How do public investments in gender equality initiatives and publication patterns interrelate? The case of Germany

Keywords: Gender Equality, Bibliometrics, Research and Innovation Policy,

Abstract (max. 200 words)

This article examines whether two of the major German flagship programmes to increase the participation of female researchers in the German science system, the "Women Professorship Programme" and the "Pact for Research and Innovation", have actually increased the number of women, especially in leadership positions. In a second step, we analyse whether such an assumed increase influences the publication patterns of authors with German affiliation. This article is based on literature and desk research as well as bibliometric analysis using Scopus. The most important result is that the number of women in research has indeed increased significantly in recent years and that, accordingly, more women are the (co)authors of scientific publications. In particular, it can be seen that quality indicators such as citations and excellence rates are high for female authors. This enables us to show that more women in the science system not only bring about a "gain in justice", but also a concrete scientific benefit.

1. Introduction

For decades, the German research and innovation system has been characterized by strong research and innovation capacities on the one hand and a low participation of female researchers and inventors on the other hand (see Frietsch et al. 2009, 2012, European Commission 2016c, European Commission 2016b, Bührer et al. 2017 etc.). The reasons for this are manifold, ranging from a strong role of the business sector, where women are traditionally underrepresented, high shares of STEM disciplines (science, technology, engineering, mathematics), where women are also less represented, the skewed division of labour within families expressed in the above-average part-time rates of women workers, through to still existing stereotypes preventing women breaking through the "glass ceiling". Against this background, the German government launched two major policy initiatives aiming to change this situation - at least in the public sector. These initiatives are the “Women Professorship Programme”, which is directed towards the higher education sector, and the “Pact for Research and Innovation”, which is directed towards the four big German research performing organisations (Max Planck, Fraunhofer, Helmholtz and Leibniz) and the German Research Foundation DFG.

The national context

The German research and innovation system is complex as it is shaped not only by the decision-making processes of the federal government, but also by those of the 16 Länder (federal states). The government of the respective state is responsible for funding research

and teaching at public universities in that state. Furthermore, the states co-fund the Max Planck Society, the Fraunhofer-Gesellschaft, the Helmholtz Association, and the Leibniz Association in different intensities (see Frietsch, Schubert 2012). These research-performing organisations (RPOs) cover a broad spectrum from basic to applied research with different disciplinary backgrounds and foci and provide research services. The joint research funding provided by the federal government and the Länder is based on the joint task of Article 91b (1) sentence 1 of the Constitution. Under this provision, the federal government and the Länder may cooperate in cases of supra-regional importance in the promotion of science, research and teaching. The decision-making body is the Joint Science Conference (GWK, Gemeinsame Wissenschaftskonferenz), which coordinates the research policies between the federal government and the state governments.

In Germany, freedom of science, research and teaching is a fundamental right pursuant to Article 5 of the Constitution (Grundgesetz, GG). Accordingly, universities as well as RPOs have comparatively high autonomy. The German RPOs administer their processes themselves. They are also rather independent in setting their strategies but work in close collaboration with their supervisory boards. Representatives of the federal and state governments are members of these boards. Each RPO has the right to choose the scope and intensity of its gender equality (GE) policy within the broad framework of the respective state law and the federal German Framework Act. In line with this structure, actors in the R&I system have committed to gender equality goals and there are positive incentives, but only a few legally binding measures. This can be assumed to be one of the reasons why gender equality is improving in R&I, but only slowly.

There were numerous legal and political initiatives to promote gender equality in the German Higher Institutions (HEIs) before the women professorship programme was launched. One peak can be observed in the mid 1980s: In 1985, the university framework law (Hochschulrahmengesetz) formally required the promotion of gender equality; furthermore, offices of women's representatives were established at the German HEIs. In 1988, the "Wissenschaftsrat" (WR, German Science Council) integrated recommendations to improve the situation for female researchers in its HEI reports; and in 1989, the "Bund-Länder-Kommission", the predecessor of the GWK, published its first report on the situation of women in science. From the 1990s onwards, several special programmes were launched for women in science which primarily focussed on the re-entry and promotion of junior scientists with children (e.g. the 1991 university special programme), but also the promotion of habilitations. All these primarily person-oriented special programmes, however, did not significantly improve the situation of women in HEIs (Mühlenbruch 2008). At the end of the 1990s, there was an important shift from the promotion of single women ("fix the women") to the promotion of equal opportunities following a structural change approach ("fixing the institutions"), strongly fostered by WR recommendations from 1998 and the amendment of the higher education framework

law (also in 1998). This law required that the allocation of funds and evaluations must consider gender equality, so that gender equality became part of new management concepts at HEIs (Mühlenbruch 2008, p. 13). At the beginning of the new century, special programmes were launched for women in science and education which combined the promotion of women with a structural approach aiming at the removal of still existing barriers. Gender equality now became part of all big federal programmes like the Pact for R&I, the Hochschulpakt 2020 and the Excellence Initiative. The combination of the promotion of individuals with structural change elements is the most important characteristic of the women professorship programme, too (Mühlenbruch 2008, p. 13). Thus, the aim of the measure is not only to further increase the number of female professors at universities but to further strengthen structural change at German HEIs. In order to be able to participate in the programme, the HEIs must present future-oriented gender equality concepts. These concepts should contain, among other things, statements on an analysis of the situation and deficits with regard to gender equality, the setting of own gender equality targets, an assessment of measures implemented to date and an assessment of their effectiveness in terms of an analysis of strengths and weaknesses.

The total number of researchers in HEIs rose between 2005 and 2013, in both the EU and Germany. At the same time, the number of female researchers grew faster than the number of male researchers. Thus, the share of women at all qualification and career levels has increased constantly, but slowly. However, inequality continues: With every step higher on the career ladder, the share of women decreases - this applies to both Europe and Germany (European Commission 2015b, 2013b, 2009). There is not one scientific field, in which women account for more than 30% of grade A positions, neither in Germany nor Europe. The German share is lower than the European share in all years and in every field of science. Even though the numbers have been rising constantly since 2007, women are still underrepresented in grade A positions in all fields of science (European Commission 2015b).

In academia in Germany, researchers often work under uncertain conditions about their future because most have non-permanent contracts until they achieve a full professorship position. As women hold lower positions on average than men do in the sector, they work in such disadvantageous working conditions more often than men do. Compared to the European average, around twice as many female researchers in Germany have precarious working contracts (European Commission 2015b). This holds also for leadership positions at both universities and non-university research institutions. Female professors have disproportionately often restricted/limited contracts and work part-time.

Gender inequality in R&I in Germany is linked to the working time and attendance culture. The working time culture in academia in Germany means that even researchers in full-time positions regularly work overtime (Eurostat 2016b). Male researchers work more overtime than female ones (Eurostat 2016b), which may lead to further career

advantages for men. A further important hindrance in Germany is the still very traditional division of labour with regard to care, which often prevents women in particular from caring for children and pursuing their careers at the same time (Metz-Göckel et al. 2014).

The Joint Science Conference (GWK) summarises the fundamental trends concerning equal opportunities for men and women in research as follows (GWK 2016a):

- The share of women at all qualification and career levels is increasing constantly, but slowly. With every step upwards on the career ladder, the share of women decreases. This also holds true for leadership positions at both universities and non-university research institutions.
- Female professors have temporary contracts and work part-time disproportionately often. The biggest share of women professorships are junior professorships.
- In STEM, the underrepresentation of women is structurally hardened and remains around 30% of matriculations. Progress can be seen in the engineering sciences. Here, the share of women increased from 19.6% in 1995 to 24.9% in 2014. Traditionally, women are overrepresented in medicine (2014: 68.9%), linguistics and cultural studies (2014: 73.9%) as well as some natural sciences (biology, biotechnology).

The Pact for Research and Innovation

The "Pact for Research and Innovation" started in 2006 and has since been extended to 2020. The current "Pact for Research and Innovation" has two predecessors. The first phase lasted from 2005-2010, the second phase from 2011-2015 and the third phase runs from 2016-2020.

The overriding goal of the concerted action by the federal government and the states is to strengthen the competitiveness of the German research system. It addresses the DFG as the most important source of third-party funds in Germany and the publicly funded non-university research institutions Fraunhofer-Gesellschaft, Max Plank Society, Helmholtz Association and Leibniz Association. The Pact obliges the research organisations to comply with several negotiated targets. The organisations themselves are responsible for the progress towards these targets and must document this in an annual monitoring report. In return for their compliance, the organisations' budgets receive an annual boost of currently 3%. Furthermore, the government guarantees them sufficient autonomy and flexibility in budgeting, human resources and construction, public procurement and participation rights. In the context of the "Pact for Research and Innovation", the research organisations also set targets for the share of women at different hierarchy levels, applying the logic of the cascade principle (BMBF 2016d; GWK 2016b).

The concrete objectives vary for each of the Pact phases although the overriding objectives remain the same. In all three phases, promoting gender equality plays a crucial role. In the current phase, the following objectives are defined: 1. Dynamic development

of the science system; 2. Collaboration in the science system; 3. Deepening international and European cooperation; 4. Strengthening the exchange of science with industry and society; 5. Attracting the best minds to German science; and finally *6. Ensuring structures and processes that are suitable for equal opportunities and family-friendliness.* The overriding goal is still to achieve significant changes in the quantitative representation of women, especially in top-level positions. The RPOs are expected to ensure that the targets set for more women at all career levels and, in particular, in scientific and management positions are met. Furthermore, the RPOs shall create suitable and goal-oriented overall GE concepts. The proportion of women in scientific management bodies should be at least 30%.

Goal attainment is measured continuously by annual monitoring reports. GE is the only field among the policy objectives with such measurable targets.

The Pact is a flagship project in Germany for several reasons: its size (3% growth rate of the institutional funding for each of the RPOs; during phase 1, even 5%), duration (since 2006), functional mechanism (linking overall policy objectives including GE with institutional funding), and complex actor constellation (joint programme of the "Bund" and the "Länder", decentral organisation of the RPOs).

As regards the expected outputs, outcomes and impacts, first and foremost, it is expected that the number of women in research teams and decision-making positions will increase according to the cascade principle. Second, a structural change within the RPOs is expected as a direct effect of the Pact, not a focus on single measures to promote women in science. The main impacts are thus improved GE structures and a better representation of women at all career levels through a comprehensive cultural change at the RPOs. Cultural change includes a greater acceptance of GE among all the relevant stakeholders, but particularly the heads of the RPOs.

The RPOs themselves have established a broad variety of instruments which specifically address the individual challenges they are facing. The instruments refer to the following fields of activity: 1) Recruiting and promotion of careers like special recruitment initiatives, networking, mentoring, career building programmes etc.; 2) Family-friendliness through flexible working-time, home office, care facilities, dual career offers; 3) Qualification and training including raising awareness of unconscious bias; 4) Guidelines for recruiting, scientific careers and gender-sensitive language; 5) Specific programme to promote women in science like promoting women professors, women in expert panels etc. Besides these specific instruments, the RPOs report increased budgets for gender equality and diversity activities; the establishment of a continuous monitoring system, including active communication on goal attainment; target quotas in accordance with the cascade model; programme evaluations; the promotion of internal and external

dialogues; employee surveys to measure change, diversity criteria as part of the variable income components (heads of institutes).

Women Professorship Programme

The Women Professorship Programme is a national initiative that addresses higher education institutions (HEIs) in Germany. Not only universities but universities for applied sciences ("Fachhochschulen") and art and / or music colleges are eligible for funding. The eligibility criteria are different for HEIs applying for funding for the first time, and those that have already participated in one of the precursor stages. If HEIs apply for funding a second or even third time, they have to describe the success and / or failure of previous gender equality measures and the lessons learned for the future. They also have to indicate the evaluation approaches planned for continuous monitoring. Furthermore, they have to describe how they intend to anchor their GE interventions in a sustainable way (BMBF 2018, Bekanntmachung).

The Women Professorship Programme ("Professorinnenprogramm") was launched in March 2008 when the funding guidelines were announced. In June 2012, the GWK decided to continue the programme ("Professorinnenprogramm II"). The third round ("Professorinnenprogramm III") was launched in February 2018 (BMBF 2018, Bekanntmachung).

The programme grants funding to universities for initial appointments of women to tenured professorships at the rank of a full professor (W2 and W3 positions). Submitting a promising and tailored gender equality plan (and in later stages, providing evidence for its successful implementation) is the prerequisite to receive funding (BMBF 2018).

The programme offers primarily financial resources: Each HEI with an approved GEP (gender equality plan) can receive funding for up to three professorships for a duration of 5 years maximum. The maximum sum for each professorship is 150,000 euros per year during the first two phases and 165,000 euros in the third phase. In round three, a maximum of 10 HEIs with top scores in the appraisal can receive further funding for a fourth professorship.

Overall, the federal ministry and the states have together dedicated 200 million euros for the period 2018 to 2022 (BMBF 2018). Within the third funding period, a successful HEI can receive between 2,475,000 and 3,300,000 euros. The second funding period, which lasted from 2013 until 2017, foresaw a total of 150 million euros, with each HEI receiving a maximum 2,250,000 euros for up to three professorships (150,000 euros per professorship). (Bekanntmachung 2012). The first funding period had a total sum of 150 million euros at its disposal (BMBF Website Information).

Within the first funding period, a total of 152 HEIs submitted a gender equality concept, and 124 were successful. Within the second funding period, 184 HEIs participated in

total; 147 were selected for funding. In the meantime, 525 women professors have been appointed within the context of this programme (BMBF Internet Information). These figures mean that about two thirds of the German HEIs which are members of the HRK (German Rectors' Conference, Hochschulrektorenkonferenz) applied for funding and that a 10% increase in applications can be observed between the first and the second programme (GESIS 2017). Overall, the success rate is 80% and more than half of all the HRK-HEIs participated (ibid.).

2. Aims & objectives

The aim of this paper is to investigate whether the two large-scale German programmes to promote gender equality in the national research and innovation system described above achieve the desired gender equality effects (i.e. more women[1] in public research organisations, especially in top positions) and what impacts this has on German publication patterns. First, we investigate the GE outcomes of the German Women Professorship Programme as well as the Pact for Research and Innovations. In a second step, we analyse publication data based on Scopus for a 12-year period, i.e. from 2005 to 2016. Indicators are the number of publications, number of citations, the excellence rate and co-publications. All indicators are analysed by female and male authors and differentiated according to the type of institution: Higher Education Institutes (HEIs) and the four big research performing organisations in Germany, namely the Fraunhofer-Gesellschaft (FhG), the Max Planck Society (MPG), the Helmholtz Association (HGF) and the Leibniz Association (WGL).

3. State of the art

There are numerous academic articles that investigate the effects of female authorship on publication outputs (Abramo, D'Angelo & Caprasecca 2009; Ashcroft et al. 1996; Allison & Long 1990; Bentley 2003; Campbell, Mehtani, Dozier & Rinehart 2013; Cole & Zuckerman 1984; Corley / Gaughan 2005; Dasaratha et al. 1997; Dundar & Lewis 1998; Kvik 1990; Pan & Kalinaki 2015; Frietsch, Haller, Funken-Vrohlings & Grupp 2009; Hunter & Leahey 2010; Long 1992; Long et al. 1993; Maske et al. 2003; Matthews and Anderson 2001; Prpic 2002; Rothausen-Vange et al. 2005; Suitor et al. 2001; Symonds, Gemmell, Braisher, Gorringe & Elgar 2006; Tower et al. 2007; van Arensbergen, van der

1 We are aware that the dichotomous use of the gender concept does not adequately reflect reality (see for example Researchers at The Queensland University of Technology (QUT) has listed a whopping 33 options (https://www.lifehacker.com.au/2016/07/explained-the-33-gender-identities-recognised-by-the-2016-australian-sex-survey); Gender Identity Definitions (2017) (https://www.cbsnews.com/news/transgender-gender-identity-terms-glossary/)

Weijden & van den Besselaar 2012; Xie & Shaumann 1998). Overall, the most important results can be summarised as follows:[2]

- The share of *female authors* increased during the past decade, accounting for 33 % in 2014, reflecting the general share of women among researchers (Frietsch, Bührer & Helmich 2016).
- Female authors publish *less in terms of quantity* (van Arensbergen et al. 2012; Xie & Shaumann 1998; Penas & Willett 2006; Xie & Shaumann 2003), but this gap has been decreasing (Pan & Kalinaki 2015; Cole & Zuckerman 1984; Long 1992; Xie & Shaumann 1998; Prpic 2002; Symonds et al. 2006; Abramo et al. 2009; Nakhaie 2002; Penas & Willett 2006; Taylor, Fender & Burke 2006; Ledin, Bornmann, Gannon & Wallon 2007).
- There are also studies showing that 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).
- Publications of mixed teams, i.e. with a high share of female authors, receive higher citation rates than homogenous teams; respectively, women have higher citation rates than men (Campbell et al. 2013; Long 1992; Penas & Willett 2006; Tower, Plummer & Ridgewell 2007; Powell, Hassan, Dainty & Carter 2009; Ledin et al. 2007).
- Men and women differ significantly regarding the *scientific fields* where they publish. *Higher presence* of female authors can be observed in: food/nutrition; social sciences, others; humanities; pharmacy; medicine; biology/biotechnology. *Low presence***:** computers, mathematics, physics, engineering (Frietsch et al. 2009; 2016; Jung, Ejermo 2014; Bunker-Whittington, Smith-Doerr 2005, Hunt et al. 2013).
- In subject areas with skewed gender ratios that favour males, female researchers are more likely to focus on similar topics as their male counterparts. In contrast, in subject areas with more balanced gender distribution, women *tend to focus on different topics* (Pan & Kalinaki 2015).
- Mixed-gender publications are more interdisciplinary but less collaborative internationally than mono-gender publications, but female-only publications are the most internationally collaborative (Pan & Kalinaki 2015).
- The team size of female authors is larger than that of men (Frietsch et al. 2016).

---

2 Depending on the concrete bibliometric method, the results differ: For example, there are also studies that do not show any productivity gaps between male and female authors. However, the results listed below present a common understanding shared by the majority of the studies.

The reasons for the above described picture are manifold and can be clustered as follows:

- Individual characteristics: Marriage and motherhood can keep women away from publishing (Long 1992, Gobo 2016). The relevant mechanism in this regard is that women more often interrupt their career to have children and start a family (Prozesky 2008). Having children also causes a greater decline in research productivity growth for women than for men (Hunter & Leahey 2010; Fuchs, van Stebut & Allmendinger 2001). Finally, women were found to initiate their careers at a later age than men (Karamessini 2004; Prozesky 2008).
- Structural and institutional support factors: Women seem to be more active in institutional settings where publishing is not expected or encouraged. Women seem to be less encouraged than men to publish (Bunker-Whittington 2006; Bunker-Whittington & Smith-Doerr 2005). Women also work, on average, at lower ranking positions and in less prestigious institutions. Thus, men outnumber women in positions of formal power, authority and high income (Xie & Shaumann 1998; Timmers et al. 2010).
- Access to resources: According to Zuckerman, Cole and Bruer (1991) women do not have equal access to research instrumentation like funding, laboratory space and time allocation, i.e. women often remain in "the outer circle" of the scientific community. Especially the variable "time" seems to play a crucial role.
- Access to networks and social capital: Male researchers generally have better networks than female researchers (Kyvik & Teigen 1996; Fuchs et al. 2001), women have more difficulties to find co-authors (Ashroft et al. 1996, Suitor et al. 2001, Bentley 2003) and collaboration influences performance (Lee & Bozeman 2005). Moreover, women receive less academic support and mentoring than men (Landino & Owen 1988; Fuchs et al. 2001).
- Research topics: Women specialise less clearly in their topic than men (Leahey 2006) and they often choose less exploitable research areas (Bunker-Whittington 2006; Bunker-Whittington & Smith-Doerr 2005).
- Women concentrate more often on teaching and service and therefore spend less time on research (Taylor et al. 2006; Snell, Sorensen & Rodrigues 2009, Dasaratha et al. 1997, Matthew and Anderson 2001, Maske et al. 2003; Corley & Gaughan 2005).
- Women tend to work under more precarious situations, i.e. part-time, temporary, non-tenure track (Dasaratha et al. 1997, Matthew and Anderson 2001, Maske et al. 2003; Corley & Gaughan 2005).
- It seems that the female participation rate in the science system is higher in countries with comprehensive childcare and a cultural attitude that does not stigmatise female participation in the labour force (Frietsch et al. 2009).

- However, there are indications that there is also a negative selection effect or a crowding out effect in countries where public research remuneration is comparatively lower than in other countries. Men seem to focus mostly on the better-paid jobs and leave the "lemons" (Ackerloff 1970) to the women (Frietsch et al. 2009; Jung and Ejermo 2014).

4. Methods

Scientific publications are the major output of the science system. Researchers usually publish their scientific achievements in journals, which enables other researchers to access and eventually cite them if they are deemed appropriate for their own research. Bibliometrics is the scientific measurement of scientific output by means of publication data. Bibliometrics mostly deals with publications in scientific journals, but recently the usage of books and conference proceedings has gained more interest, although this area is still too young and methodological restrictions prevent its broad use. No standard analysis has been established here, especially as the databases covering these kinds of publications are still under development.

The use of bibliometrics to measure and assess the performance of scientists is now a well established standard. It has also become an important instrument for analysing innovation systems and for assessing the scientific and technological competitiveness of nations. Publications are used as indicators of the scientific strength of science systems or of early-stage innovation activities and may offer a perspective on future innovations based on current scientific and technological strengths (Michels et al. 2013). The vast majority of publications come from public research, e.g. universities, colleges and other research institutions. Companies are significantly less involved in scientific publications.

As a data source for the analyses, we use so-called citable items (articles, letters, notes, reviews) in Elsevier's Scopus database, which provides information on articles published in about 22,000 journals worldwide (https://www.elsevier.com/solutions/scopus). It mainly covers journals in science, technology and medicine, but also social sciences and the humanities – although the latter two areas are not covered to the same extent (Schmoch et al. 2012). Based on this database, a detailed analysis of women's and men's scientific publications and citations is possible for most countries in the world. We identified the gender of the authors based on lists of country-specific first names (Jörg Michael 2007). As we were able to access Scopus raw data, we were also able to broadly assign the gender of the authors in our dataset. In addition, based on this raw data, we also calculated field-specific expected citations rates as the average number of citations per paper in a particular field for each of the years in our observation period (2005-2016). For the definition of the scientific fields, we employed the 27 fields of the 2-digit level of the Scopus classification of journals.

5. Results

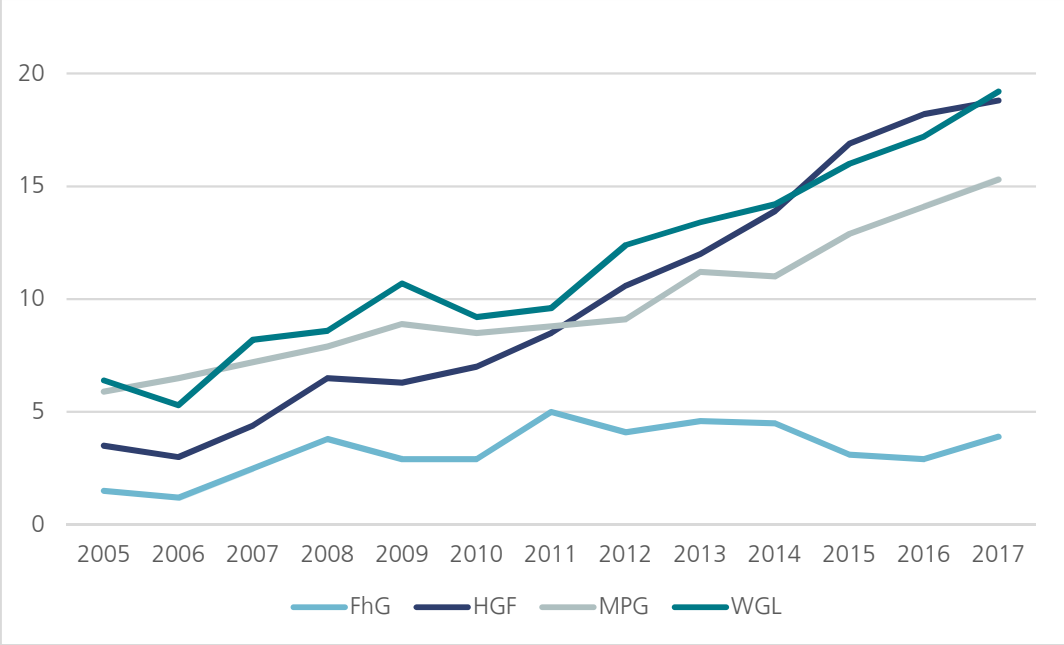
In the following chapters, we present our results. First, we describe how the shares of women have developed, especially in top positions in German research institutions. Then, we describe the main characteristics of scientific output in Germany, broken down into female and male authors.

5.1 Gender equality effects

The following graph shows the share of women in leading positions in the four big German research performing organisations. Due to an organisation-specific definition of three "management levels", a comparison of the total figures between the Fraunhofer-Gesellschaft (FhG), the Helmholtz Association of German Research Centres (HGF), the Max Planck Society (MPG) and the Leibniz Association (WGL) is only possible to a limited extent.

The share of women in management positions in science rose from a total of 2.0 % in 1992 to 17.8 % in 2016. The four research organisations differ greatly in their development between 1992 and 2016. MPG, WGL and HGF show slowly but steadily increasing shares of women in management positions during this period, while at 4.5 % in 2016, the share of women in the Fraunhofer-Gesellschaft was even lower than in the two previous years. What is also noticeable is that the strongest increase occurred after the establishment of the Pact in 2005.

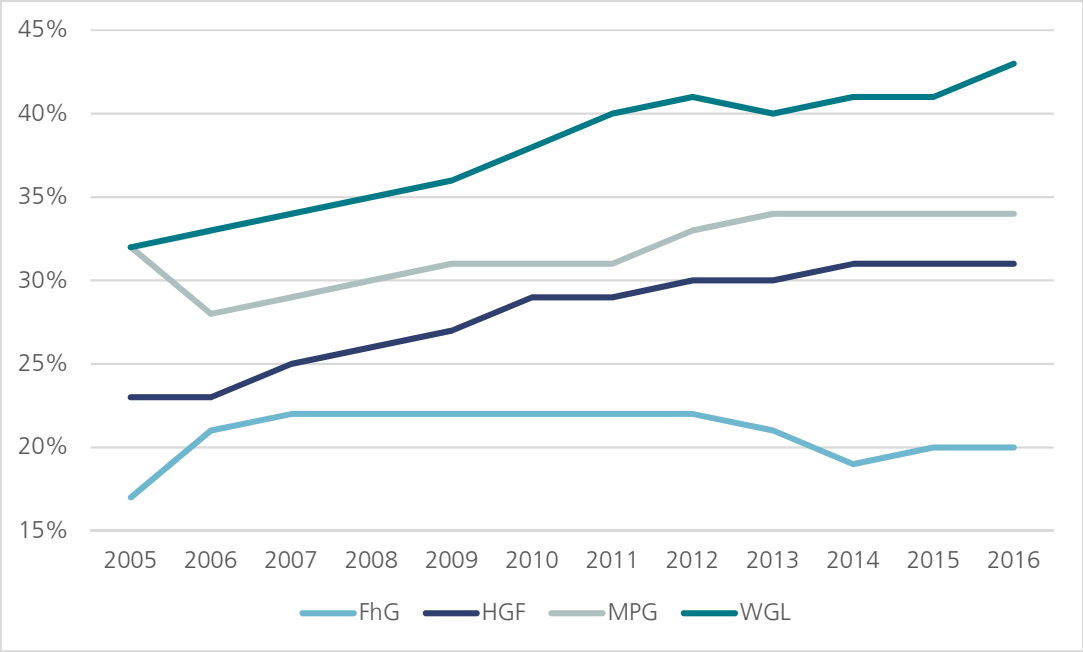
Figure 1: Share of women in leading positions at non-university research institutions 1992-2016



Source: GWK 2012, GWK 2018

Apart from the significant increase of women in decision-making positions at the four big German RPOs, we also find a steady but much smaller growth of female researchers at lower hierarchical levels. Thus, the Pact seems to have achieved its GE objectives.

Figure 2: Share of women among scientific staff (German RPOs, 2005-2016)

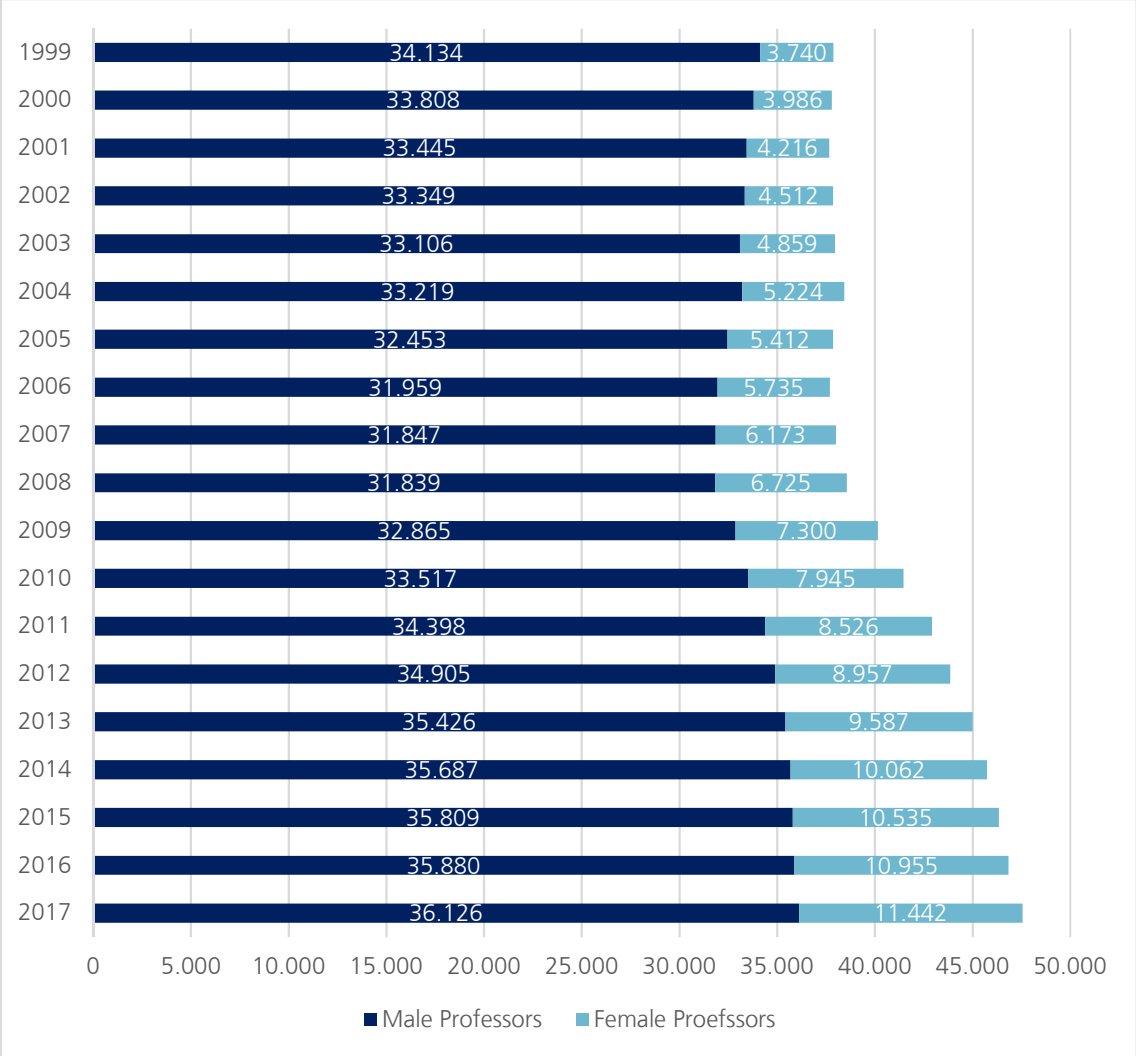


Source: GWK 2012, GWK 2018

The following statistics show the number of full-time professors at German universities between 1999 and 2017. 36,126 male full-time professors and 11,442 female full-time professors were employed at German universities in 2017.

Here, too, it can be seen that the number of women professors has risen far more strongly than the total number of professorships. A particularly dynamic development can also be observed here that coincides with the launch of the women professorship programme in 2008.

Figure 2: Number of male and female professors 1999-2017



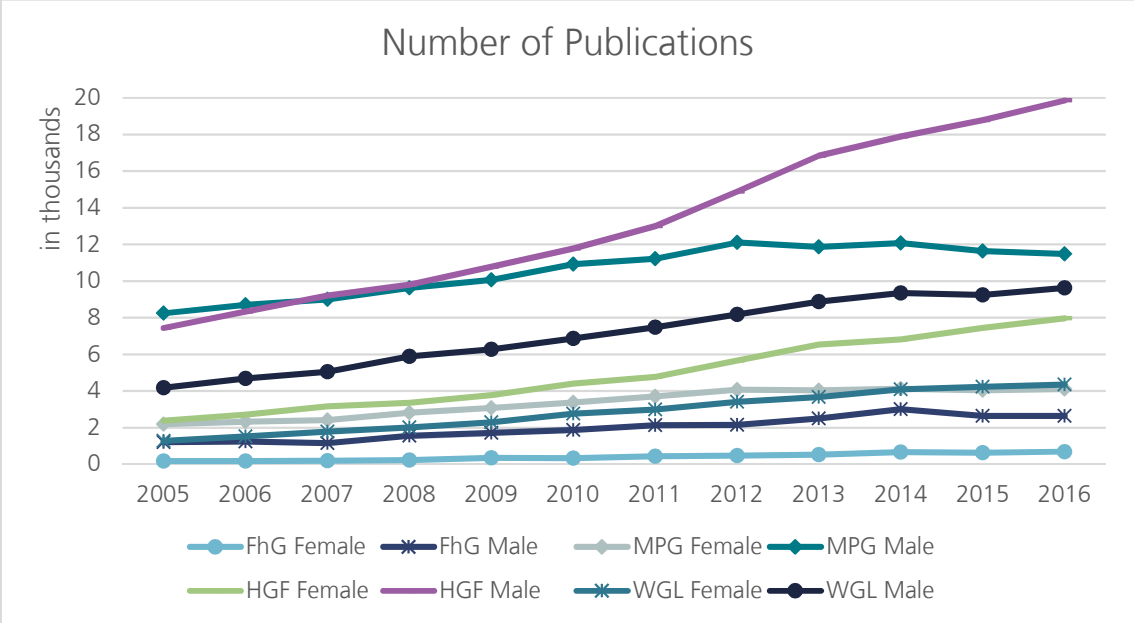
https://de.statista.com/statistik/daten/studie/160365/umfrage/professoren-und-professorinnen-an-deutschen-hochschulen/

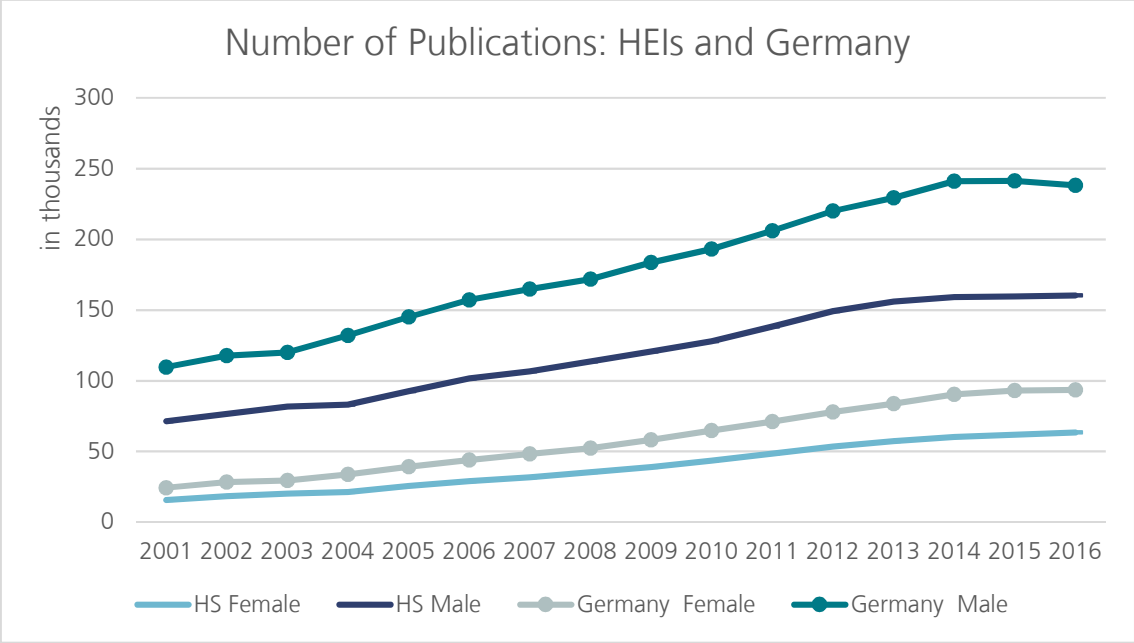
One of the most important results from the second evaluation of the women professorship programme (GESIS 2017) is that the proportion of women professors rose more strongly during the programme than the trend of previous years would have suggested. The respective value is 2.2 percentage points higher than the annual increase in previous years (1990-2017). This increase is mainly due to the universities participating in the Women Professors' Programme. (GESIS 2017, p. 4). The authors conclude: "These differences in the increase in the proportion of women professors between participating and non-participating universities are strong indications that the women professors' programme is having a positive effect to increase the proportion of women professors and thus establish a central objective of the programme fulfilled!" (GESIS 2017, p. 4).

5.1 Number of publications

In a first step, we look at the development of publication figures for researchers working in Germany between 2001 and 2016. First of all, it is noticeable that the number of publications has risen sharply, especially since 2008.

Figure 4: Number of publications from German RPOs, HEIs and Germany between 2001 and 2016,

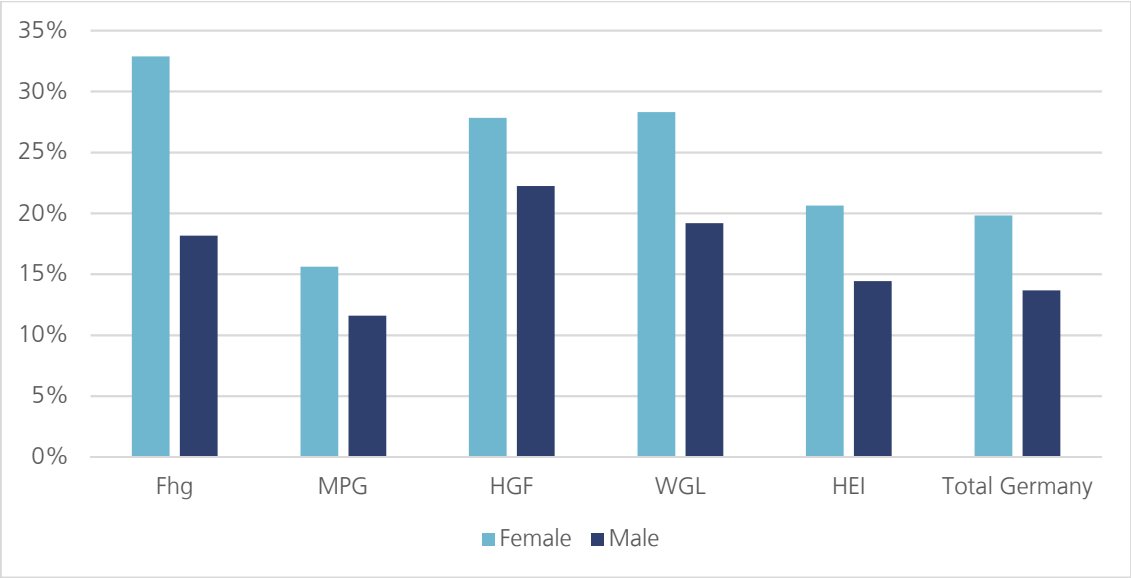




Source: Elsevier - Scopus; Fraunhofer ISI calculations.

In line with their overall employment as scientific staff, men publish far more than women. This applies to all the institutions considered, i.e. to non-university research as well as university research. However, it can also be shown that the number of publications by women has increased significantly more than that of men. This can be observed most clearly for female researchers of the Fraunhofer-Gesellschaft.

Figure 5: Average annual growth rate in publications by women and men in Germany between 2005 and 2016

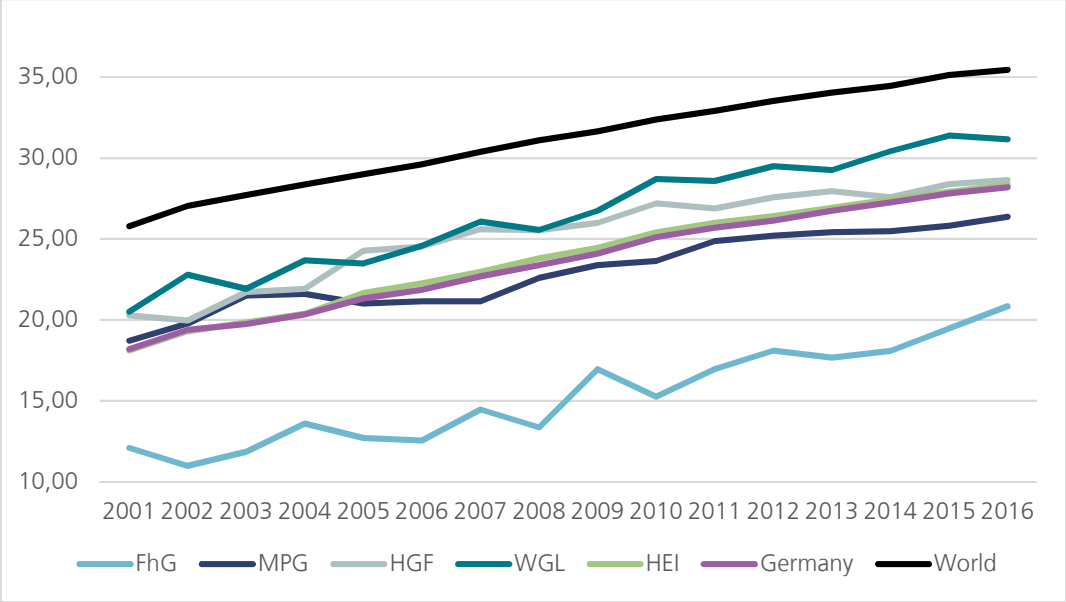


Source: Elsevier - Scopus; Fraunhofer ISI calculations.

Another perspective shows that women authors have significantly increased their share in the past 10 years, even though Germany as a whole is still far below the world average. The increase in the proportion of women in scientific publications is again most pronounced at the Fraunhofer- Gesellschaft, although this started from the lowest level among the research organisations.

The overall increase in female authorship may be the result of a changed gender discourse in the German research and innovation system that accompanied numerous policy interventions like the implementation of the Pact, the Women Professorship Programme and particularly the gender equality activities of the German research foundation (DFG), which have significantly affected how researchers perceive gender equality.

Figure 6: Share of female authors in % in Germany (2001-2016)



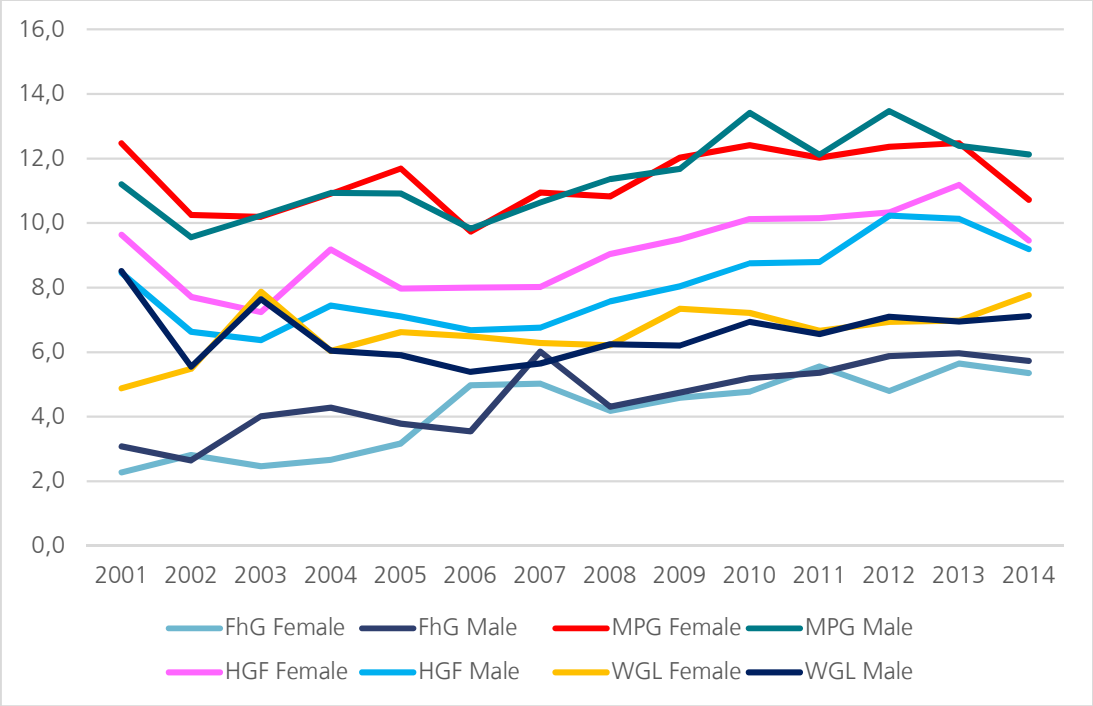
Source: Elsevier - Scopus; Fraunhofer ISI calculations.

5.2 Number of citations

If we look at the results of the citation analysis, it is noticeable that the differences between female and male authors are far less pronounced than with regard to the number of publications. This is a finding that is also widely confirmed in the academic literature (see above), namely that women typically publish less frequently overall, but with higher quality as measured by citations.

Generally speaking, publications by the Max Planck Society receive the most citations, regardless of whether they have male or female authors. For the HGF, it should be noted that female authors almost always have higher citation rates than male authors.

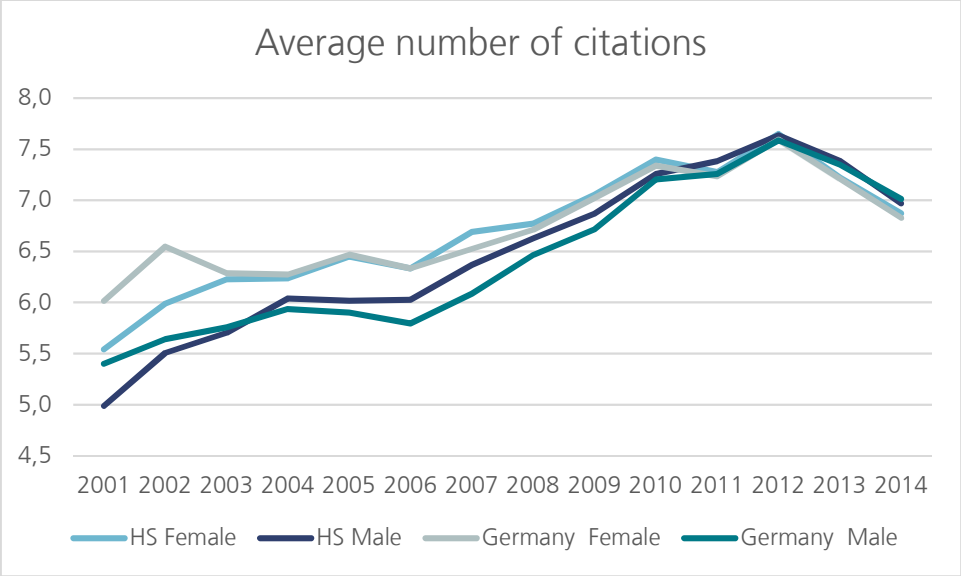
Figure 7: Average citation rate (field-specific) of publications by female and male authors of German RPOs (2005-2014)



We use a 3-year citation window here, which means that all the citations are considered that a publication receives in the year of publication and the two subsequent years; consequently, data are only available until the publication year 2014.
Source: Elsevier - Scopus; Fraunhofer ISI calculations.

There are no significant differences between men and women in the higher education sector or in Germany as a whole. This is an argument against genetic determinism and the long prevailing opinion that "women do not perform as well as men".

Figure 8: Average citation rate (field-specific) of publications by female and male authors of German HEI with a German affiliation (2005-2014)

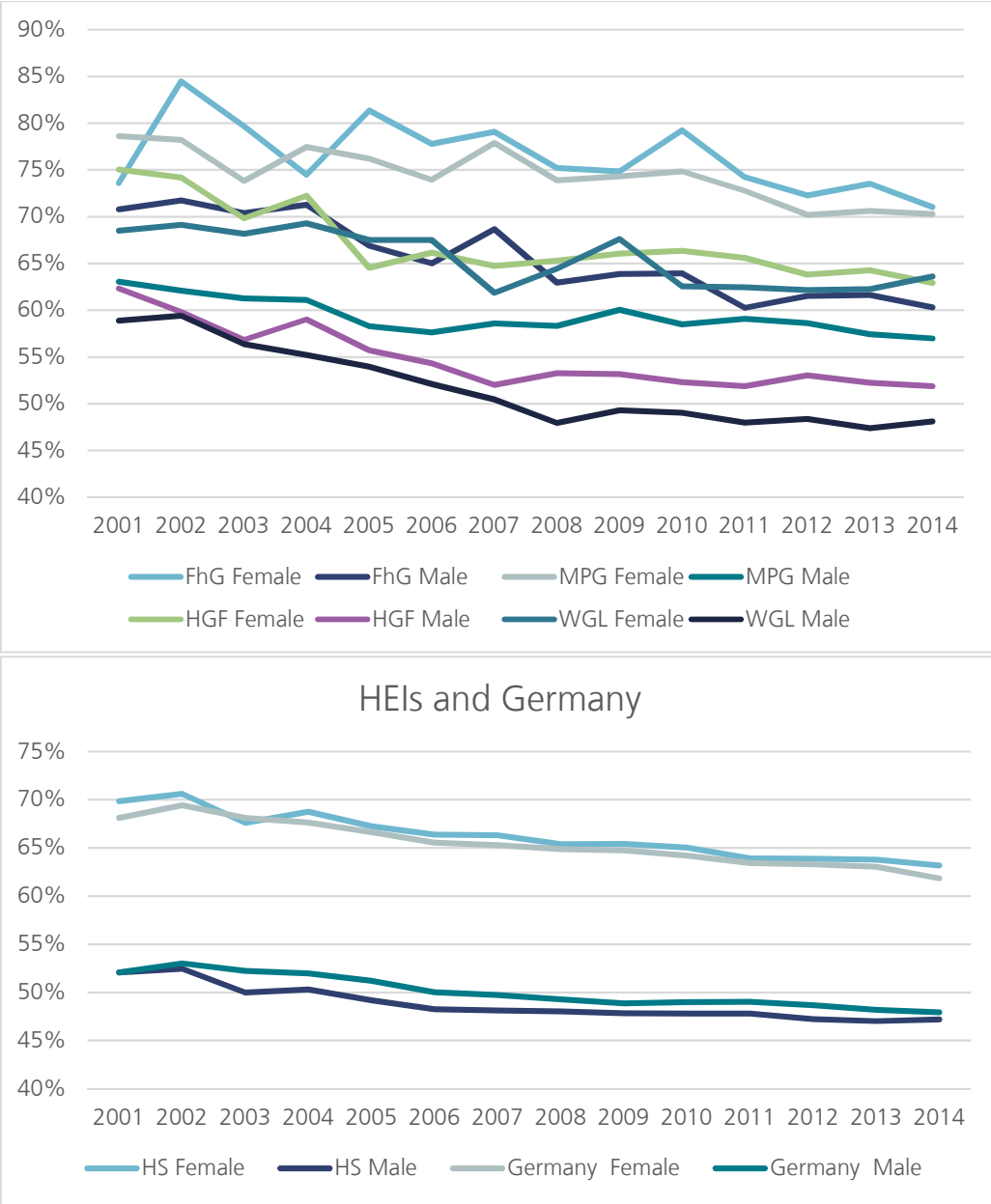


We use a 3-year citation window here, which means that all the citations are considered that a publication receives in the year of publication and the two subsequent years; consequently, data are only available until the publication year 2014.
Source: Elsevier - Scopus; Fraunhofer ISI calculations.

5.3 Excellence rate

The excellence rates are the shares of publications of an institution that belong to the top 10% of most highly cited articles in their particular fields. Our analysis shows that women are not inferior to men here. On the contrary, their excellence rate is higher than that of men on average, for both the university and the non-university sector.

Figure 9: Excellent rate of authors from a German RPO (2001-2014)

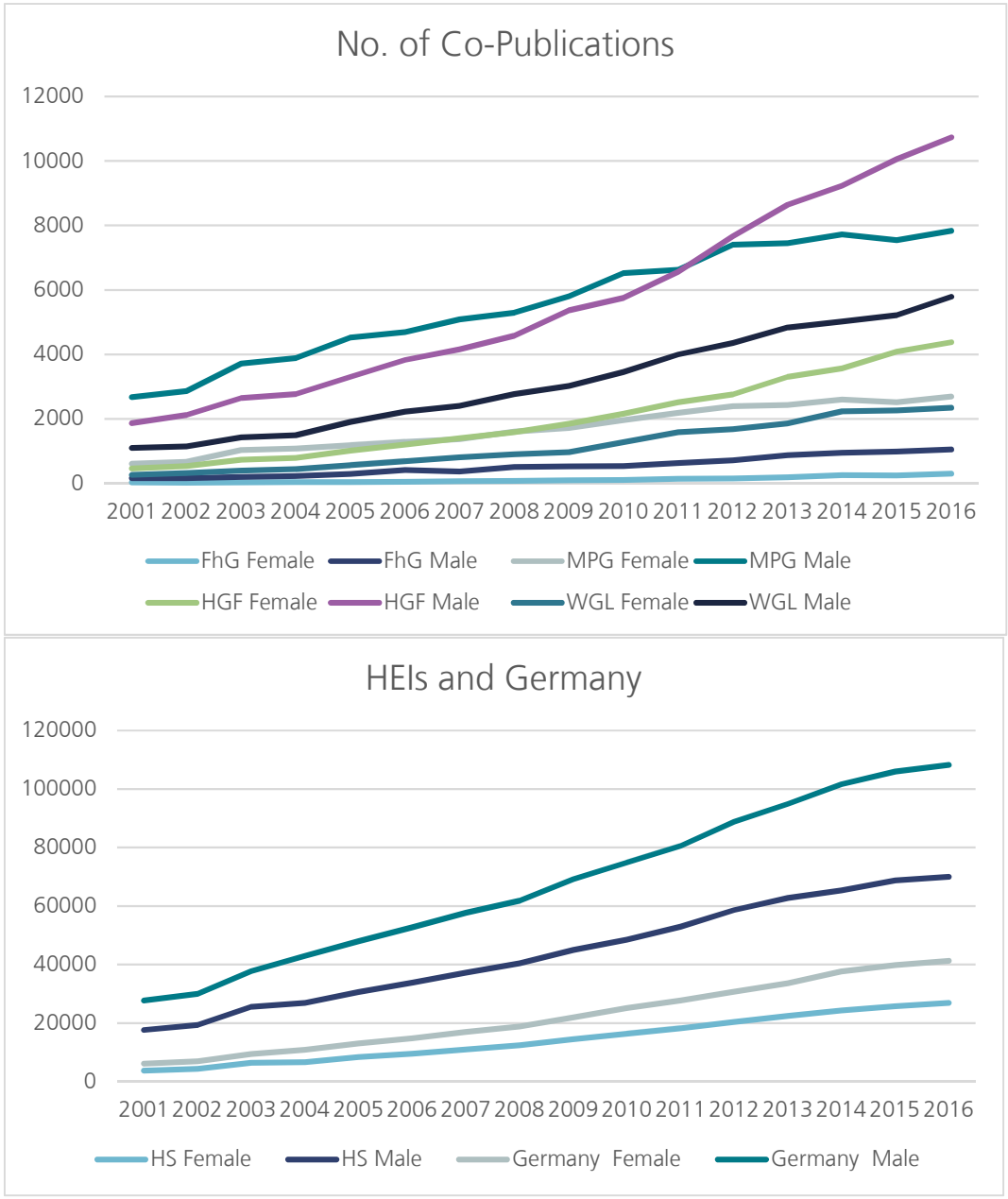


Source: Elsevier - Scopus; Fraunhofer ISI calculations.

5.4 International co-publications

Corresponding to the total number of publications, the number of international co-publications also shows a significantly higher number for male authors, regardless of the author's type of institution.

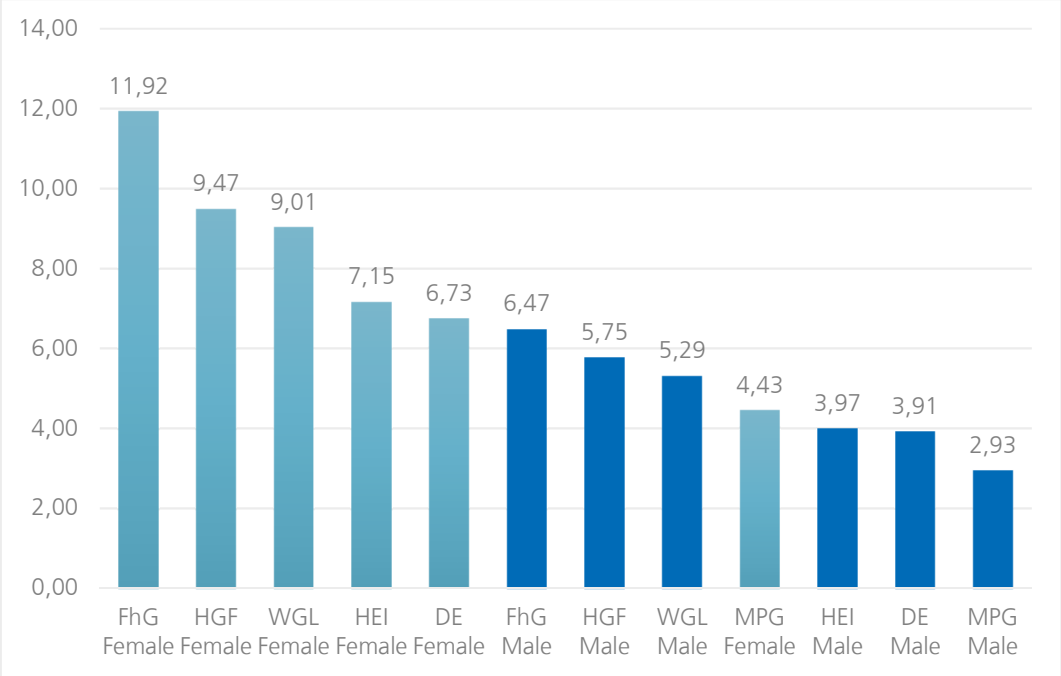
Figure 10: Number of international co-publications from authors of a German RPO (2001-2016)



Source: Elsevier - Scopus; Fraunhofer ISI calculations.

However, we can also see a significant increase of female author co-publications. As was the case above, female researchers at Fraunhofer show the highest increase rates.

Figure 12: Increase rate (2001-2016)



Source: Elsevier - Scopus; Fraunhofer ISI calculations.

6. Conclusions and discussion

The analysis has shown that the role of women academics in the German publication landscape has changed significantly over the past 15 years. There has been a clear increase in the number of (co-)publications by female authors. The higher participation of women in publications goes along with a general increase in the number of female staff in the research performing institutions in Germany and underlines the benefits associated with their better representation. Furthermore, although the overall number of women has also increased significantly since the introduction of the flagship promotional measures of the Women Professorship Programme and Pact for Research and Innovation, it has not risen to the same extent as women's participation in scientific publications. This means there are clear benefits for Germany in terms of scientific outputs from an increased proportion of women in its scientific workforce.

Our investigation has not yet been able to establish a direct link between the launch of the programmes and the improved representation of women in the different bibliometric indicators. However, we have good reasons to assume that the programmes have at least contributed not only to the higher shares of women within the research performing organisations, but - as a long-term impact - also to improved female publication patterns, especially in terms of citations and excellence rates.

7. References

Abramo, Giovianni; D'Angelo, Ciriaco Andrea; Caprasecca, Alessandro (2009): Gender differences in research productivity: A bibliometric analysis of the Italian academic system, Scientometrics, Vol 79, No, 3, 517-539.

Akerlof, George A. (1970): The market for "lemons". Quality uncertainty and the market mechanism. In: Quarterly Journal of Economics 84, S. 488–500.

Allison, Paul D., and J. Scott Long. 1990. "Departmental effects on scientific productivity." American Sociological Review 55 (4): 469-478.

Ashcroft, Kate, Stephen Bigger, and David Coates (1996). Researching into equal opportunities in colleges and universities. London: Practical Research Series, Kogan Page.

Bentley, Jerome T. (2003). Gender differences in the careers of academic scientists and engineers: A literature review. Arlington, VA: National Science Foundation, Division of Science Resource Statistics.

Bührer, Susanne; Hochfeld, Katharina, Hufnagl; Miriam; Klein, Saskia; Koch, Annika; Striebing, Clemens (2017). EFFORTI – Deliverable 2.2. Country Note Germany. Brussels.

Bunker Whittington Kjersten (2006): Gender and Scientific Dissemination in Public and Private Science: A Multivariate and Network Approach. Department of Sociology. Stanford University

Bunker Whittington Kjersten; Smith-Doerr, Laurel (2005): Women and commercial science: women's patenting in the life sciences. Journal of Technology Transfer, 30, 335-370.

BMBF: Federal Ministry of Education and Science (Bundesministerium für Bildung und Forschung). 2016d. Pakt für Forschung und Innovation. Retrieved from https://www.bmbf.de/de/pakt-fuer-forschung-und-innovation-546.html

Bundesministerium für Bildung und Forschung (BMBF) (2018): Bekanntmachung. Richtlinie zur Umsetzung des Professorinnenprogramms des Bundes und der Länder zur Förderung der Gleichstellung von Frauen und Männern in Wissenschaft und Forschung an deutschen Hochschulen – Professorinnenprogramm III. Bundesanzeiger vom 21.02.2018 (https://www.bmbf.de/foerderungen/bekanntmachung-1600.html vom 13.03.2018).

Bundesministerium für Bildung und Forschung (BMBF) (ohne Datum): Informationen zur zweiten Begutachtungsrunde des Professorinnenprogramms. (Download: https://www.bmbf.de/files/informationen_zweite_begutachtungsrunde_professorinnenprogramms.pdf vom 13.03.2018)

Bundesministerium für Bildung und Forschung (BMBF) (ohne Datum): Informationen zum ersten Aufruf des Professorinnenprogramms (Download:

https://www.bmbf.de/files/Uebersicht-Hochschulen-Bundeslaender.pdf vom 13.03.2018)

Campbell, Lesley; Siya Mehtani, Mary Dozier and Janice Rinehart (2013): Gender-Heterogeneous Working Groups Produce Higher Quality Science, Plos One, Vol.8, Issue 10, e79147

Cole, Jonathan R.; Zuckerman, Harriet (1984): The productivity puzzle: persistence and change in patterns of publications among men and women scientists. In: Steinkamp, M.W.; Maehr, M. (eds.): Advances in Motivation and Achievement. JAI Press, Greenwich.

Corley, Elizabeth, and Monica Gaughan (2005). Scientists' participation in university research centers: What are the gender differences? Journal of Technology Transfer 30 (4), 371–381.

Dasaratha, V. Rama, Kannan Raghunandan, Lawrence B. Logan, and Beryl V. Barkman (1997). "Gender differences in publications by promoted faculty". Issues in Accounting Education 12(2): 353–365.

Dundar, Halil, and Darrell R. Lewis. 1998. "Determinants of research productivity in higher education." Research in Higher Education 39 (6): 607-630.

European Commission. (2009). She Figures 2009: Statistics and Indicators on Gender Equality in Science. Luxemburg. Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/she_figures_2009_en.pdf

European Commission. (2013b). She Figures 2012: Gender in Research and Innovation. Statistics and indicators. Research and Innovation. Luxembourg: Publications Office of the European Union. Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/she-figures-2012_en.pdf

European Commission. 2013c. Gendered innovations: How gender analysis contributes to research. Luxembourg: Publications Office of the European Union.

European Commission. 2015b. Indicators for promoting and monitoring Responsible Research and Innovation. Report from the Expert Group on Policy Indicators for Responsible Research and Innovation. Luxembourg: Publications Office of the European Union.

European Commission. 2016b. Research Innovation Observatory. Luxembourg: Publications Office of the European Union.

European Commission. 2016c. She Figures 2015. Luxembourg: Publications Office of the European Union.

Eurostat. (2016b). Average number of actual weekly hours of work in main job, by sex, professional status, full-time/part-time and occupation (hours) [lfsa_ewhais].

Retrieved from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfsa_ewhais&lang=en

Fuchs, Stefan, Janina van Stebut, and Jutta Allmendinger. 2001. “Gender, science and scientific organization in Germany.” Minerva 39 (2): 175-201.

Frietsch, Rainer; Haller, Inna; Funken-Vrohlings, Melanie; Grupp, Hariolf (2009): Gender-specific patterns in patenting and publishing, Research Policy, 38, 590-599.

Frietsch, Rainer, Christian Rammer, Torben Schubert, Susanne Bührer, and Peter Neuhäusler. 2012. Innovationsindikator 2012. Bonn: Deutsche Telekom Stiftung.

Frietsch, Rainer; Bührer, Susanne; Helmich, Patricia (2016): Scientific and technological output of women and men). Presentation at the STI Conference in Valencia, September 2016

GESIS (2017): Evaluation des Professorinnenprogramms des Bundes und der Länder: Zweite Programmphase und Gesamtevaluation. Abschlussbericht. Januar 2017. Beauftragt vom Bundesministerium für Bildung und Forschung (Download: http://www.gwk-bonn.de/fileadmin/Papers/Evaluation_des_Professorinnenprogramms-Bericht _Januar_2017.pdf am 13.03.2017)

Gobo Giampetro (2016), The Care Factor: A Proposal for Improving Equality in Scientific Careers, in M. Bait, M. Brambilla and Crestani, V. (eds.), Utopian Discourses Across Cultures. Scenarios in Effective Communication to Citizens and Corporations, Bern: Peter Lang, pp. 157-183. ISBN 9783631693247

GWK: Joint Science Conference (Gemeinsame Wissenschaftskonferenz). 2012. Pakt für Forschung und Innovation. Monitoring-Bericht 2012. Heft 28. (http://www.gwk-bonn.de/themen/wissenschaftspakte/pakt-fuer-forschung-und-innovation/).

GWK: Joint Science Conference (Gemeinsame Wissenschaftskonferenz). 2018. Pakt für Forschung und Innovation. Monitoring-Bericht 2018. Heft 58. (http://www.gwk-bonn.de/themen/wissenschaftspakte/pakt-fuer-forschung-und-innovation/).

GWK: Joint Science Conference (Gemeinsame Wissenschaftskonferenz). 2015. Pakt für Forschung und Innovation. Monitoring-Bericht 2015. Heft 42. (http://www.gwk-bonn.de/themen/wissenschaftspakte/pakt-fuer-forschung-und-innovation/).

GWK: Joint Science Conference (Gemeinsame Wissenschaftskonferenz). 2016a. Chancengleichheit in Wissenschaft und Forschung. 20. Fortschreibung des Datenmaterials (2014/2015) zu Frauen in Hochschulen und außerhochschulischen Forschungseinrichtungen. Retrieved from http://www.gwk-bonn.de/fileadmin/Papers/GWK-Heft-50-Chancengleichheit.pdf

Hunt, Jennifer; Garant, Jean-Philippe; Herman, Hannah; Munroe, David J. (2013): Why are women underrepresented amongst patentees? In: Research Policy 42 (4), S. 831–843.

Hunter, Laura A., and Erin Leahey. 2010. “Parenting and research productivity: New evidence and methods.” Social Studies of Science 40 (39): 433-451.

Jung, Taeyhun; Ejermo, Olof (2014): Demographic patterns and trends in patenting. Gender, age, and education of inventors 86, S. 110–124.

Karamessini, Maria. 2004. Women’s representation and progression in science careers in Greece. Athens: KETHI Research Centre for Gender Equality.

Kassinis, George, Alexia Panayiotou, Andreas Dimou, and Georgia Katsifaraki. 2016. “Gender and environmental sustainability: A longitudinal analysis.” Corporate Social Responsibility and Environmental Management.

Kyvik, Svein (1990). “Motherhood and scientific productivity”. Social Studies of Science 20 (1), 149–160.

Kyvik, Svein, and Mari Teigen. 1996. “Child care, research collaboration and gender differences in scientific productivity.” Science, Technology and Human Values 21 (1): 54-71.

Landino, Rita A., and Steven V. Owen. 1988. “Self-efficacy in university faculty.” Journal of Vocational Behaviour 33: 1-14.

Lee, Sooho, and Barry Bozeman. 2005. “The impact of research collaboration on scientific productivity.” Social Studies of Science 35 (5): 673-702.

Ledin, Anna; Bornmann, Lutz Gannon, Frank; Wallon, Gerlind (2007): A persistent problem – traditional gender roles hold back female scientists. In: EMBO reports, 8(11), 982-987.

Long, J. Scott (1992): Measures of sex differences in scientific productivity. In: Social Forces 71(1), 159-178.

Long, J. Scott P. D. Allison Paul D., and Robert McGinnis, (1993). “Rank advancement in academic careers: Sex differences and the effects of productivity”. American Sociological Review 58(5): 703–722.

Maske, Kellie L., Garey C. Durden, and Patricia E. Gaynor (2003). “Determinants of scholarly productivity among male and female economists”. Economic Inquiry 41(4): 555–564.

Mathews, A. Lanethea, and Kristi Andersen (2001). “A gender gap in publishing? Women’s representation in edited political science books”. Political science and politics 34 (1): 143–147.

Metz-Göckel, Sigrid; Heusgen, Kirsten; Möller, Christina; Schürmann, Ramona; Selent, Petra (2014): Karrierefaktor Kind: zur generativen Diskriminierung im Hochschulsystem. Opladen: B. Budrich,

Michael, Jörg (2007): 40000 Namen, IN: c't 17/07, p. 182; https://www.heise.de/ct/ftp/07/17/182/

Nakhaie, M. Reza (2002): Gender differences in publication among university professors in Canada. In: Canadian Review of Sociology and Anthropology – Revue Canadienne De Sociologie et D Anthropologie, 39(2), 151-179

Pan, Lei, and Elizabeth Kalinaki. 2015. Mapping gender in the German research area. Elsevier Research Intelligence.

Peñas, Celia Sánchez, and Peter Willett. 2006. "Gender differences in publication and citation counts in librarianship and information science research." Journal of Information Science 32 (5): 480-485.

Powell, Abigail; Hassan, Tarek M.; Dainty, Andrew R.J.; Carter, Chris (2009). Exploring gender differences in constructing research: A European perspective. In: Construction Management and Economics, 27(9), 803-807.

Prozesky, Heidi (2008): "A career-history analysis of gender differences in publication productivity among South African academics." Science Studies 21 (2): 47-67.

Prpic, Katarina (2002): Gender and productivity differentials in science. In: Scientometrics, 55(1), 27-58.

Rothausen-Vange, Teresa J., Janet H. Marler, and Patrick M. Wright (2005). "Research productivity, gender, family, and tenure in organization science careers". Sex Roles: A Journal of Research 53(9/10): 727–738.

Snell, Clete, Jon Sorensen, and John J., Kuanliang, Attapol Rodrigues. 2009. "Gender differences in research productivity among criminal justice and criminology scholars." Journal of Criminal Justice 37 (3): 288-295.

Suitor, J. Jill, Dorothy Mecom and Ilana S. Feld (2001). "Gender, household labor, and scholarly productivity among University professors". Gender Issues 19 (4): 50–67.

Symonds, Matthew R.E.; Gemmell, Neil J.; Braisher, Tamsin L.; Gorringe, Kylie L.; Elgar, Mark A. (2006): Gender differences in publication output: Towards and unbiased metric of research performance. In: PLoS ONE, 1(1), e127.

Taylor, Susan Washburn; Fender, Blakely Fox; Burke, Kimberly Gladden (2006): Unraveling the academic productivity of economists: The opportunity costs of teaching and service. In: Southern Economic Journal, 72(4), 846-859.

Timmers, Tanya M., Tineke M. Willemsen, and Kea G. Tijdens. 2010. "Gender diversity policies in universities: a multi-perspective framework of policy measures." Higher Education 59 (6): 719-735.

Tower, Greg; Plummer, Julie; Ridgewell, Brenda (2007): A multidisciplinary study of gender-based research productivity in the world's best journals. In: Journal of Diversity Management, 2(4), 23-32.

van Arensbergen, Pleun; van der Weijden, Inge; van den Besselaar, Peter (2012) Gender differences in scientific productivity, a persisting phenonemon? Scientometrics 93 (2012) 857-868

Xie, Yu; Shaumann, Kimberlee A. (1998): Sex differences in research productivity: new evidence about an old puzzle. American Sociological review 63 (6), 847-870

Xie, Yu; Shaumann, Kimberlee A. (2003): Women in Science: Career processes and Outcomes. Harvard University Press, Cambridge MA.

Zuckerman, Harriet, Jonathan R. Cole, and John T. Bruer. 1991. The outer circle. Women in the scientific community. New Haven: Yale University Press.

Acknowledgements:

Parts of this paper relates to the H2020 project EFFORTI that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 710470