Scientometrics (2010) 83:93–101
DOI 10.1007/s11192-009-0025-y

Scientific output and impact of postdoctoral scientists: a gender perspective

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Received: 5 November 2008 / Published online: 10 June 2009

Abstract This paper analyses the scientific output and impact of 731 Ph.D. holders who were awarded their doctorate at Spanish universities between 1990 and 2002. The aim was to identify any differences in the amount of scientific output and the impact of publications, in terms of citations, according to gender. The analysis revealed no significant differences in the amount of scientific output between males and females. However, the proportion of female Ph.D. holders with no postdoctoral output was significantly higher than that of their male counterparts, and the median number of papers published after Ph.D. completion was also lower among women. As regards pre- and postdoctoral research, the data showed that early scientific output may be a good predictor of subsequent productivity in both gender groups. The results also indicated that articles by female Ph.D. holders were cited significantly more often, even when self-citations were excluded.

Keywords Gender equality · Scientific output · Scientific impact · Ph.D. holders · Spain

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Introduction

Many studies have shown that women are under-represented in science, especially in the highest echelons of the scientific career. Data published by the European Union show that the more senior the scientific post, the fewer women are present. Indeed, women hold fewer than 15% of full professorships in Europe (EU 2006, p. 55).

Scholarly publishing is central to academic success because the quantity and quality of publications determine performance evaluations, funding decisions, promotions and salaries, and it is with this in mind that the present study aims to examine publication patterns of male and female researchers. The literature to date has produced mixed findings and conclusions as regards the extent to which (if at all) women are less productive than men in academic research in terms of both quantity and quality (Tower et al. 2007).

Past studies have generally reported lower productivity among women in academic research publications. Cole and Zuckerman (1984, p. 218) observed that "more than 50 studies covering various time periods and fields of science report sex differences in published productivity, more specifically, that men publish more than women, even when age and other important social attributes are taken into account". Their results showed that men published on average almost twice the number of papers as women in the first 12 years of their careers. Besides, twice as many women scientists failed to publish a single paper during these 12 years, and women were under-represented among prolific scientists.

More recent studies continue to show large gender differences in research performance. For example, Kyvik and Teigen (1996) found that during a three-year period men published an average of 6.9 articles, while the figure for women was 5.6. They also observed a relationship between age and productivity: male faculty members under the age of 40 published twice as many article equivalents as their female counterparts, whereas for faculty over 40 the difference was small (10–15%). Prpic (2002) found that young female researchers in Croatia published an average of two scientific papers fewer than their male counterparts over a five-year period, and that their publications reach 70.6% of males' publication productivity in the same period. Sax et al. (2002) showed that although publication rates among faculty had increased significantly in recent decades, the gender gap in research productivity continued unabated, particularly at the highest levels of productivity. Even when controlling for having children, structural factors and personal characteristics, Stack (2004) found that women still publish significantly less than men. In a study of publication records in a cohort of life scientists, Symonds et al. (2006) noted that there was a clear difference in the number of publications produced by males and females in the field, with men publishing on average almost 40% more papers than women. More specifically, there were very few males with fewer than ten publications, but almost a quarter of females fell into this category. At the other extreme, there were a few hyper-productive males, whereas there were no women with more than 45 articles. More recently, Ledin et al. (2007) looked at the publications of EMBO Long-Term Fellowships and Young Investigator Programme applicants and found that on average women published fewer papers than men.

In contrast to the above, some authors have found no relationship between gender and productivity. In a study of social scientists and biologists, Ward and Grant (1995) reported a convergence of publication levels for men and women, while Dasaratha et al. (1997) found no significant differences in publication productivity for the top five journals in accounting. Similarly, Xie and Shauman (1998) argued that once sex differences in academic positions and resources are taken into account, differences between

men and women are negligible. In a sample of American associate professors of organization science, Rothausen-Vange et al. (2005) suggested that women published more than men in more research-oriented departments, but less than men in less research-oriented departments. More recently, Tower et al. (2007) conducted a gender-based examination of the top six journals in the world and found no difference between male and female productivity when the percentage of women participating in the academic work force is factored in.

Some studies have also presented mixed results depending on the variables considered. Thus, Kyvik (1990) noted that productivity differences depended on several factors such as discipline and academic rank. Long et al. (1993) found that women had significantly more publications prior to beginning their jobs as assistant professors, although by the last year in rank this difference had reversed in favour of men.

As regards the study of gender differences in citation counts, some studies have noted no differences or even a higher average number of citations per paper in the case of women. Among the first group of studies, Cole and Zuckerman (1984) showed that when average citations per paper were compared for men and women, no differences were found. Lewinson (2001) showed little difference in the citations to male-authored versus female-authored papers. Ledin et al. (2007) found no significant differences in citations per paper between men and women. Noteworthy among those authors who provide support for the idea that females produce higher quality research compared to their male counterparts are Long (1992), Sonnert and Holton (2006) and Symonds et al. (2006). Long (1992) found that the average paper of a female scientist was cited more frequently than the average paper of her male equivalent. Sonnert and Holton (2006) also concluded that although men tend to publish more papers than women, women's papers are more comprehensive and of better quality, as measured by the number of citations. The data examined by Symonds et al. (2006) provide support for the idea that, for a given level of productivity, females produce higher quality research compared to their male counterparts.

Few studies have examined the quantity and impact of scientific output of female researchers in Spain. Thus, Bordons et al. (2003) analysed the productivity and impact of scientists at the Spanish National Research Council according to gender and professional category. They found no significant differences in productivity between genders within each category, although the outliers with the highest production were mostly males. Output appeared to be related to academic rank, and the lower productivity of women could be explained by the fact that they were working at lower professional ranks than men, as productivity tends to increase as professional category improves. In a more recent study, Moya-Anegón et al. (2007) evidenced an unequal development by gender that was strongly influenced by the patterns of publication in the different subject areas. According to these authors, gender differences are rooted not only in stereotypes, but also in the dynamics of different areas of scientific activity or research.

Taking as a starting point a previous report in which we considered gender imbalance in the number of Spanish male and female students who successfully completed their Ph.D. studies (Villarroya et al. 2008), the present study seeks to determine whether there are differences in the quantity and impact of the scientific output of Spanish postdoctoral researchers. More specifically, our first aim was to study whether there are any differences in the amount of scientific output according to gender, distinguishing between pre-doctoral and postdoctoral publications. The second aim was to analyse the impact of scientific output in terms of citations received according to gender and taking into account the effect of self-citations on this figure.

Methodology

In order to conduct our study we first established a cohort of Ph.D. graduates who had obtained their Ph.D. at Spanish universities between 1990 and 2002, and then analysed their scientific output—in terms of articles available through the Thomson Reuters ISI Web of Science (WoS)—up until 2006. This sample was derived from a previous study (Villarroya et al. 2008). The search for the authors' output was performed by two independent observers and, in the case of disagreement between them, a third observer determined the researcher's output.

Although our previous study covered all scientific disciplines, humanities were excluded at this stage of the project due to the specific publication habits of academics in this area: they publish considerably fewer journal articles and more books than do researchers in other fields and they tend to use their native language to write and publish in national journals that are frequently not included in the WoS. Eleven subjects were also excluded from the study because the three independent observers were not able to agree on their publication output. Finally, a total of 731 Ph.D. holders ($n = 426$ males (58.3%) and $n = 305$ females (41.7%)) were surveyed. The mean number of years since Ph.D. completion was 9.65 for males (standard deviation (SD): 3.65, confidence interval 95% (CI): 9.30 ÷ 10.00) and 9.03 for females (SD: 3.72, CI: 8.61 ÷ 9.45).

The number of articles published before and after completion of the Ph.D. by every subject was recorded. For the purposes of this study we considered as pre-doctoral articles those published before or in the same year as Ph.D. completion. However, these data should be interpreted with caution as some journals show a long delay between reception of a manuscript and publication of the article.

The number of citations received by each of the articles was also recorded. Self-citations were identified according to three categories: self-citations by the Ph.D. holder, self-citations by any of the article's co-authors but not the Ph.D. holder, and self-citations by any of the co-authors.

The impact factors of the journals in which the articles had been published were retrieved through the Thomson Reuters Journal Citation Reports. The impact factor of the year in which the article had been published was recorded. When it was not available, the nearest available year was preferred.

Data analysis

The median number of articles published, the median number of citations received and the median impact factor of the journals were considered for gender comparisons. The median was preferred to the mean because it is not affected by the presence of outliers. The Mann–Whitney U test was applied to study differences between male and female groups in the number of articles, citations and self-citations. The chi-square test was used to analyse the relationship between qualitative variables. Standardized residuals were computed in order to determine which cells were the major contributors to the significant chi-square value. Thus, any residual with a value greater than $z_{0.5} = 1.96$ was considered significant at the 0.05 level. Effect size was calculated by the Phi coefficient. Regression analysis was applied to assess the predictive value of pre-doctoral scientific output with respect to postdoctoral scientific output. Finally, an analysis of covariance was computed in order to study the relationship between gender and self-citations, controlling for the number of co-authors. The relationship between variables was considered statistically significant when $p < 0.05$.

Results

Scientific output

A total of 418 Ph.D. holders (57.2%) had published at least one article in a journal indexed by the WoS, while 313 Ph.D. holders (42.8%) had failed to do so. No significant differences by gender were found between Ph.D. holders with no output and those with at least one paper published (Table 1).

When analysing the results for Ph.D. holders with at least one article published, no significant differences in the median number of articles published by male and female Ph.D. holders were observed. Even considering only the median number of papers signed by male and female Ph.D. holders as first authors, no significant gender differences were observed (Table 2). However, when considering the median number of articles published before and after completion of the Ph.D., the data showed that while the scientific output before obtaining the Ph.D. was similar for both groups, the median number of papers published after obtaining the Ph.D. was lower in the female group. Similarly, the percentage of Ph.D. holders with no postdoctoral production was significantly higher among females (Table 3).

Table 1 Scientific output by gender

	Male	Female	χ^2 (d.f.)	p
0 article	189 (44.4%)	124 (40.7%)	0.999 (1)	0.317
≥1 article	237 (55.6%)	181 (59.3%)		

χ^2: Chi-square, d.f.: Degrees of freedom, p: Statistical significance

Table 2 Scientific output by gender (Ph.D. holders with at least one article published)

	Gender	n	Median (IQR)	Statistic	p
Pre-doctoral articles	Male	237	1 (2)	$z = 0.858$	0.391
	Female	181	1 (3)		
Postdoctoral articles	Male	237	4 (9)	$z = 2.264$	0.024
	Female	181	3 (6)		
Articles as first author	Male	237	0 (0.14)	$z = 1.356$	0.175
	Female	181	0 (0.10)		
Total articles	Male	237	5 (12)	$z = 1.166$	0.243
	Female	181	5 (7)		

IQR: Interquartile range, z: z value of the Mann–Whitney U test, p: Statistical significance

Table 3 Percentage of Ph.D. holders with pre-doctoral and postdoctoral scientific output by gender

		Male	Female	χ^2 (d.f.)	p	Φ
Pre-doctoral articles	0 articles	109 (46.0%)	76 (42.0%)	0.666 (1)	0.414	–
	≥1 article	128 (54.0%)	105 (58.0%)			
Postdoctoral articles	0 articles	13 (5.5%)	21 (11.6%)	5.139 (1)	0.023	0.11
	≥1 article	224 (94.5%)	160 (88.4%)			

χ^2: Chi-square, d.f.: Degrees of freedom, p: Statistical significance, Φ: Phi coefficient

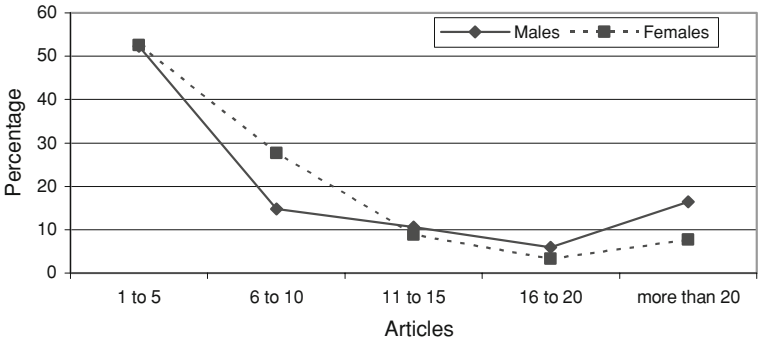

Fig. 1 Percentage of male and female Ph.D. holders with different ranges of scientific output

Table 4 Relationship between pre-doctoral and postdoctoral scientific output by gender

Gender	*n*	*r*	R^2	*F*	*p*
Male	237	0.519	0.270	86.843	<0.001
Female	181	0.296	0.088	17.226	<0.001

r: Pearson product moment correlation coefficient, R^2: Coefficient of determination, *F*: Snedecor's *F*, *p*: Statistical significance

The percentage of authors by range of production is presented in Fig. 1. The data revealed differences in some of the production ranges studied. Thus, while similar percentages of male and females were found in the lower and medium production ranges (ranges of 1–5 articles, 11–15 articles and 16–20 articles), differences were found in the range of 6–10 articles, where there was a higher percentage of female authors, and in the range of more than 20 articles, characterised by a higher percentage of males ($\chi^2 = 16.244$, d.f. $= 4$, $p = 0.003$).

In both gender groups the data revealed a significant relationship between the median number of articles published before Ph.D. completion and the amount of postdoctoral scientific output (Table 4). The regression analysis showed that the larger the pre-doctoral scientific output of the Ph.D. holder, the larger his/her postdoctoral scientific output. However, in the case of male Ph.D. holders the proportion of variance explained by the independent variable (pre-doctoral scientific output) with respect to the dependent variable (postdoctoral scientific output) was higher than in the case of female Ph.D. holders.

Citations

Analysis of the citations received by Ph.D. holders with at least one article published revealed significant differences by gender. The data showed that the percentage of female Ph.D. holders whose papers received at least one citation was higher than the percentage of male researchers doing so (Table 5). However, when self-citations by any of the co-authors were excluded, no differences by gender were observed.

When considering the median number of citations received per article, the data again showed significant differences by gender. Articles by female Ph.D. holders were cited significantly more often than articles by male Ph.D. holders, even when self-citations by any of the co-authors or simply self-citations by the Ph.D. holder were excluded (Table 6).

Table 5 Percentage of Ph.D. holders with and without citations by gender

Gender	0 citations	≥1 citations	χ^2 (d.f.)	p	Φ
Male (including self-citations)	33 (14.0%)	203 (86.0%)	5.753 (1)	0.016	0.12
Female (including self-citations)	12 (6.6%)	169 (93.4%)			
Male (excluding self-citations)	43 (18.2%)	193 (81.8%)	3.453 (1)	0.063	-
Female (excluding self-citations)	21 (11.6%)	160 (88.4%)			

χ^2: Chi-square, d.f.: Degrees of freedom, p: Statistical significance, Φ: Phi coefficient

Table 6 Citations received by gender

	Gender	n	Median (IQR)	z	p
Citations	Male	236	2 (6)	3.281	0.001
	Female	181	3 (7)		
Citations (without self-citations by any of the co-authors)	Male	236	1 (4)	2.744	0.006
	Female	181	2 (5)		
Citations (without Ph.D. holder self-citations)	Male	236	1 (5)	3.392	0.001
	Female	181	2.5 (6)		

IQR: Interquartile range, z: z value of the Mann–Whitney U test, p: Statistical significance

The proportion of self-citations (self-citations by any of the co-authors/citations) was calculated and no significant differences by gender were observed ($z = 0.526$, $p = 0.599$).

In order to test whether the contribution of co-authors to self-citations was different in the case of male and female Ph.D. holders, an analysis of covariance (ANCOVA) was performed. Thus, as the number of co-authors affects the number of citations emitted, the average number of collaborators per author was taken into account as a covariate. The proportion of collaborators' self-citations was considered as a dependent variable and the gender of the Ph.D. holder as the fixed factor. The interaction between the factor and the covariate variable was non-significant ($F = 3.188$, $p = 0.075$), meaning that there was no relationship between gender and the number of co-authors. However, analysis of covariance indicated a significant relationship between gender and collaborators' self-citations ($F = 4.744$, $p = 0.03$). Table 7 summarises the parameter estimations of the ANCOVA results, indicating that scientific output of male Ph.D. holders was cited significantly less often by their collaborators than was the scientific output of female Ph.D. holders.

Finally, the data showed that the journals where female Ph.D. holders had published presented a significantly higher median impact factor than those in which male Ph.D. holders had published (Table 8).

Table 7 Parameter estimations of the ANCOVA in self-citation analysis

Parameters	B	SE	t	p	Partial η^2
Constant	0.437	0.049	8.871	<0.001	0.202
Collaborators	0.030	0.008	3.952	<0.001	0.048
Gender (Male)	−0.083	0.038	−2.178	<0.001	0.015

B: B coefficient, SE: Standard error, t = Student's t test, p: Statistical significance, η^2: Partial eta squared

Table 8 Relationship between journals' impact factor and gender

	Gender	*n*	Median (IQR)	*z*	*p*
Journals' Impact Factor	Male	227	1.26 (1.95)	2.851	0.004
	Female	180	1.70 (2.12)		

IQR: Interquartile range, *z*: *z* value of the Mann–Whitney *U* test, *p*: Statistical significance

Conclusions

As regards our first research aim—to determine whether there are any differences in the scientific output of Spanish postdoctoral researchers—the results show no significant differences by gender between Ph.D. holders with no output and those who published their research.

When analysing the results for Ph.D. holders with at least one article published, no significant differences in the median number of articles published by male and female Ph.D. holders were observed. However, the percentages of authors by range of production show a slightly higher proportion of males among highly productive researchers, i.e. those publishing more than twenty articles. These findings show that the gender gap in research productivity continues unabated, particularly at the highest levels of productivity.

The analysis showed that while scientific output before obtaining a Ph.D. was similar for both groups, the median number of papers published after obtaining a Ph.D. was lower in the female group. This gender gap in research productivity can be explained by the "leaky pipeline", which refers to the fact that the percentage of women declines at later stages of the academic career. Similarly, the percentage of Ph.D. holders with no postdoctoral production was significantly higher among females.

Our results also suggest a positive significant relationship between the median number of articles published before Ph.D. completion and the amount of postdoctoral scientific output. Thus, the higher the pre-doctoral scientific output, the higher the postdoctoral productivity. These findings support the hypothesis that early scientific productivity may be a good predictor of subsequent publication activity. However, it should be noted that the predictive ability of the model is higher for the male group, suggesting that in the case of females other factors may be more important when it comes to predicting subsequent publication activity.

With regard to our second research objective—to analyse whether there are any differences in the impact of publications in terms of citations received according to gender—the results point to a stronger impact in the case of articles by women. Thus, articles by female Ph.D. holders were cited significantly more often than those by their male counterparts, even when self-citations were excluded. At the same time, journals where female Ph.D. holders published presented a higher impact factor than journals where male Ph.D. holders published. This finding is consistent with previous studies (Long 1992; Sonnert and Holton 2006; Symonds et al. 2006). The reasons as to why articles by female scientists are cited more often remain unclear, although as Long (1992) suggested, a different profile of publication strategies may be adopted by male and female scientists.

As regards the proportion of self-citations by male and female scientists, our results are again consistent with previous research (Symonds et al. 2006) and show no differences between the groups, i.e. the proportion of self-citations was similar for both genders. However, a deeper analysis of self-citations suggested that the contribution of self-citation by co-authors of Ph.D. holders is less evident for male as compared to female scientists.

Consequently, papers by female Ph.D.s are cited more frequently by their co-authors than are papers by male Ph.D.s, thus reaffirming through their colleagues the greater impact of their work.

Acknowledgements The research reported here was supported by the Spanish Ministry of Education and Science (EA2007-0194 and EA2008-0221).

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