 (104.18)
Average citations per paper	25.71 (48.01)	19.82 (17.46)	28.06 (20.19)	23.21 (23.00)
Total no of citations first author papers	53.89 (45.60)	50.69 (37.48)	65.08 (54.99)	56.91 (43.47)
Average citations per first author papers	16.59 (14.67)	15.29 (11.68)	23.28 (24.41)	17.76 (14.50)
Impact factor				
Total impact factor	21.88 (18.01)	23.81 (18.03)	24.17 (16.05)	17.02 (13.79)
Impact factor first authorships	11.59 (7.62)	12.34 (8.11)	12.23 (8.57)	10.15 (7.97)

3 Results and discussion

Academia is a highly competitive environment where publishing in high-ranked journals and the resulting impact, measured in citations, on the broader research community is increasingly important for receiving grants and securing faculty positions.

Even though women are the majority in all other major academic position categories within the Swedish medical faculty under investigation, they remain a clear minority among professors, representing only 28% at the time of data collection. It is evident that there is no simple explanation for the underrepresentation of women in higher academic positions. According to the theory of meritocracy, which posits that only merit should determine success, such a large difference would not be expected (Nielsen, 2016). If we accept that this disparity is not due to an inherent biological factor, such as intelligence, then it must stem from other factors. The tendency in Sweden for academics to remain in the department where they completed their PhD is more common than in many other countries, increasing the likelihood that factors other than merit influence academic promotions and hiring (Elg and Jonnergard, 2003).

3.1 Female PIs supervise disproportionally many female PhD students

Among the 367 PhD sample, the majority, 212, or 58%, were female, and 155, or 42%, were male. Of these students, 121, or 33%, had a female PI, and 246, or 77%, had a male PI. Of the female students, 85 (70%) had a female PI, while 36 (30%) of the male students had a female PI. Conversely, 127 (52%) of the female students and 119 (48%) of the male students had a male PI (Figure 1).

A statistically significant difference is observed between the gender distribution of students with male versus female PIs. While

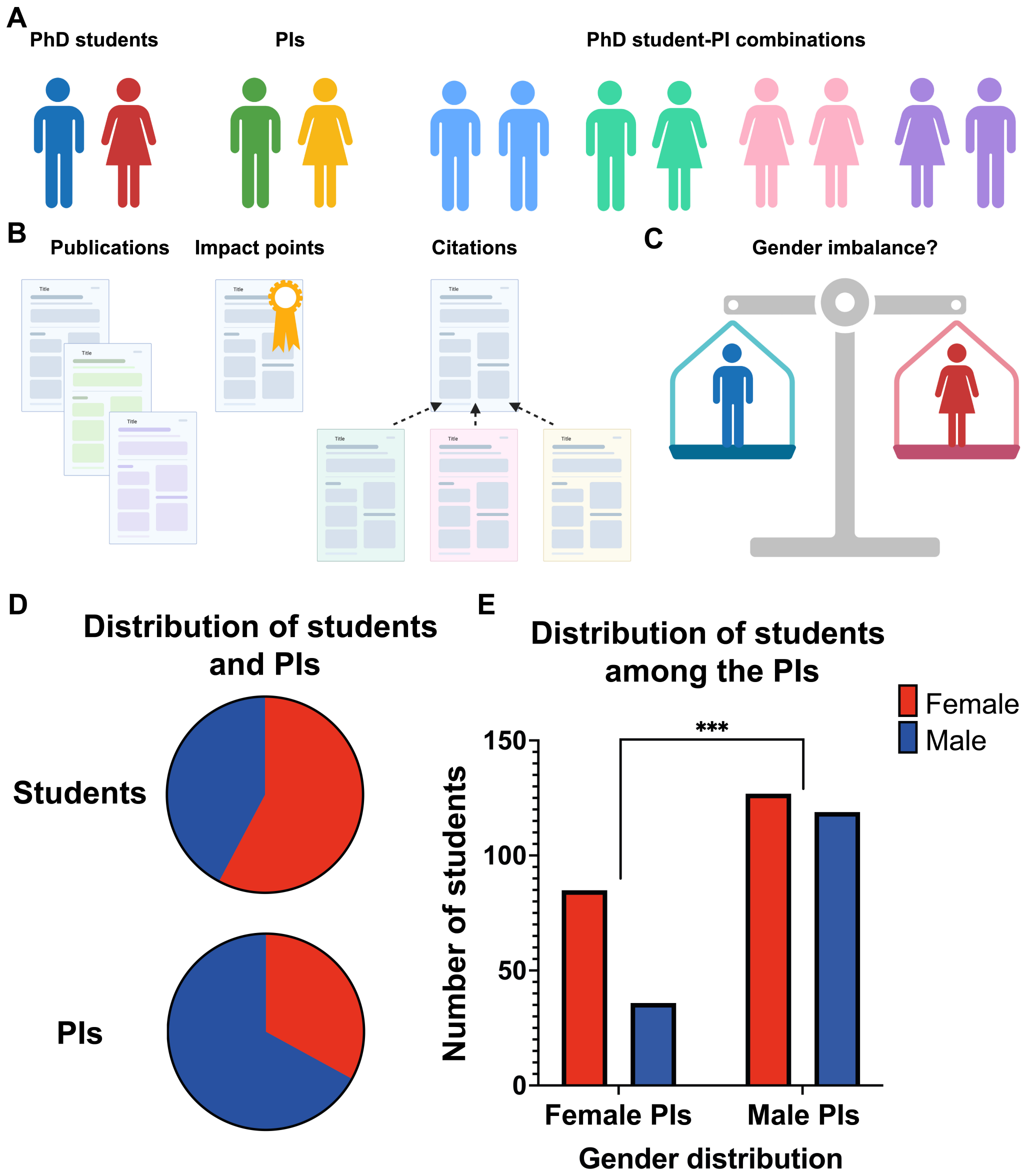

FIGURE 1
Study design and sample. **(A)** PhD students, PIs and the combination of PhD students and Pi gender has been investigated. **(B)** As a proxy for productivity, the number of publications, impact points, and citations was used. **(C)** The presence of a gender imbalance in academic productivity at the PhD student level was investigated. **(D)** The gender distribution among the students and PIs included in this study. **(E)** The gender distribution of PhD students in relation to the gender of the PI. Alpha levels used are 0.05 (*), 0.01 (**), and 0.001 (***).

the gender distribution of students with a male PI was nearly equal (52% female, 48% male), the gender distribution of students with a female PI was significantly skewed (70% female, 30% male).

This suggests that while male PIs tend to hire an equal number of male and female PhD students, female PIs preferentially hire female PhD students. In a study investigating U.S. chemistry PhD students, it was also similarly seen that female students were more likely to be supervised by a female PI than male students (Gaule and Piacentini, 2018). The causal factors behind this cannot be determined from the collected data; however, speculatively, several factors related to both the PhD student and the PI may play a role. Female prospective PhD students may preferentially apply for positions with female PIs, leading to a skewed applicant pool and increasing the likelihood of hiring a female student. It has been seen that male and female PhD candidates have different expectations and concerns about their PhD (Gaule and Piacentini, 2018), and this will likely affect their choice of which positions to apply for. This difference could also be attributed to the similar-to-me effect (Rand and Wexley, 1975). It is known that people prefer to hire people who are similar to themselves (Rivera, 2012). While men often preferentially hire men, this effect was not observed in this dataset. However, women did exhibit a preference for hiring other women. Surprisingly, the female PIs in this study exhibited stronger homosocial behavior than their male counterparts This might be because the situation of the female PIs is possibly more uncertain than that of the male PIs. Although not directly investigated in this study, female PIs are likely to hold lower academic positions than their male counterparts. As a result, they may not yet be as secure or established, both financially and within their institutions, as their male colleagues. This can be a reason to seek a student more similar to oneself, as this will ensure a more stable and easy relationship with more mutual understanding. The perception of a less complicated student-supervisor relationship may provide a sense of security and, more importantly, represents a factor they can control in an otherwise uncertain situation influenced by external factors beyond their control.

3.2 Scientific productivity

To investigate the productivity among PhD students, the total publication counts, the number of first authorships, and the number of co-authored papers were analyzed. The regression results are presented in Table 3.

A total of 222 PhD theses were analyzed to investigate possible differences in research impact and productivity depending on the gender of the PhD student, the PI, or the combination of both (Figure 1). Of these students, 94 had a female PI, and 128 had a male PI.

The data indicate a trend in which both female PhD students and those with a female PI are less productive in terms of the total number of papers produced. This difference becomes statistically significant when examining the interaction between PhD student and PI gender, where female PhD students with a female PI have produced significantly fewer publications than other PhD students.

Following these results, an investigation into whether this difference was attributed to differences in the number of first authorship papers produced was conducted, as previous studies had suggested such a difference might exist (Gannon et al., 2001). However, this data does not indicate that there are any differences attributed to the number of first authorship papers produced by the PhD students regardless of their own or their corresponding PIs gender. In this dataset, female PIs produced 5% more first authorship papers than their male counterparts; however, female PhD students produced fewer than male students.

The differences likely stem from the number of co-authored papers in which the PhD student is not the first author. Indeed, the data indicate a difference between male and female PIs, with female PIs producing significantly fewer co-authored papers. When investigating the interaction between the PhD student and PI genders, it could be seen that female PhD students with a female PI produce significantly less co-authored papers. Hence, the differences observed when it comes to productivity, lies in the fact that female PhD students with female PIs this sample, produce less collaborative co-authored papers. This is somewhat in line with previous findings that indicated that the number of collaborators is an important indicator of productivity, where PhD students with more collaborators, as measured by the number of co-authors on a paper, was more productive (Lindahl et al., 2021). These results might also indicate that gendered networking is influential, where men more often take part in gender-exclusive networking activities that translate into concrete advantages such as publishing opportunities (Murphy et al., 2022).

A slight difference in research subjects within the subfields of medicine and health science was observed between female PhD students with a female PI and other PhD students, which may partially contribute to the observed differences. However, no subfield stands out in being particularly underperforming. Nevertheless, this suggests that female PhD students may have different preferences in research subject choices, which might influence their future academic career opportunities.

The slightly higher number of first authorships among PhD students with female PIs may also reflect the overall smaller research groups and networks of female PIs, resulting in fewer collaborative research activities. Consequently, students may need to take on more major work tasks themselves to produce more papers. Nonetheless, this might be expected since the female PIs are found in less senior positions where they might not have obtained the same funding resources as well as group and network sizes as their more senior male counterparts.

Given the previous trends observed for the PIs and the PhD students in comparison, it is somewhat surprising that male PhD students with a female PI have the highest average number of publications as well as first authorships.

These results are in contrast to previous research that found that PhD students with a same-gendered PI were more productive (Gaule and Piacentini, 2018). However, they are in line with a previous case study performed at the California Institute of Technology where male students with female PIs were seen to publish more (Pezzoni et al., 2016).

Large-scale studies have found that PhD students with mid-career female PIs are the most productive in terms of publication output (Corsini et al., 2022). Since this dataset shows a bias in female PIs preferentially hiring female PhD students—attributed to the similar-to-me effect and a lower willingness to take risks—it is possible that female PIs who do hire male PhD students are more likely to be mid-career, where they may be more open to taking risks than at the beginning of their career.

3.3 Research impact

Next, this paper investigates whether there were any differences in scientific impact as measured by citations. This was done by analyzing the size-dependent total number of citations and citations per first-authored paper, as well as the size-independent average citations per publication and average first-author citations per first-authored publication. The regression results are collected in Table 4.

The data show that papers from PhD students with a female PI are statistically significantly less cited, and female PhD students with female PIs receive particularly low total citations. The total number of citations is a size-dependent measure that obviously increases more easily with a larger number of total publications. Therefore, these results are not particularly surprising, at least with regard to female PhD students with female PIs. However, male PhD students with female PIs have the highest number of papers in this dataset, but still not the highest number of citations. In addition, when analyzing the size-independent measure of average citations per publication, which is not dependent on the total number of papers produced, male PhD students with female PIs display the lowest numbers. There is also a statistically significant difference, where PhD students with female PIs have a lower average number of citations per paper.

TABLE 3 Regression results for the total number of publications (Coefficient, Significance, Estimate, 95% confidence interval for estimate).

Total no of papers	Model 1	Model 2	Model 3	Model 4
Student gender	−0.096 (0.104, 0.909, 0.810-1.020)	−0.055 (0.359, 0.946, 0.841-1.065)	−0.020 (0.797, 0.981, 0.844-1.139)	
Supervisor gender		−0.089 (0.133, 0.915, 0.814-1.027)	0.041 (0.644, 1.042, 0.875-1.241)	
Student gender + Supervisor gender interaction			−0.174 (0.148, 0.840, 0.664-1.064)	−0.154* (0.026, 0.858, 0.749-0.982)
First authorship publications	**Model 1**	**Model 2**	**Model 3**	
Student gender	−0.067 (0.371, 0.936, 0.808-1.083)	−0.073 (0.330, 0.930, 0.802-1.077)	−0.080 (0.418, 0.923, 0.761-1.120)	
Supervisor gender		0.054 (0.475, 1.055, 0.910-1.224)	0.045 (0.695, 1.046, 0.837-1.307)	
Student gender + Supervisor gender interaction			0.017 (0.914, 1.017, 0.755-1.370)	
Co-authorship publications	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Student gender	−0.284 (0.264, 0.753, 0.457-1.2239)	−0.306 (0.218, 0.736, 0.452-1.199)	0.151 (0.662, 1.163, 0.591-2.287)	
Supervisor gender		−0.504* (0.037, 0.604, 0.376-0.971)	0.076 (0.852, 1.079, 0.486-2.401)	
Student gender + Supervisor gender interaction			−0.933 (0.069, 0.394, 0.144-1.075)	−0.782*** (0.001, 0.458, 0.285-0.735)

Poisson regression was run for the total no of papers and first authorship results, and negative binomial regression was run for the co-authorship results. Alpha levels used are 0.05 (*) and 0.001 (***).

Notably, when analyzing the size-dependent and independent measures for first authorship citations, the data indicate a dependence on PhD student gender, most evident in the average citations per first-authored paper, where female PhD students receive statistically significantly more citations than their male counterparts. Interestingly female PhD students with male PIs consistently display the highest number in both size-dependent and size-independent citation measures.

The number of citations appears to be more strongly linked to the gender of the PI, as both male and female students with a female PI display the lowest citation numbers. The number of citations is probably more dependent on the reputation and establishment of the PI than on the students themselves. In contrast, the first authorship citations are lower for male students regardless of PI gender, indicating the importance of the student's gender rather than the PI's.

The average citations per publication may be influenced more by PI gender, as both male and female students with a female PI have lower numbers of citations per publication. This number may be more dependent on the network and visibility of the PI than on the individual PhD student. On the other hand, a male student gender may be linked to a lower first authorship average number of citations per publication.

These numbers are inconsistent with some previous studies that have indicated that PhD students with female PIs received more citations (Larivière et al., 2013; Corsini et al., 2022), although this has not been found in every instance. In a study performed in France covering all STEM fields, PhDs found that having a productive, mid-career, low-experience, female PI was associated with more productive PhD students (Corsini et al., 2022). From the dataset of this paper, the status of the PI cannot be deduced, and it is possible that such trends would be visible here as well. Other studies align more with my results, reporting that papers with female authors in lead or senior positions received fewer citations, with papers authored by females in both lead and senior position receiving about half the number of citations as papers with male authors in both lead and senior position (Chatterjee and Werner, 2021).

Female PhD students have fewer total citations but more average citations and first-author citations, indicating that even though they have produced fewer papers, their work has had a slightly higher impact on the scientific community. Previous studies have found country-based differences between the number of average citations per paper authored by male or female researchers, where females were less cited and read in some less equal countries and more in others (Thelwall, 2018). Given that both the number of papers and citations are important in researcher evaluations, female PhD students remain at a disadvantage due to having fewer publications, which also results in fewer overall citations.

TABLE 4 Regression results for the total number of citations (coefficient, significance, estimate, 95% confidence interval for estimate).

Total no of citations	Model 1	Model 2	Model 3
Student gender	−0.047 (0.693, 0.954, 0.757-1.203)	−0.026 (0.822, 0.974, 0.773-1.227)	0.036 (0.816, 1.036, 0.767-1.400)
Supervisor gender		−0.252* (0.033, 0.777, 0.616-0.980)	−0.165 (0.368, 0.848, 0.593-1.212)
Student gender + Supervisor gender interaction			−0.152 (0.527, 0.859, 0.536-1.376)
Average citations per publication	Model 1	Model 2	Model 3
Student gender	0.095 (0.367, 1.100, 0.894-1.352)	0.123 (0.245, 1.131, 0.919-1.391)	0.087 (0.522, 1.091, 0.835-1.426)
Supervisor gender		−0.210* (0.048, 0.811, 0.658-0.999)	−0.260 (0.110, 0.771, 0.560-1.061)
Student gender + Supervisor gender interaction			0.087 (0.683, 1.091, 0.717-1.662)
Citations per first authorship publications	Model 1	Model 2	Model 3
Student gender	0.149 (0.158, 1.160, 0.944-1.426)	0.159 (0.132, 1.172, 0.953-1.442)	0.189 (0.169, 1.208, 0.923-1.580)
Supervisor gender		−0.103 (0.330, 0.902, 0.733-1.110)	−0.061 (0.941, 0.682-1.297)
Student gender + Supervisor gender interaction			−0.073 (0.930, 0.610-1.418)
Average first authorship citations per first authorship publications	Model 1	Model 2	Model 3
Student gender	0.241* (0.013, 1.273, 1.053-1.538)	0.255** (0.008,1.291, 1.069-1.559)	0.322** (0.01, 1.380, 1.080-1.765)
Supervisor gender		−0.180 (0.063, 0.836, 0.691-1.010)	−0.085 (0.572, 0.919, 0.685-1.233)
Student gender + Supervisor gender interaction			−0.164 (0.404, 0.849, 0.577-1.248)

Negative binomial regression was run for the total number of citations and number of first authorship citation results, and gamma regression was run for the average citations per publication and the average number of first authorship citations per first authorship publications results. Alpha levels used are 0.05 (*) and 0.01 (**).

3.4 Impact factor

Given the previous findings, this paper aimed to understand whether there were any differences regarding the total impact factor of the publications. A potential difference in the number of papers published may stem from differences in publication patterns regarding the impact factor. Fewer published papers may be offset by publishing more comprehensive papers in journals with a higher impact factor. The regression results are presented in Table 5.

The results show that there is a clear interaction effect between the PhD student and PI gender, where female PhD students with female PIs publish in journals with lower impact factors. This trend is evident both when analyzing the total impact factor, summing the impact factors of all published papers, and the summed impact factors of only the first-authored papers, although this trend only becomes statistically significant for the total impact factor. The fewer number of published papers from female PhD students with female PIs are thus not offset by publishing in journals with a higher impact factor. Again, female PhD students with male PIs are found instead at the top. Interestingly, male PhD students with female PIs are in second place, indicating the importance of the gender combination.

These findings are partially consistent with previous findings that showed, across all academic positions, that women publishing with a similar number of co-authors and in similar impact factor journals received fewer citations than their male counterparts in addition, it has been shown that the impact factor of a journal is negatively correlated with female representation as a lead or senior author (Bendels et al., 2018). The data of this study also follows these patterns.

Additionally, the peer review process commonly used in academia has been demonstrated to favor men in that both males and females are seen to value their achievements more highly (Larivière et al., 2013; Fox and Paine, 2019). This might be one of the reasons why I found a lower total summed impact factor for the female-female gender combination of PhD student and PI. In the absence of a male in either lead or senior authorship positions, the research produced by the women might be seen as less valuable, resulting in acceptance to a journal with a lower impact factor. It might also be the case that the females themselves are valuing their

TABLE 5 Gamma regression results for the total impact factor, first authorship impact factor, and co-authorship impact factor (coefficient, significance, estimate, 95% confidence interval for estimate).

Total impact factor	Model 1	Model 2	Model 3	Model 4
Student gender	−0.075 (0.430, 0.928, 0.770-1.118)	−0.073 (0.441, 0.930, 0.772-1.119)	0.100 (0.416, 1.105, 0.869-1.405)	
Supervisor gender		−0.153 (0.108, 0.858, 0.712-1.034)	0.084 (0.564, 1.088, 0.817-1.449)	
Student gender + Supervisor gender interaction			−0.418* (0.030, 0.658, 0.451-0.960)	−0.293** (0.006, 0.746, 0.606-0.918)
First authorship impact factor	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Student gender	−0.058 (0.494, 0.944, 0.799-1.114)	−0.054 (0.527, 0.948, 0.803-1.119)	0.053 (0.629, 1.055, 0.850-1.308)	
Supervisor gender		−0.074 (0.385, 0.929, 0.786-1.097)	0.076 (0.566, 1.079, 0.833-1.397)	
Student gender + Supervisor gender interaction			−0.261 (0.132, 0.771, 0.549-1.082)	−0.170 (0.074, 0.844, 0.701-1.016)

Alpha levels used are 0.05 (*) and 0.01 (**).

research as less valuable and therefore do not aim as high, in terms of journal impact factor, as their male counterparts.

The data suggest that students with a female PI, as well as female students, are less productive and impactful, and the combination of female students and female supervisors is seen as the least productive and impactful combination.

This was especially prominent when investigating the total number of produced papers and their summarized impact points, where female students with a female PI published significantly fewer papers than the other student-PI combinations or had significantly fewer impact points than female students with a male PI and male students with a female PI. This contradicts previous research where having a female PI was deemed of high importance for the success of a female PhD student (Acker, 2008).

Although this data cannot give any causal explanation for these findings, they are likely caused by a combination of factors, where the social environment (Broström, 2019), family responsibility (Ceci and Williams, 2011), and different career goals (Gino et al., 2015) may be influential. However, given that most Swedish PhD students are in their mid to late 20s, they are less likely to have started a family than more senior academics, and only 39% of all Swedish PhD students report that they have children under 18 years old living at home (Gröjer et al., 2016). As PhD students within the medical and health field also report that it is less acceptable to take parental leave compared to PhD students in other fields, it is likely that the number of PhD students with children is lower within this field. Thus, gender differences in family responsibility are likely not a major contributing factor to these results. Similarly, Swedish PhD student positions are almost exclusively financed by the PI, and thus gender differences in the ability to obtain funding should not be a major contributor either.

Differences in merits, other than publications, might make it harder for female faculty to allocate funding for research. The merit of showing mobility might, for example, be easier for male researchers to achieve, whereas female researchers, especially those having a partner or a family, may have a harder time relocating to another country (Fritsch, 2016). Additionally, the peer review process commonly used in academia has been shown to favor men through the fact that both males and females are seen to value their achievements higher (Larivière et al., 2013). This is an advantage for men over women both regarding the publication of research papers and in regard to applying for academic positions and funding. These might all be partially contributing factors explaining the results within this paper.

Future studies could explore the long-term impact of gender imbalances on academic career trajectories across different disciplines. By conducting longitudinal research that follows PhD students from their doctoral studies into their careers, it could be investigated whether early differences in research productivity and impact, linked to gender and PI relationships, persist throughout career progression, such as in the promotion to full professor roles or tenure-track positions. Moreover, such studies could be expanded to include various academic fields, including engineering, social sciences, and the humanities, to assess whether gender disparities are more pronounced in specific disciplines or academic environments.

Additionally, qualitative methods, such as interviews or surveys with PhD students and their PIs, could provide deeper insights into the reasons behind the observed gender disparities. These approaches could uncover underlying factors such as gendered expectations, biases in mentoring, and unequal access to networking opportunities, offering a more nuanced understanding of how gender influences research outcomes beyond what is captured through quantitative analysis alone.

4 Conclusion

This study has shown that there are differences in research productivity and impact emerging early on at the PhD student level.

These differences were related to both the gender of the student and the gender of the PI. A general trend was observed in the data, where both female students and students with a female PI were less productive, as determined by the number of published papers, and less impactful, as determined by the impact points and citations that the published papers had accumulated. Additionally, it was found that female students with female PIs published fewer papers than the other student-PI gender combinations and had fewer impact points than both female students with male PIs and male students with female PIs.

These results may provide an important clue as to why fewer women reach the professoriate. Research output and impact are widely believed to be key criteria for promotion, and poor research performance thus hinders women from obtaining full professorships (Gardiner et al., 2007). It is, however, surprising to find that women are lagging in research productivity and impact already at the PhD student level, where presumed and often cited factors, such as unequal family and household responsibility, have not yet fully emerged. This indicated that other lesser-known factors are at play and still need to be uncovered.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MA: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

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Supplementary material

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References

Acker, J. (2008). Helpful men and feminist support: More than double strangeness The metaphor of the stranger. *Work Organ.* 15, 288–293. doi: 10.1111/j.1468-0432.2008.00393.x

Aksnes, D. W., Langfeldt, L., and Wouters, P. (2019). Citations, citation indicators, and research quality: An overview of basic concepts and theories. *SAGE Open* 9:2158244019829575. doi: 10.1177/2158244019829575

Astegiano, J., Sebastián-González, E., Castanho, C., and Camila de Toledo Castanho C. (2019). Unravelling the gender productivity gap in science: a meta-analytical review. *R. Soc Open Sci.* 6:181566. doi: 10.1098/rsos.181566

Bendels, M. H. K., Müller, R., Brueggmann, D., and Groneberg, D. A. (2018). Gender disparities in high-quality research revealed by Nature Index journals. *PLoS One* 13:e0189136. doi: 10.1371/journal.pone.0189136

Broström, A. (2019). Academic breeding grounds: Home department conditions and early career performance of academic researchers. *Res. Policy* 48, 1647–1665. doi: 10.1016/j.respol.2019.03.009

Cameron, E. Z., White, A. M., and Gray, M. E. (2016). Solving the productivity and impact puzzle: Do men outperform women, or are metrics biased? *BioScience* 66, 245–252. doi: 10.1093/biosci/biv173

Ceci, S. J., and Williams, W. M. (2011). Understanding current causes of women's underrepresentation in science. *Proc. Natl Acad. Sci.* 108, 3157–3162. doi: 10.1073/pnas.1014871108

Chatterjee, P., and Werner, R. M. (2021). Gender disparity in citations in high-impact journal articles. *JAMA Netw. Open* 4:e2114509. doi: 10.1001/jamanetworkopen.2021.14509

Corsini, A., Pezzoni, M., and Visentin, F. (2022). What makes a productive Ph.D. student? *Res. Pol.* 51:104561. doi: 10.1016/j.respol.2022.104561

DiVA - Digitala Vetenskapliga Arkivet (2016). Available online at: https://www.diva-portal.org (accessed October 22, 2016).

Elg, U., and Jonnergard, K. (2003). The inclusion of female PhD students in academia: A case study of a Swedish University Department. *Gender Work Organ.* 10, 154–174. doi: 10.1111/1468-0432.00009

Filipsson, H. L. (2011). Not just family matters. *Nat. Geosci.* 4, 346–346. doi: 10.1038/ngeo1163

Fox, C. W., and Paine, C. E. T. (2019). Gender differences in peer review outcomes and manuscript impact at six journals of ecology and evolution. *Ecol. Evol.* 9, 3599–3619. doi: 10.1002/ece3.4993

Fritsch, N.-S. (2016). Patterns of career development and their role in the advancement of female faculty at Austrian universities: New roads to success? *High. Educ.* 72, 619–635. doi: 10.1007/s10734-015-9967-6

Gannon, F., Quirk, S., and Guest, S. (2001). Searching for discrimination. Are women treated fairly in the EMBO postdoctoral fellowship scheme? . *EMBO Rep.* 2, 655–657. doi: 10.1093/embo-reports/kve170

Gardiner, M., Tiggemann, M., Kearns, H., and Marshall, K. (2007). Show me the money! An empirical analysis of mentoring outcomes for women in academia. *High. Educ. Res. Dev.* 26, 425–442. doi: 10.1080/07294360701658633

Gaule, P., and Piacentini, M. (2018). An advisor like me? Advisor gender and post-graduate careers in science. *Res. Pol.* 47, 805–813. doi: 10.1016/j.respol.2018.02.011

Gino, F., Wilmuth, C. A., and Brooks, A. W. (2015). Compared to men, women view professional advancement as equally attainable, but less desirable. *Proc. Natl. Acad. Sci. U. S. A.* 112, 12354–12359. doi: 10.1073/pnas.1502567112

Graddy-Reed, A., Lanahan, L., and Eyer, J. (2019). Gender discrepancies in publication productivity of high-performing life science graduate students. *Res. Pol.* 48:103838. doi: 10.1016/j.respol.2019.103838

Gröjer, A., Wikström Öbrand, I., Elenäs, J., Gillström, P., Palestro, J., and Dryler, H. (2016). *Doktorandspegeln 2016 - en Enkät om Studenternas Studiesituation*. Stockholm: Universitetskanslersämbetet.

Hicks, D., Wouters, P., Waltman, L., de Rijcke, S., and Rafols, I. (2015). Bibliometrics: The Leiden Manifesto for research metrics. *Nature* 520, 429–431. doi: 10.1038/520429a

Huang, J., Gates, A. J., Sinatra, R., and Barabási, A.-L. (2020). Historical comparison of gender inequality in scientific careers across countries and disciplines. *Proc. Natl. Acad. Sci. U. S. A.* 117, 4609–4616. doi: 10.1073/pnas.1914221117

Journal Citation Reports (2016). Available online at: https://jcr.incites.thomsonreuters.com (accessed October 27, 2016).

Lapidow, A., and Scudder, P. (2019). Shared first authorship. *J. Med. Lib. Assoc.* 107, 618–620. doi: 10.5195/jmla.2019.700

Larivière, V., Ni, C., Gingras, Y., Cronin, B., and Sugimoto, C. R. (2013). Bibliometrics: Global gender disparities in science. *Nature* 504, 211–213. doi: 10.1038/504211a

Lindahl, J., Colliander, C., and Danell, R. (2021). The importance of collaboration and supervisor behaviour for gender differences in doctoral student performance and early career development. *Stud. High. Educ.* 46, 2808–2831. doi: 10.1080/03075079.2020.1861596

Merton, R. K. (1968). The Matthew effect in science. *Science* 159, 56–63. doi: 10.1126/science.159.3810.56

Murphy, M., Callander, J. K., Dohan, D., and Grandis, J. R. (2022). Networking practices and gender inequities in academic medicine: Women's and men's perspectives. *EClinicalMedicine* 45:101338. doi: 10.1016/j.eclinm.2022.101338

Nielsen, M. W. (2016). Limits to meritocracy? Gender in academic recruitment and promotion processes. *Sci. Public Pol.* 43, 386–399. doi: 10.1093/scipol/scv052

Pezzoni, M., Mairesse, J., Stephan, P., and Lane, J. (2016). Gender and the publication output of graduate students: A case study. *PLoS One* 11:e0145146. doi: 10.1371/journal.pone.0145146

Raj, A., Carr, P. L., Kaplan, S. E., Terrin, N., Breeze, J. L., and Freund, K. M. (2016). Longitudinal analysis of gender differences in academic productivity among medical faculty across 24 medical schools in the United States. *Acad. Med.* 91, 1074–1079. doi: 10.1097/ACM.0000000000001251

Rand, T. M., and Wexley, K. N. (1975). Demonstration of the effect, "similar to me", in simulated employment interviews. *Psychol. Rep.* 36, 535–544. doi: 10.2466/pr0.1975.36.2.535

Researchgate. (2016). Available online at: *https://www.researchgate.net* (accessed November 5, 2016).

Rivera, L. A. (2012). Hiring as cultural matching: The case of elite professional service firms. *Am. Sociol. Rev.* 77, 999–1022. doi: 10.1177/0003122412463213

Roksa, J., Wang, Y., Feldon, D., and Ericson, M. (2022). Who is publishing journal articles during graduate school? Racial and gender inequalities in biological sciences over time. *J. Div. High. Educ.* 15, 47–57.

Rørstad, K., and Aksnes, D. W. (2015). Publication rate expressed by age, gender and academic position – A large-scale analysis of Norwegian academic staff. *J. Inform.* 9, 317–333. doi: 10.1016/j.joi.2015.02.003

Rossello, G., Cowan, R., and Mairesse, J. (2023). Ph.D. publication productivity: The role of gender and race in supervision in South Africa. *J. Prod. Anal.* 61, 215–227. doi: 10.1007/s11123-023-00681-4

Rossiter, M. W. (1993). The Matthew Matilda effect in science. *Soc. Stud. Sci.* 23, 325–341.

Staniscuaski, F., Kmetzsch, L., Soletti, R. C., Reichert, F., Zandonà, E., Ludwig, Z. M. C., et al. (2021). Gender, race and parenthood impact academic productivity during the COVID-19 pandemic: From survey to action. *Front. Psychol.* 12:663252. doi: 10.3389/fpsyg.2021.663252

Thelwall, M. (2018). Do females create higher impact research? Scopus citations and Mendeley readers for articles from five countries. *J. Inform.* 12, 1031–1041. doi: 10.1016/j.joi.2018.08.005

Thompson, L., Perez, R. C., and Shevenell, A. E. (2011). Closed ranks in oceanography. *Nat. Geosci.* 4, 211–212. doi: 10.1038/ngeo1113

van Arensbergen, P., van der Weijden, I., and van den Besselaar, P. (2012). Gender differences in scientific productivity: A persisting phenomenon? *Scientometrics* 93, 857–868. doi: 10.1007/s11192-012-0712-y

Waltman, L. (2016). A review of the literature on citation impact indicators. *J. Inform.* 10, 365–391. doi: 10.1016/j.joi.2016.02.007

Web of Science (n. d.). Available online at: *https://apps.webofknowledge.com*

West, J. D., Jacquet, J., King, M. M., Correll, S. J., and Bergstrom, C. T. (2013). The role of gender in scholarly authorship. *PLoS One* 8:e66212. doi: 10.1371/journal.pone.0066212

Yair, G. (2009). Gender, discipline, and scientific productiviey: The case of Israeli doctoral students. *Equal Opportunit. Int.* 28, 50–64.