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5 Gender differences in scientific productivity: a persisting phenomenon?[1]

Abstract

There is substantial literature on research performance differences between male and female researchers, and its explanation. Using publication records of 843 social scientists, we show that performance differences indeed exist. However, our case study suggests that in the younger generation of researchers these have disappeared. Moreover the top is no longer strongly dominated by men, as the share of top performing women has increased considerably. If this indicates a new trend, a cultural change in developed societies, where women increasingly outperform men in all levels of education, is also becoming effective in the science system.

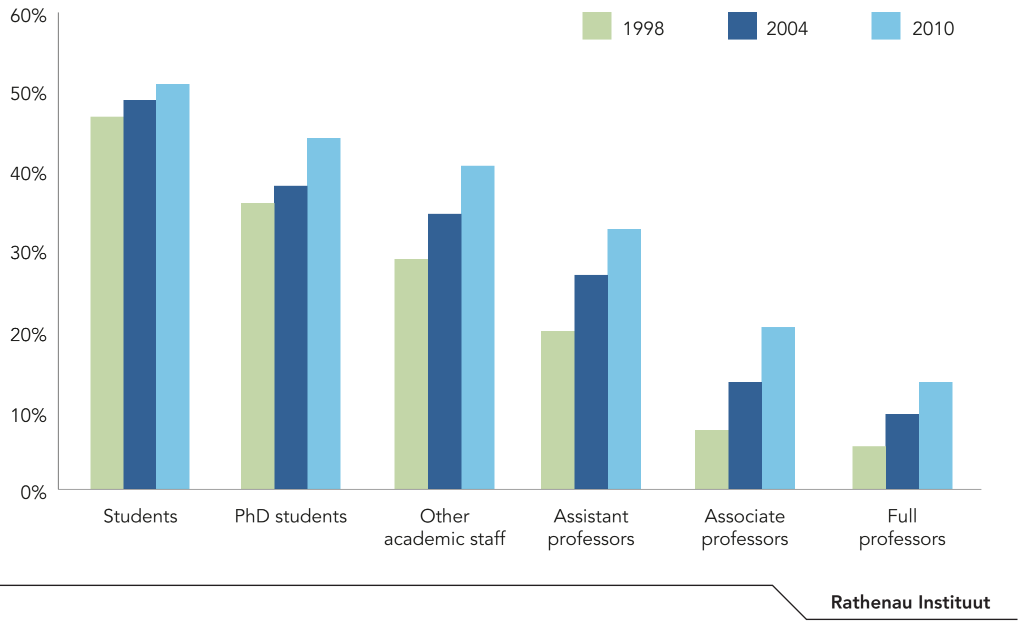
5.1 Introduction

The academic world has been dominated by men for a long time. However, the share of women in academia is gradually increasing. Worldwide female students nowadays even outnumber male students, with 55% in the UK and USA and with 59% in the Scandinavian countries (OECD, 2010). And of the new entrance in European higher education about 55% is female.[2] Figure 1 shows the percentage of women in different academic positions in the Netherlands. There, the position of women in higher academic positions is even lower than elsewhere. The growing share of women is characteristic for all positions, however the general rule still is 'the higher the rank in academia, the lower the number of women' (Brouns, 2000; De Weert, 2001; Timmers, Willemsen & Tijdens, 2010). Although female researchers are improving their position, the process is rather slow. Is the weak position due to women having in average fewer ambitions in pursuing an academic career? Are career decisions characterized by gendered social closure, structurally disadvantaging women? Or are women weakly represented in high ranks because their male colleagues outperform them? In this paper we will address the last question by focusing on differences in research performance between male and female researchers.

1 This chapter is a slightly modified version of the paper published earlier in Scientometrics as Van Arensbergen, P., Van der Weijden, I. & Van den Besselaar P. (2012). Gender differences in scientific productivity: a persisting phenomenon? *Scientometrics, 93*(3), 857-868.). For details about the changes see footnote 4 and 12.

2 Of course this differs between the various fields of study. In most science, technology and engineering fields, the share of women is low.

Figure 1 Share of women in academic positions in the Netherlands 1998-2010 (source: VSNU)



Ample evidence has been provided for a productivity difference between men and women over time, with men producing more research output than women (Abramo, D'Angelo, Caprasecca, 2009; Cole & Zuckerman, 1984; Ledin, Bornmann, Gannon et al., 2007; Long, 1992; Nakhaie, 2002; Penas & Willett, 2006; Prpic, 2002; Symonds, Gemmell, Braisher et al., 2006; Taylor, Fender & Burke 2006; Xie & Shauman, 1998). However, with regard to citations per publication no gender differences were found (Penas & Willett, 2006; Ledin et al., 2007; Tower, Plummer & Ridgewell, 2007), or even a difference in the opposite direction; women having a higher citation score than men (Long, 1992; Powell, Hassan, Dainty et al., 2009). The lower research productivity of women implies that female researchers receive in average a lower total number of citations than men do.

Zuckerman (2001) suggest four different types of explanations of the *productivity puzzle* (Cole & Zuckerman, 1984): scientific ability, self-selection, social selection, and accumulated disadvantage. According to the scientific ability explanation, male and female academics have different biological and psychological characteristics that directly affect the research output. However no direct gender effect has been found in earlier research (e.g. Xie & Shauman, 1998).

The self-selection explanation argues that scientific productivity is influenced by the individual choices of the academics themselves. Several studies confirm the influence of individual choices. For example, women more often interrupt their career to have children and start a family (Prozesky, 2008). Having children causes a decline in research productivity growth, more for women than for men (Fuchs, Von Stebut & Allmendinger, 2001; Hunter & Leahey, 2010). Women were also found to initiate their careers at a later age than men (Karamessini, 2004; Prozesky, 2008). This also holds for their publication career: women produce fewer publications than men during the first decade of their career, but later in their career they more or less catch up with male researchers (Long, 1992; Symonds et al., 2006). Other factors which are found to affect research productivity and can be considered as self-selection are marital status[3], career ambitions, amount of research time, extent of specialization, discipline, reputation of the university and department, international network (collaboration and co-authoring), and academic rank (Allison & Long, 1990; Bland, Center, Finstad et al., 2006; Carayol & Matt, 2006; Dundar & Lewis, 1998; Leahey, 2006; Lee & Bozeman, 2005; McNamee, Willis & Rotchford, 1990; Prpic, 2002; Puuska, 2010; Taylor et al., 2006). Many of these factors have a gender dimension, as women in average work at lower ranks, in less prestigious institutions, have in average less experience and a weaker (inter)national network. They also specialize less (Leahey, 2006) and more often concentrate on teaching and service, and therefore spend less time on research (Snell, Sorensen, Rodriguez et al., 2009; Taylor et al., 2006). However one should recognize that these factors cannot always be fully ascribed to self-selection. For example, decisions related to collaboration and academic rank are partly in the hands of other people and the organization of the university.

Zuckerman's third type of explanation, social selection, outlines how research productivity of women is affected by gender-based decisions made by others (Zuckerman, 2001). Just as in society in general, there may exist mechanisms of discrimination in the social organization of science (Prpic, 2002). Men outnumber women in positions of formal power, authority and high income (Timmers et al., 2010; Xie & Shauman, 1998). Research on professorial appointments shows there are gender differences in the selection and recruitment procedures. A clear disparity was found in the success rates of male and female applicants to the disadvantage of females (Van den Brink, Brouns & Waslander, 2006). This implies that career decisions are characterized by gendered social closure (Van den Brink, 2009).

A similar situation has been observed in the procedures of grant allocation. Quite some research has focused on gendered aspects of peer review, especially since Wenneras and Wold (1997) published their study on nepotism and sexism in science. They showed that women needed a higher performance to be as successful as male researchers. And, researchers without committee members in their network needed much higher performance than those with an adequate network. A similar study on grant applications in the Netherlands confirmed that gender matters (Brouns, 2000). However it showed that the way it matters varies for different disciplines. Whereas in some disciplines in case of equal average publication scores more men than women were evaluated as excellent, less productive women also obtained grants in other disciplines. Replicating the study of Wenneras and Wold ten years later, Sandstrom and Hallsten (2008) found no sexism anymore; female researchers even had a slightly better chance than males. Clearly, the council studied in both papers changed its policy in the meantime. However, nepotism was as strong as before. If that is the case, this may still influence female researchers, as male researchers generally have better networks than female researchers (Fuchs et al., 2001; Kyvik & Teigen, 1996) and collaboration influences performance (Lee & Bozeman, 2005). Furthermore, women receive less academic support and mentoring than men (Fuchs et al., 2001; Landino & Owen, 1988). This may disadvantage women too, as academic careers depend on support by academic mentors (Van Balen, 2010).

3 Other evidence suggests that the effect of marital status is less univocal (Fox, 2005).

The factors described above may overlap and constitute the source of other events influencing research productivity. For example status in science can be both the cause and effect of scientific collaboration. The same holds for the relation between scientific status and publication productivity (Fox, 2005). The accumulation of decisions or events over time generally placing women at a disadvantage is called cumulative disadvantage (Zuckerman, 2001). However, if productivity differences relate to individual (often gendered) factors, such as ambition, focus on research and changing gender roles and responsibilities in family life (Prozesky, 2008; Taylor et al., 2006; Xie & Shauman, 1998), one may expect that gradually changing gender roles in the last decades may have resulted into changed behavior.

In a recent review, Ceci & Williams (2011) discuss the evidence about discrimination against women in science, in journal reviewing, grant funding, and in hiring. They suggest that no evidence is available that supports the current discrimination against women in science. As a consequence, the unequal position of women in science is based on quality differences between male and female researchers that may partly be based on free choices, and partly on discriminatory arrangements in society at large - e.g., inequalities related to division of domestic work and child care. If this is correct, a careful analysis of these performance differences between male and female researchers is necessary - especially an analysis of changes in performance differences over time. We would actually expect changes, as women increasingly perform better at all levels in the educational system (Buchmann, DiPrete & McDaniel, 2008; Pekkarinen, 2008).

5.2 Research question

In this study, we answer the question of whether the gendered productivity differences are persistent or whether they change over time. As it was suggested that the productivity gap occurs in the early career (Symonds et al., 2006), we especially focus on the gendered performance differences among the youngest generation. Research performance in this paper is defined in terms of productivity (number of publications), and in terms of impact (number of citations).

5.3 Materials and methods

Comparing male and female researchers requires a good identification of the population. We use data on research grant applications in the Netherlands to analyze productivity differences. The dataset[4] covers about 1100 applications, in a three years period (2003-2005), covering three programs: early (ECG) and advanced career grants (ACG), and an open competition scheme (OC), all within the social sciences.

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4 For this chapter, we redid the data collection compared to the original publication (Van Arensbergen et al., 2012). There we used data based on *automatic* coupling of application data with Social Sciences Citation Index data, using family name and first initial. This is of course never perfect, and cannot avoid error based on homonyms and synonyms, applicants using different first initials in applications compared to publications, and titles taken for first names. For this version, we recollected all data *manually* in order to avoid all these problems. We also extended the search, as we now also included non-Dutch addresses and Science Citation Index-expanded publications. In the previous version only publications with a Dutch address and indexed in the Social Sciences Citation Index were included. We now also used a slightly longer citation window (up to 31-12-2006). The new data indeed show many small and several larger differences compared to the original dataset. However, the results of the analyses and the conclusions remain highly similar, suggesting that the error in the data even out. Details about the new data collection will be published elsewhere (Van den Besselaar, forthcoming).

1. The young career grant scheme is meant for researchers who got a PhD within the previous three years. The grant allows them to continue to develop their ideas further.
2. The advanced career scheme is for senior researchers with a long (up to 15 years) post-doctoral experience, and who have shown the ability to successfully develop their own innovative lines of research and to act as coaches for young researchers. The grant allows them to build their own research group.
3. The open competition is for professors and senior researchers. They can apply for a 4-year full-time PhD research project or a 3-year full-time postdoc project.

We had name, field, and institutional affiliation of all applicants. This enabled us to find almost all applicants on the Web, and through that we could identify their résumé and their publications. Those applicants that could not be found were removed from the analysis[5]. This set of applicants can be considered as a good representation of active social science researchers, as active researchers are expected to apply regularly in these programs. As several researchers applied two or more times during the three years, the number of researchers is smaller than the number of applications: 843 researchers, of which 269 (32%) female. The advanced career applicants and the open competition applicants belong to the established generation. The young career grant is clearly for the new generation of scientists. This means we can distinguish two generations of researchers:

1. 355 young researchers, having finished their PhD studies within the last three years;
2. 488 established researchers, generally within the associate or full professor rank.

Full and associate professors are generally older than 40, with an average of 51 years and a standard deviation of 7 years. Those with an ACG grant are on the younger side within this group: they are in average 40 years old with a standard deviation of 4 years.

The ECG grantees represent the young researchers; in our sample, they are between 27 and 41 years, with a few older: researchers who got their PhD at an older age. In average, the young researchers are 33 years old, with a standard deviation of 3 years.

For this paper we define research performance as the number of articles in scholarly (peer reviewed) journals, and as the number of citations received. Research managers and science policy makers increasingly emphasize this type of output and the performance indicators based on it.[6] More specifically, we measured scholarly performance of all researchers, in terms of publications from the *three years before the application* and citations to these publications received until the end of 2006. So we take recent performance and not lifetime performance into account. We used the Web of Science for measuring performance. As we had the résumés and publication lists of almost all applicants, we did not have the problem of synonyms and homonyms (of names). Thus, only the correct publications were included.

5 This also explains some of the differences with the original article.
6 Of course, this does not cover all scientific output, let alone the societal output of researchers (De Jong, Van Arensbergen, Daemen et al., 2011).

The social sciences are heterogeneous, as they consist of psychology, education, pedagogy, anthropology, sociology, communication studies, geography, demography, economics and law. As publication and citation patterns differ between these fields, performance should be standardized in order to use the social and behavioral sciences as one population. However, as the next table shows, three fields dominate the applications: psychology, economics and law. In this paper, we therefore do the analysis first for the (unstandardized) total sample, and then repeat it for the psychology and economics individually.

Table 1 Applications by field and funding instrument

	ECG	OC + ACG
Psychology	97	146
Law	40	110
Economics	105	104
Sociology	27	55
Political science	13	31
Communication	6	15
Geography	12	16
Anthropology	12	9
Education	50	9
Demography	1	5
Grand Total[7]	355	488

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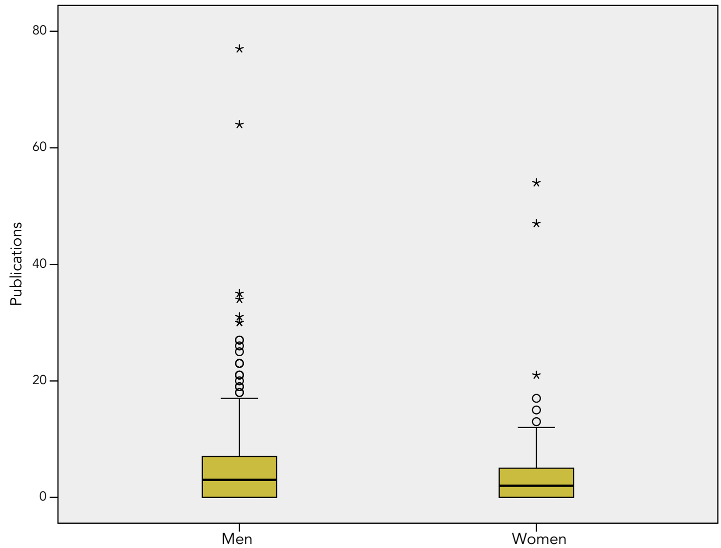
OC = open competition;
ACG = advanced career grant;
ECG = early career grant

5.4 Gender differences

First of all, distribution of research performance is heavily skewed. Generally, a small number of the researchers produce the far majority of publications, and a large amount of researchers have a very small output - therefore we use non-parametric statistics. More specifically we use the Monte Carlo method, a powerful simulation technique for obtaining an accurate significance level for highly skewed distributed data, especially regarding small samples.

7 The grand total is smaller than the sum of field counts, as in the overall analysis for applicants who submitted in more than one field only the most recent application was included.

Figure 2 Productivity by gender, established generation social sciences, 2003-2005



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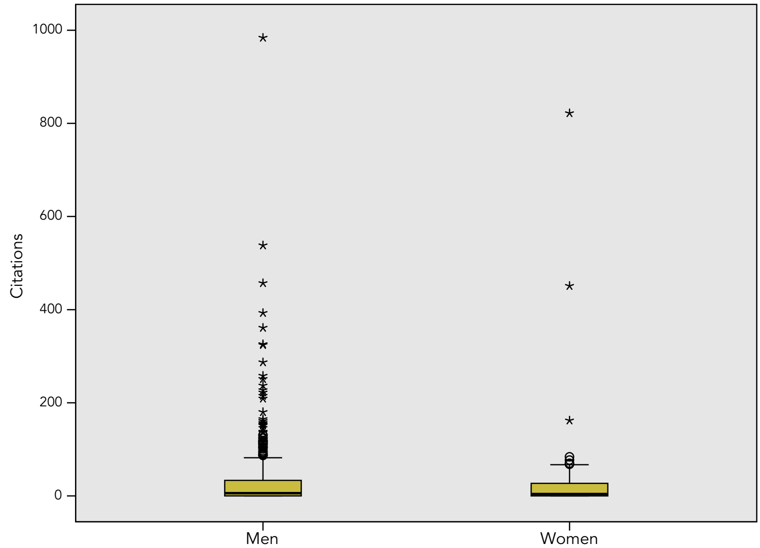
In the established generation, we have 488 applicants, of which about 22% are female. In the three years period, male researchers did publish in average more than female researchers (mn[8]=5.4 publications versus mn =4.0). The distribution of publications by gender for the established generation (ACG and OC) is shown in figure 2. Clearly, the distributions are very skewed, and we test whether these distributions differ significantly. They do (men mdn[9] = 3 versus women mdn = 2, Mann-Whitney U[10] = 18514.5, p (Monte Carlo, 1-tailed[11])= 0.048).

8 mn = mean
9 mdn = median
10 From now on will be referred to as U
11 From now on will be referred to as p

Figure 3 Impact by gender, established generation social sciences, 2003-2005



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Also in line with earlier findings, in the established generation male researchers receive more citations than female researchers do (mn= 36.6 versus mn= 27.2). The differences are smaller than in the publications. Figure 3 presents the again skewed distributions, which are found to differ (men: mdn= 6 versus women: mdn = 4, *U*=18933.0, *p*=0.092).

5.5 Changing gender differences?

We repeated the analysis for the young generation (ECG applicants) with a different result. First of all, of the 355 applicants, about 45% are women. This is a huge increase compared with the established generation (women 22%). In the young generation of scientists, the publication differences have decreased and seem to be disappearing (figure 4). Male researchers still have a slightly higher average number of publications than female researchers (mn=2.3 versus mn=1.9) but the gender difference has become much smaller. That also holds - to a somewhat lesser degree - for the rank order comparison (mdn=2 versus mdn =1, *U*=14202.5, *p*=0.068).

Also the citation patterns have changed, and differences have disappeared more or less (figure 5). Male researchers have a somewhat higher median (mdn=2 versus mdn=1.5) but a lower average (mn=13.4 versus mn=14.0). The Monte Carlo test fails to show a significant difference between the distributions (*U*=15077.0, *p*=0.292).

Figure 4 Productivity by gender, young generation social sciences, 2003-2005

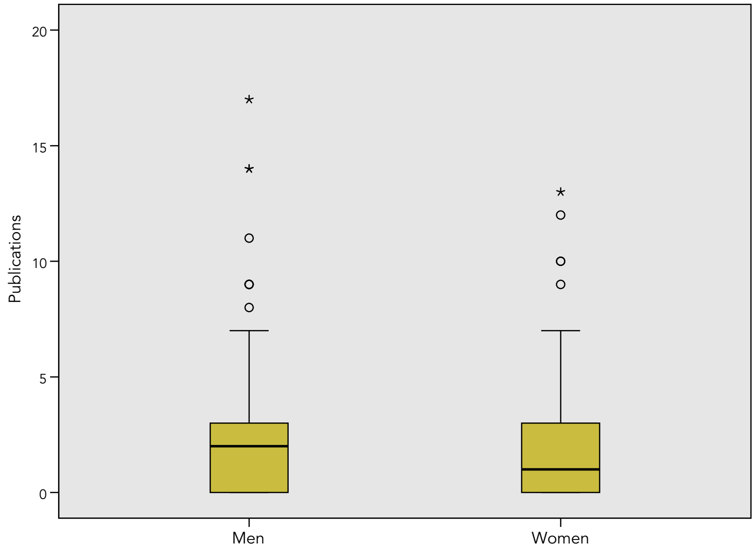

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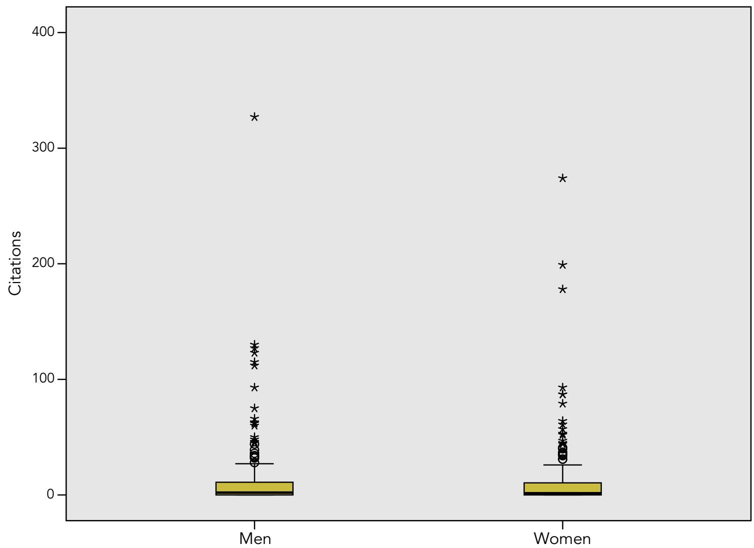
Figure 5 Impact by gender, young generation social sciences, 2003-2005



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When we look specifically at the top of the distribution (the 9-10%), women considerably caught up with men (table 2). While in the established generation 4.6% of the women belonged to the top compared to 10.3% of the men, of the young women 8.8% belongs to the top. In terms of impact the catching up by women is even stronger. In the top 10% impact ranks, women are overrepresented in the young generation. This result differs from what we found for the established generation and is generally found in the literature: an overrepresentation of female researchers in the lower part of the distribution, and an overrepresentation of male researchers in the higher part of the distribution.

Table 2 Performance by gender

	Established generation		Young generation	
	% men in top	% women in top	% men in top	% women in top
Top ± 10% nr. publications *	10.3	4.6	10.8	8.8
Top 10% nr. citations**	12.1	2.8	9.2	10.6

*: For older generation: >13 publications, for younger generation: >5
**: For older generation: >92 citations, for younger generation: >39

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5.6 A more detailed view on specific disciplines: psychology and economics

The previous analysis was done at the level of the social sciences as a whole. What if we focus on specific disciplines? We took two social science disciplines with the highest number of applications and in which English language journal articles are the main form of scholarly output.

5.6.1 Psychology

Also within the group of the established psychology researchers, men (N=104) in average outperform women (N=42) in publications (mn=12.1 vs mn=7.7; mdn=10 vs mdn=4, U=1276.5, p=0.000) and in citations (mn= 107.3 vs mn=64.3; mdn=60.5 vs mdn=29, U=1352.0, p=0.000).

The younger generation (N=97) consists of more women than men, about 55%. Here, the picture is different - in line with the findings for the social sciences as a whole. Output differences between male and female researchers have strongly declined (Mn=4.1 vs Mn=3.1; Mdn=3 vs Mdn=3, U=1028.5 p=0.158) in the younger generation, as have citation differences (Mn=35.4 vs Mn=24.7; Mdn=16 vs Mdn=9, U=1064.0, p=0.234).

As shown in table 3, the female researchers are underrepresented in the higher part of the ranking of the established generation. However, in the top of the younger generation ranking they are still underrepresented, although their representation has slightly increased.[12]

12 In the previous version of the paper (Van Arensbergen et al 2012), we found that women outperformed men in the top of the distribution. This has changed with the new data. The potential reason is that we now also include publications in the Science Citation Index, reflecting the more (life) science part of psychology - characterized by higher numbers of publications and citations. Men are overrepresented there. Field normalization might change this again.

Table 3 Performance by gender - Psychology

	Established generation		Young generation	
	% men in top	% women in top	% men in top	% women in top
Top ±10% nr. publications*	8.7	4.8	13.6	5.7
Top ±10% nr. citations**	11.5	4.8	13.6	5.7

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*: For older generation: >23 publications, for younger generation: >7
**: For older generation: >224 citations, for younger generation: >66

5.6.2 Economics

In line with the general findings, in economics established male researchers have more publications (mn=5.0 vs mn=3.0; mdn=3 vs mdn=3, U=376.0, p=0.281), and receive more citations (mn=18.2 vs mn=7.7; mdn=9 vs mdn=5, U=362.0, p=0.221) than established female researchers do. The differences are considerable, however not statistically significant. This could be ascribed to the small number of women (N=9) among the established generation of economists.

In the younger generation, performance differences have changed in favor of women. Average publication and citation numbers are found to be almost equal. More specifically with regard to publications, men do slightly better (men: mn=1.6 vs women: mn=1.2; men: mdn=1 vs women: mdn=1, U=904.5, p=0.100). In terms of citations, women do slightly better (men: mn=4.6 vs women: mn=5.2; men: mdn=2 vs women: mdn=0, U=902.5, p=0.091). However, according to the Monte Carlo tests these differences are not significant.

Table 4 shows that in the established generation women are not present in the in the top 10% of the population. Yet, they are to a considerable extent entering the higher performance groups. In the younger generation about 7% of the women economists belongs to the top 10% in terms of publications compared to 13% of the men. When we look at the top performing researchers with regard to number of citations, women are even stronger represented than men. This suggests a similar generational trend as observed within social sciences as a whole. Also in line with the general trend is the increase in the share of women. In the established generation (N=104), women are some 9% and in the younger generation (N=105) this has increased to 27%. However, compared to the share of women among the young researchers within psychology (55%) and the social sciences as a whole (45%) this can still considered to be low.

Table 4 Performance by gender - economics

	Established generation		Young generation	
	% men in top	% women in top	% men in top	% women in top
Top ±10% nr. publications*	10.5	0	13.0	7.1
Top ±10% nr. citations**	10.5	0	9.1	10.7

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*: For older generation: >10 publications, for younger generation: >3
**: For older generation: >48 citations, for younger generation: >14

5.7 Conclusions and discussion

Our analysis suggests that the gendered performance differences are disappearing. In the older generation, men outperformed women in terms of publications and citations, but this is not any more the case in the younger generation. In other words, the traditional performance differences seem to disappear over time. This is in line with experiences in other parts of the education system, where female pupils and students are increasingly even doing better than male.

This finding is significant as earlier studies found that the performance gap between male and female researchers emerged in the early career phase (Symonds et al., 2006), and exactly in this phase the differences seem to be disappearing. This also suggests that the gendered division of domestic labor, and gender differences in motivation and career planning, may be weakening. As publication and citation scores are increasingly influencing academic careers, the disappearing performance differences may be a stimulus for changing gender relations within science. Of course, the question has to be answered as whether performance differences now emerge in later phases of the research career, a question that requires additional - preferably longitudinal - research.

The current analysis is restricted to the social sciences, and it would be useful to extend the analysis to other fields, such as science, technology, engineering and medicine. Possible performance differences in these fields may be partly due to the low number of female researchers in many of these fields. However, it is also often argued that men have better math and science capacities than women, which would lead to performance differences. This question has been studied intensively, and research suggests these differences - as far as they exist - are decreasing over time (EACEA, 2009; Hyde, Fennema & Lamon, 1990).

Moreover, this study is on a west European case. As the position of women (and consequently of female researchers) differs between countries, the introduction of a cross-cultural perspective would be another useful extension.

Our study indicates that the gender distribution in the group of active social science researchers has changed considerably. In the older generation only about 22% of the applicants are female, in the younger generation this has increased to 45%. Within economics the share of women can still be considered to be low, although it tripled up to 27%. Within psychology, female researchers even have become the majority in the younger generation. If ‘mass’ explains performance, the remaining performance differences (in fields were the share of women is still relatively low) may disappear when women enter those research fields at a larger share. In those fields, efforts to increase the number of female researchers remain important.

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