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# Is There a Motherhood Penalty in Academia?

## The Gendered Effect of Children on Academic Publications

Mark Lutter and Martin Schröder


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## Abstract

Based on data that tracks CV and publication records as well as survey information from sociologists in German academia, we examine the effects of parenthood on the publication output of male and female academics. Results indicate that having children leads to a significant decline in the number of publications by women, while not affecting the number of publications by men. We also find that the gendered effect of children on productivity hardly mitigates differences in publication output between men and women, as women still publish about 20 percent less than men after controlling for the adverse effects of children on productivity. We further find that the gendered effect of childbearing depends partly on prior levels of women's academic achievements, which suggests mechanisms of performance-driven self-selection. Lower-performing women tend to suffer a stronger motherhood penalty, while the publication output of more successful women (who have been granted academic awards) is not reduced through childbirth. The results indicate that women are better at managing the "double burden" of parenthood and career if external, award-giving committees have bestowed prestige upon them and indicated their potential for a scientific career. Overall, these findings contribute to a better understanding of how to reduce the adverse effect of children on female publication output.

**Keywords:** academic career, academic publications, children, gender gap, motherhood penalty

## Zusammenfassung

Auf Basis eines Datensatzes, der Lebenslauf- und Publikationsdaten sowie Informationen aus einem Online-Survey von deutschen Soziologinnen und Soziologen verbindet, untersuchen wir die Auswirkungen von Elternschaft auf den Publikationsoutput von Wissenschaftlern und Wissenschaftlerinnen. Die Ergebnisse zeigen, dass Elternschaft zu einem signifikanten Rückgang der Publikationen bei Frauen, nicht aber bei Männern führt. Ebenso zeigt sich jedoch, dass dieser geschlechtsspezifische Effekt bestehende Publikationsunterschiede zwischen Männern und Frauen kaum beseitigt. Frauen publizieren etwa 20 Prozent weniger als Männer, auch nachdem statistisch kontrolliert wird, dass Kinder die Publikationen von Frauen stärker senken als von Männern. Ferner zeigt sich, dass der negative Kinder-Effekt bei Frauen teilweise durch ihre bisherigen akademischen Errungenschaften erklärt werden kann, was auf Selbstselektionseffekte hinweist. Frauen, die mit akademischen Preisen als aussichtsreiche Kandidatinnen für eine akademische Karriere ausgezeichnet wurden, erleben einen geringeren Rückgang an Publikationen, wenn sie Kinder haben. Insgesamt tragen die Resultate zu einem besseren Verständnis dazu bei, wie die negativen Effekte von Elternschaft auf den Publikationsoutput von Frauen verringert werden könnten.

**Schlagwörter:** Benachteiligung von Müttern, Geschlecht, Kinder, wissenschaftliche Karrieren, wissenschaftliche Publikationen

## Contents

# Is There a Motherhood Penalty in Academia? The Gendered Effect of Children on Academic Publications

## 1 Introduction

Across disciplines, age groups, and cohorts, men in academia publish significantly more than women (Cole and Zuckerman 1987, 119; Cole and Singer 1991; Leahey 2006, 756; Lutter and Schröder 2016; Sax et al. 2002, 424; Stack 2004; Xie and Shauman 1998; 2003). What explains this gender gap in publication output? Empirical studies suggest that raising children is one of the main factors explaining women's disadvantaged labor market position (Correll, Benard, and In Paik 2007; Petit 2007, 385; Sigle-Rushton and Waldfogel 2007, 67–77). The same is true in academia: scholars attribute the publication gap to motherhood and childcare responsibilities (Mason, Wolfinger, and Goulden 2013, 29; Rivera 2017, 1114).

However, empirical findings on whether motherhood actually explains the publication gap in academia show mixed results (see the reviews in Hunter and Leahey 2010, 433; Joecks, Pull, and Backes-Gellner 2014, 517; Sax et al. 2002, 425; Stack 2004, 893). Some studies indeed confirm that motherhood decreases the publication output of women (Hargens, McCann, and Reskin 1978, 161; Long 1990); yet others argue that only young children decrease publication output (Kyvik 1990, 158; Kyvik and Teigen 1996, 69; Mason, Wolfinger, and Goulden 2013, 29; Stack 2004, 914). Others do not find any effect: Hamovitch and Morgenstern (1977, 643) were the first to conclude that, after controlling for academic rank, teaching duties, years since PhD completion, type of university, and academic discipline, "the remaining sex difference in publication (20 percent fewer articles published by women than by men) is not due to any relationship or tradeoff between children and productivity." In line with Hamovitch and Morgenstern, newer studies also do not find that children affect the publication output of women differently than that of men (Cole and Zuckerman 1987, 125; Fox 2005, 146; Jaksztat 2017, 357; Krapf, Ursprung, and Zimmermann 2017; Sax et al. 2002, 435). For example, Hunter and Leahey (2010, 447) show that "[s]ignificant gender differences in productivity growth were eliminated once we controlled for differential effects of children by gender," while Sax et al. find that "family-related factors do not interfere with scholarly productivity" (Sax et al. 2002, 438). Krapf et al. (2017) find no general effect but suggest that there might be a motherhood penalty for very young mothers or for mothers who have two or more children. Some studies even find that children increase the publication output of mothers (Joecks, Pull, and Backes-Gellner 2014, 526; Nakhaie 2002; Stack 2004, 913; Toutkoushian and Bellas 1999).

We would like to thank Sabine Köszegi and Ingo Rohlfing for suggestions and comments on a previous version. The paper benefitted from constructive comments at the MZES colloquium in Mannheim and at the sociological colloquium at the University of Konstanz, for which we thank all participants.

To understand why studies have come to such opposite results, we suggest that it is important, first, to distinguish between-level effects from within-level effects. Many prior studies base their conclusions solely on cross-sectional or between-level effects. These studies therefore compare groups, but do not take into account individual career changes, or within-level effects, obtained through fixed-effects regressions. Second, we suggest that it is important to control for possible selection effects that took place before childbirth, because researchers who have been assured of their academic potential early on in their career may tenaciously stick to an academic career and continue to publish even when they have children (Cole and Zuckerman 1987, 125; Fox 2005, 145; Joecks, Pull, and Backes-Gellner 2014, 520). For researchers who have not been assured of their academic potential, and thus feel more strongly an incommensurability of their role as researcher with other parts of their social identity, parenthood may not increase their determination to publish, but instead provide a road out of academia (Haas, Koeszegi, and Zedlacher 2016; Haas and Koeszegi 2017).

In this study, we analyze how having children affects the publication rate of men and women differently and control this effect for prior levels of academic performance as an indication for possible selection effects. We also disentangle between-level from within-level effects and test how the effects of parenthood on publication output change if we interact and distinguish between low and high levels of prior academic performance.

In doing so, we make use of a unique panel dataset that tracks CV and publication records from almost all sociologists working in all sociology departments in Germany. We combine this data with an online survey in which we asked all sociologists whether they have children, and if so, when they were born. We study German sociologists before tenure to assure that everyone in our dataset is under similar institutionalized pressure to publish while deciding about parenthood. In contrast to countries such as France, the UK, or the US, Germany has virtually no permanent positions below a full or associate professorship and no established tenure track system. In addition, German labor law forces everyone to leave academia after twelve years of temporary employment, making it a drastic "up or out" system. Scholars therefore have to publish as much as they can during the typical age for parenthood (the average age for getting a first tenured professorship is forty-one in Germany).

We focus on the discipline of sociology, because it has a relatively equal representation of men and women (unlike the natural sciences), which makes it ideally suited to analyze career trajectories of both genders (Jungbauer-Gans and Gross 2013; Leahey 2006, 760; Stack 1994, 81; 2002, 286). Sociology is a uniquely suited field to study the impact of children on publication output, because unlike the lab sciences, work in sociology is relatively portable. It is easier to write an essay or conduct statistical analyses from home than to conduct an experiment. Because of both the relative equality in terms of gender representation and the more portable work situation, researchers suggest that if children matter in fields such as sociology, they are likely to matter even more in the natural sciences (Hunter and Leahey 2010, 436f.; Mason, Wolfinger, and Goulden 2013, 25).

Our findings show that parents generally publish less than childless researchers in comparable situations. Within-effects based on fixed-effects models show that childbirth leads to a significant decline in the number of publications by women, while it does not affect the publication output of men. These results remain stable, even if we control for differences in individual career paths via fixed-effects individual slopes regression (Ludwig and Brüderl 2018). We also find that the gendered effect of children on publications explains some of the female publication gap, but not all of it. Finally, we find that the gendered effect of childbearing on publication output partly depends on the levels of women's prior academic achievements. In particular, we find that women who have received more academic awards show no negative motherhood effects, i.e., they show no decline in their publication output once they become mothers, while women who have received no awards experience a much stronger decline in the number of publications once they have children.

## 2 The gendered effect of children on publication output: Theoretical considerations and empirical results

Several mechanisms may explain why and in what direction children affect academic research output (for a review of these mechanisms, see Cole and Zuckerman 1987; Fox 2005; Hunter and Leahey 2010; Joecks, Pull, and Backes-Gellner 2014; Stack 2004). In line with Joecks et al. (2014), children may influence publication output through (1) effects of self-selection, (2) effects of time constraints, and (3) incentive effects and changes in preferences.

The first mechanism, self-selection, may operate in two opposite ways, depending on career orientation and how much academic acclaim researchers have received at early stages of their academic career. On the one side, self-selection may mean that the most determined, career-oriented academics become parents, as they are more likely to assume that they can keep up their publication output after having children. In this case, the measurable effect of children on productivity could be neutral or even positive. This has been alluded to in the literature but not systematically tested (Stack 2004, 899). For example, Cole and Zuckerman (1987, 125) find no effect of children on the research productivity of women and suggest this is because childbearing women in their sample have "eliminate[d] almost everything but work and family" from their lives to remain productive. The proposed mechanism behind this is that researchers who are more assured that an investment into academia will "pay off" remain committed to their career after becoming parents, so that the most productive researchers should not experience a steep decline in their publication output after childbirth.

On the other side, researchers who have been less assured of their academic success may decide to drop out of academic publishing when faced with the "double burden" of par-

enthood and career. We should thus see that having children interacts with prior signals of success. In societies with traditional gender roles such as Germany (Blossfeld, Drobnic, and Rohwer 2001; Gangl and Ziefle 2015; Schulz and Blossfeld 2006), this mechanism should be more relevant for women than for men. When their partner is in charge of most of the childrearing and housework, men do not need to be assured of their eventual academic success to keep on publishing after having children, since the traditional separation of labor in the household can even help them to publish more, not less, than before. Recent research on the effects of gender-neutral, tenure-clock-stopping policies suggests that male academics indeed benefit from traditional gender roles, as they tend to use parental leaves to continue publishing papers (Antecol, Bedard, and Stearns 2018).

The second mechanism is that children can lower publication productivity simply because childcare consumes time, which would otherwise be available for research. This effect is directly related to the first mechanism and may again be related to prior signals of academic success. To the degree that academics have been assured of their academic success, they may continue to publish post-childbirth, for example, by placing their children in professional childcare early on. Therefore, this mechanism also suggests that researchers with lower early signals of academic achievement may experience a stronger decline in publication output after having children.

The third mechanism is that children may change work incentives and preferences – again depending on the signals an academic has received before parenthood. On the one hand, when academics have received signals that assure them of a realistic chance for an academic career, then parenthood may increase the incentive to seek the economic security of tenure, which in turn requires additional publications. Thus, children may incentivize parents to publish more to the degree that researchers have adopted a breadwinner role and can realistically assume to fulfill this role through a professorship.

Parenthood also provides an alternative source of identity (see Gangl and Ziefle 2015) and can lead to severe stress, especially for mothers (Giesselmann, Hagen, and Schunck 2018). As a result, publication output might decline after childbirth. Especially when researchers have not been encouraged before having children, for example, through early academic success or the signaling function of academic awards, they may abandon the pursuit of publishing research when an alternative source of identification arises or when levels of stress increase. However, those whose identity as a researcher has been confirmed through prior academic success may be more willing to keep on engaging in this role after their children are born. Thus, the effect of children on publication productivity post-birth may again depend on prior levels of academic success.

Recent empirical results suggest this. Fox et al. (2005, 146) find that "young children are not associated with depressed publication productivity" but caution that this is true for "women who have survived a rigorous and demanding process of scrutiny, selection, and evaluation in science," suggesting that the effect of children interacts with prior signals of academic achievement. Hunter and Leahey (2010, 447) show that researchers with

children do have more publications at each career step but a lower rate of publication, also suggesting that even though children in and of themselves may depress publication productivity, only the most determined researchers may have children in the first place.

## 3 Data and methods

### Data

We use a unique panel dataset that covers the pre-tenure careers of all sociologists employed at a sociology department in a German university in the year 2013. To collect the data, we identified all seventy-five sociology departments in Germany, plus two research institutes. Based on the department and faculty websites, we hand-coded all available CV data and publications. The constructed longitudinal career dataset therefore contains individual time-series data of virtually all German academic sociologists, starting from their first publication until they either got tenure as a full or associate professor, or the year 2013 was reached. We limit our data to sociologists who obtained their PhD after the year 1980 and we only include individuals with at least one publication. After collecting this data, we conducted an email survey in which we asked all academics in our database whether or not they have children and, if so, when their children were born. The response rate of the survey was 64 percent.[1] After strictly anonymizing all information, we integrated both data sources and arranged the data as a person-year panel. We collected data on a total of 1,260 sociologists, nested in 11,833 person-years. The regressions below use the subset of those 64 percent who responded to our survey and thus had all variables necessary for our analysis. The final dataset therefore contains time-varying profiles with 7,667 person-year observations from 805 sociologists. Our dependent variable is the annual number of peer-reviewed SSCI journal articles (see next section for details), so we lag all independent variables by one year to avoid simultaneity bias and to better distinguish between current and prior publications. This reduces the dataset to 6,846 person-year observations from 729 sociologists in the regressions below (297 female and 432 male sociologists).

### Dependent variable

Analogous to existing research, our dependent variable is the yearly number of articles published in peer-reviewed journals (cf. Fox 2005, 134; Hunter and Leahey 2010, 438;

1 This response rate is relatively high. One reason may be that the survey was just a quick email. It did not contain a link to an external online survey; respondents delivered their answer simply by replying with the number and birth years of their children.

Joecks, Pull, and Backes-Gellner 2014, 523). We only consider journals listed in the Social Science Citations Index (SSCI) because these adhere to standards of quality and peer review (Bohannon 2013). The double-blind peer review of these journals is also important for our purposes, as empirical studies show how the work of female scientists is devalued when their gender is known (van den Brink and Benschop 2011; Wennerås and Wold 1997). We adjust all publications for co-authorship through the formula *2/(number of authors+1)*, which weighs single-authored publications as 1 publication, co-authored publications as 0.67, publications with three authors as 0.5, and so on. In robustness tests, we also used unweighted adjustments of co-authorships (with the formula *publication/number of authors*) and used no authorship adjustment (counting every publication as 1, regardless of co-authors). Neither produced large differences compared with the main results that we present below (available upon request).

## Independent variables

Our main predictors are *number of children* (which vary by year) and gender (coded as 1=*female*). Since we lag the number of children and all other independent variables by one year, we estimate the effect of childbearing on the research publication productivity of the following years. Robustness checks also test a two-year lag for the number of children (see below, Tables A1 and A2).

To control for how prior signals of academic achievement influence the effect of children on publication output, we include several variables that measure achievement and status within an academic career. These can be divided into three groups of variables.

The first group of controls consists of three variables that capture research experience below the level of a tenured professorship, so that we can compare researchers in comparable career stages. *Doctorate* is a dummy variable that turns from 0 to 1 when a person obtains a doctorate degree. The dummy variable *habilitation* does the same when a person finishes a habilitation, which in Germany is like a second dissertation that scholars complete as qualification toward a professorship. The third variable, *years in academia*, measures academic age, notably the years since a researcher's first publication.

The second group of variables measures research output and academic performance through several indicators, so that we can control current publications for earlier publications. The first three variables measure different types of prior publications. *SSCI journal articles* is the cumulated number of journal articles an academic has published up until each year in his or her career. *Books* consists of all published monographs and textbooks, cumulated in the same way. *Book chapters* does the same for articles published in edited volumes. *Awards* is the total number of academic awards a researcher has received up until each point in his or her career. This includes all academic awards mentioned on a CV, such as best paper awards, dissertation awards, and so on, but ex-

cludes stipends or research grants. *Co-authors* consists of the number of people a person has published with so far up until each given year. *International publications* represents a person's number of English-language publications. *DFG grants* is the cumulated number of years during which a researcher received funding through a main research grant *("Sachbeihilfe")* from the German Research Foundation (DFG). As grants are essentially a resource input, we expect them to increase the number of future publications.[2] Controlling for these variables also controls for women being disadvantaged, as they may have less access to publishing avenues and third-party funding (van den Brink and Benschop 2011; Wennerås and Wold 1997). Generally, we control for prior publications and research funding to be able to compare researchers with similar prior input and output.

The third group of variables controls for academic mobility. They measure the degree to which an academic has accumulated international and national experience with different institutions and academic cultures, which we expect to increase the number of research publications. The first of these measures, *months abroad,* represents the number of months a person stayed abroad at another institution. If the CV did not contain the exact number of months but noted a year or specific semester (such as academic year 2012–2013 or fall term 2012/13), then we counted five months for a semester and ten months for an academic year. *Mobility* consists of the number of times an academic changed university or institution for a new academic job. *Interim professor* is the number of times a person worked as an interim professor ("*Vertretungsprofessur*" in German). An interim professor is a position where a non-tenured postdoc substitutes for a full professor for a limited period, usually six to twenty-four months.

All of these variables help us to assess performance up until each point in a researcher's career. By taking them into account, we can therefore compare the effect of parenthood on productivity relative to, but also irrespective of, a researcher's general productivity.

## Analytical strategy

Table 1 presents a descriptive overview. This is followed by three types of regression models: Table 2 shows random-effects models that estimate how gender and children are related to research publications before and after including controls for career stages and prior academic measures of accomplishment. Table 3 uses fixed-effects models to obtain within-person coefficients; these models estimate how having children affects the publications of men and women separately. All models include the main predictor variable – number of children – and then control for the postulated selection effects by gradually including measures of academic career status and prior performance. Table 4 estimates interaction effects between performance measures and number of children

2 We collected this data from a database of the DFG (gepris.dfg.de) and merged it into our database through the names of the researchers and their years of funding.

separately for men and women. This tests whether having children has different effects on men and women who have accumulated different measures of academic achievement before parenthood.

All models estimate cluster-robust standard errors (clustered by person using the bootstrap method as suggested by Cameron and Trivedi 2010). All independent variables except dummies are logged to account for nonlinearity and diminishing marginal effects. For variables with zero as the minimum value, we added the constant 1 before taking the natural logarithm.

## 4 Results

### Descriptive results

Table 1 shows the means and standard deviations of all variables used in this study. Column 1 displays the statistics for our entire sample. Columns 2 and 3 separate the descriptive data into men and women. Columns 4–7 further split up the data into men and women without children, fathers, and mothers (defined as men and women having at least one child).

Column 1 of Table 1 shows that we have 7,667 person-year observations from 805 different researchers. During an average year in our dataset, researchers publish 0.161 (co-author-adjusted) SSCI journal articles per year. Comparing column 2 and 3, men publish about 1.5 times more SSCI articles per year than women (0.185 to 0.120). Columns 4–7 further differentiate between male and female academics with or without children. Fathers publish the most, followed by childless men, mothers, and childless women. Interestingly, there is not only a publication gap between men and women, but also a gender gap with regard to children. Male sociologists have about 1.5 times more children on average than female sociologists (0.650 to 0.429).

### Results from random-effects models

Table 2 shows the results of random-effects regressions. The constant in Model 1 shows that men publish 0.197 SSCI articles per year, while women publish 0.062 fewer articles on average. Hence, without further controls, female sociologists publish about 34 percent fewer articles than their male counterparts. Note that this is virtually the same effect that the descriptive overview in Table 1 documents, which is reasonable, as the model does not include relevant control variables.

Table 1 Descriptive overview on all variables: overall, by gender, and by gender and having children

| | (1) Overall | (2) Men | (3) Women | (4) Men childless | (5) Women childless | (6) Fathers | (7) Mothers |
|---|---|---|---|---|---|---|---|
| SSCI journal articles per year (dependent variable) | 0.161 (0.437) | 0.185 (0.473) | 0.120 (0.368) | 0.172 (0.461) | 0.112 (0.362) | 0.205 (0.490) | 0.142 (0.384) |
| Female | 0.383 (0.486) | | | | | | |
| No. of children | 0.565 (0.869) | 0.650 (0.925) | 0.429 (0.751) | | | 1.642 (0.731) | 1.488 (0.617) |
| Doctorate | 0.459 (0.498) | 0.481 (0.500) | 0.422 (0.494) | 0.345 (0.475) | 0.310 (0.463) | 0.690 (0.463) | 0.697 (0.460) |
| Habilitation | 0.0819 (0.274) | 0.0984 (0.298) | 0.0552 (0.228) | 0.0496 (0.217) | 0.0369 (0.189) | 0.173 (0.378) | 0.101 (0.301) |
| Years in academia | 6.673 (5.941) | 6.921 (6.039) | 6.273 (5.758) | 5.277 (5.240) | 5.067 (4.990) | 9.432 (6.311) | 9.256 (6.411) |
| SSCI journal articles | 0.951 (1.938) | 1.152 (2.197) | 0.627 (1.366) | 0.804 (1.671) | 0.497 (1.234) | 1.683 (2.732) | 0.949 (1.605) |
| Books | 1.010 (1.237) | 1.141 (1.363) | 0.800 (0.967) | 0.777 (1.078) | 0.678 (0.941) | 1.696 (1.552) | 1.103 (0.964) |
| Book chapters | 4.926 (7.666) | 5.490 (8.368) | 4.016 (6.268) | 3.843 (6.715) | 3.141 (5.713) | 8.006 (9.882) | 6.178 (7.014) |
| Awards | 0.119 (0.476) | 0.136 (0.539) | 0.0921 (0.352) | 0.109 (0.458) | 0.0824 (0.343) | 0.176 (0.641) | 0.116 (0.372) |
| Co-authors | 10.70 (20.79) | 11.97 (23.65) | 8.657 (14.84) | 8.928 (17.64) | 7.354 (13.98) | 16.62 (30.05) | 11.88 (16.36) |
| International publications | 2.842 (6.346) | 3.014 (6.653) | 2.565 (5.805) | 1.911 (4.026) | 1.832 (4.011) | 4.699 (9.081) | 4.374 (8.525) |
| DFG grants | 0.0732 (0.608) | 0.0775 (0.665) | 0.0661 (0.503) | 0.0496 (0.630) | 0.0311 (0.285) | 0.120 (0.713) | 0.153 (0.817) |
| Months abroad | 9.825 (23.10) | 8.657 (20.08) | 11.71 (27.18) | 7.323 (15.77) | 11.20 (26.04) | 10.69 (25.15) | 12.98 (29.77) |
| Mobility | 1.454 (1.522) | 1.415 (1.480) | 1.518 (1.585) | 1.145 (1.345) | 1.405 (1.526) | 1.828 (1.578) | 1.798 (1.691) |
| Interim professor | 0.111 (0.523) | 0.123 (0.601) | 0.0914 (0.363) | 0.111 (0.676) | 0.0680 (0.307) | 0.141 (0.462) | 0.149 (0.468) |
| *Persons* | 805 | 469 | 336 | 256 | 217 | 213 | 119 |
| *Person-years* | 7,667 | 4,734 | 2,933 | 2,861 | 2,088 | 1,873 | 845 |

Notes: mean coefficients; sd in parentheses.

Model 2 analyzes whether including the number of children reduces this publication gap by controlling the effect of the number of children separately for men and women. The results show that with each log increase in the number of children, men publish 0.06 more annual SSCI articles and women 0.044. As parents tend to be more experienced researchers and, as such, generally have more publications, we have to additionally control for their level of experience. Model 3 controls for a researcher's career stage and level of seniority. As can be seen, the effect of children now turns negative for both genders, but only significantly so for women and almost twice as much for them as for men.

Table 2 Random-effects regression on SSCI productivity

| | (1) Gender gap | (2) Children added | (3) Experience added | (4) Publications added | (5) Mobility added | (6) Full model without children variable | (7) Women only | (8) Men only |
|---|---|---|---|---|---|---|---|---|
| Female | –0.062** (–3.25) | –0.058** (–2.93) | –0.062** (–3.14) | –0.038** (–3.25) | –0.038** (–3.22) | –0.044*** (–4.59) | | |
| Men * No. children (ln), $_{t-1}$ | | 0.060* (2.10) | –0.035 (–1.08) | –0.052* (–2.36) | –0.052* (–2.34) | | | |
| Women * No. children (ln), $_{t-1}$ | | 0.044+ (1.83) | –0.065* (–2.28) | –0.056** (–2.61) | –0.050* (–2.30) | | | |
| No. of children (ln), $_{t-1}$ | | | | | | | –0.050* (–2.10) | –0.052* (–2.22) |
| Doctorate, $_{t-1}$ | | | 0.138*** (6.64) | 0.091*** (4.86) | 0.086*** (4.59) | 0.063*** (4.17) | 0.076* (2.51) | 0.094*** (3.80) |
| Habilitation, $_{t-1}$ | | | –0.057 (–1.45) | –0.064 (–1.57) | –0.048 (–1.14) | –0.070* (–2.37) | –0.060 (–1.30) | –0.046 (–0.80) |
| Years in academia (ln), $_{t-1}$ | | | 0.034*** (4.27) | –0.023* (–2.22) | –0.023* (–2.18) | –0.035*** (–4.46) | –0.028* (–2.20) | –0.017 (–1.06) |
| SSCI journal articles (ln), $_{t-1}$ | | | | 0.212*** (10.77) | 0.212*** (10.77) | 0.227*** (9.75) | 0.173*** (5.02) | 0.227*** (8.73) |
| Books (ln), $_{t-1}$ | | | | –0.032 (–1.55) | –0.029 (–1.34) | –0.034+ (–1.80) | –0.031 (–1.29) | –0.028 (–1.01) |
| Book chapters (ln), $_{t-1}$ | | | | –0.053*** (–4.02) | –0.054*** (–3.94) | –0.035** (–3.17) | –0.012 (–0.97) | –0.078*** (–4.02) |
| Awards (ln), $_{t-1}$ | | | | 0.176*** (3.86) | 0.172*** (3.67) | 0.121** (2.99) | 0.201** (3.04) | 0.158** (2.79) |
| Co-authors (ln), $_{t-1}$ | | | | 0.013 (1.61) | 0.016* (1.98) | 0.021** (3.09) | 0.002 (0.24) | 0.025* (2.33) |
| International publications (ln), $_{t-1}$ | | | | 0.054*** (4.29) | 0.042** (3.28) | 0.032** (2.80) | 0.039* (2.51) | 0.042* (2.30) |
| DFG grants (ln), $_{t-1}$ | | | | 0.147 (1.08) | 0.151 (1.11) | 0.080 (0.78) | 0.115 (0.88) | 0.158 (0.77) |
| Months abroad (ln), $_{t-1}$ | | | | | 0.017** (3.15) | 0.018*** (3.86) | 0.018* (2.50) | 0.020* (2.33) |
| Mobility (ln), $_{t-1}$ | | | | | –0.004 (–0.37) | 0.001 (0.11) | –0.006 (–0.44) | –0.006 (–0.31) |
| Interim professor (ln), $_{t-1}$ | | | | | –0.049+ (–1.72) | –0.032 (–1.15) | –0.059 (–1.19) | –0.041 (–1.11) |
| Constant | 0.197*** (14.05) | 0.200*** (13.83) | 0.213*** (13.71) | 0.194*** (19.72) | 0.193*** (19.56) | 0.196*** (22.11) | 0.151*** (13.21) | 0.193*** (18.18) |
| *$R^2$-overall* | 0.005 | 0.004 | 0.029 | 0.159 | 0.162 | 0.150 | 0.141 | 0.169 |
| *$R^2$-within* | 0.000 | 0.005 | 0.029 | 0.008 | 0.009 | 0.005 | 0.004 | 0.013 |
| *$R^2$-between* | 0.013 | 0.007 | 0.047 | 0.536 | 0.533 | 0.541 | 0.535 | 0.519 |
| *N (persons)* | 729 | 729 | 729 | 729 | 729 | 1109 | 297 | 432 |
| *N (person-years)* | 6,846 | 6,846 | 6,846 | 6,846 | 6,846 | 10,581 | 2,592 | 4,254 |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Even though having children decreases the number of publications by women almost twice as much as those by men, controlling for children hardly changes the female publication gap, as the coefficient of the female dummy shows. This means that women publish less than men, net of the differences in career stage and net of the negative effects of children on their publication output.

The female publication gap may be further explained by prior academic performance, as men may accumulate more publications, academic awards, grants, or international experience early on. Model 4 controls for accumulated publications, awards, co-author-

ships, international publications, and third-party funding, while Model 5 adds mobility variables. After controlling for prior academic measures of achievement, we find that having children significantly decreases the number of publications for men as well. The effect of children on publication output is now significantly negative for both men and women. This means that, on average, both male and female academics experience a decline of publications after becoming parents, relative to what would be expected, given their level of experience, prior scientific output, etc.

Controlling for prior achievement and parenthood also reduces the gender publication gap. For instance, the constant in Model 4 shows that men with average research experience publish 0.194 SSCI articles per year, while women publish 0.194−0.038=0.156 articles. Controlling for prior performance thus reduces the female publications gap to about 20 percent. The reduction from 34 percent in Model 1 to 20 percent in Model 4 suggests that differences in prior accumulated achievement as well as the negative effects of children explain part of the female publication gap. Note that the control variables also show that researchers generally publish more SSCI articles after becoming parents when they have published more before then. However, those who have accumulated more book chapters subsequently publish fewer SSCI articles. This may result from different publishing cultures, where people either specialize in book chapters or SSCI articles.

Model 5 adds mobility variables, which generally show that researchers who spent more months abroad publish more SSCI articles. It also shows that adding the mobility variable has a negligible effect on the influence of children on publication output. In other words, researchers with children do not seem to publish less because they are less mobile.

Model 6 is the same as Model 5, but does not control for the gendered effect of children on publications. Keep in mind that Model 5, after including all possible controls, shows that women publish about 20 percent less than men (0.038/0.193=19.7%). Model 6, which does *not* include the gendered effect of children on publications, shows that women publish 0.044/0.196=22.4 percent less than men at the same career stage at similar prior productivity levels. This means that the female publication gap only narrows slightly after controlling for the number of children, as it is only 12.3 percent (19.7/22.4=0.877) lower after accounting for the gendered effect of children on publications. Thus, it seems that the effect of childbearing, while significantly decreasing publication output, does not strongly affect the overall female publication gap, which instead exists independently of the effect of children.

Last, Models 7 and 8 split the regressions by gender. Both models again suggest that having children decreases the number of publications similarly for both genders, thus confirming the results of Model 5. Note that the effect of the number of children for men and women in Models 7 and 8 is exactly the same as in Model 5.

Overall, the results point out that the effect of children on publication output is similarly negative for men and women. However, a disadvantage of the random-effects approach is that these models mix between- and within-effects into one effect size. These models therefore do not clarify whether parents as a group publish less than nonparents (between-effect) or whether the same academic publishes less after having become a parent (within-effect). To analyze the latter, the next section uses fixed-effects regressions.

## Results from fixed-effects models

To test how childbirth affects publication output when comparing only within, rather than between academic careers, Table 3 estimates fixed-effects regressions. Fixed-effects models cannot identify the effect of time-constant variables such as gender, as they only show the effect of change over time within the careers of researchers. We therefore calculate separate regressions for women (Models 1, 3, 5, 7) and men (Models 2, 4, 6, 8). Models 1 and 2 in Table 3 estimate the effect of children without controls, then Models 3 to 8 gradually add controls for seniority, academic achievements such as prior publications, and finally, mobility.

In the uncontrolled Models 1 and 2 of Table 3, the within-effect of parenthood on research output is positive for both genders. As in the random-effects regressions, this may be the case because childbirth takes place during the more advanced stages of a career, in which research productivity is generally higher. To correct for this confounding effect, Models 3 and 4 control for seniority levels. This turns both effects negative, but not significantly so (only at $p<.1$ for women). This changes when we control for measures of prior performance in Models 5–8. Then the effect turns significantly negative for women, while it remains insignificantly negative for men. Substantively, having children depresses the subsequent research performance of women about twice as much as for men (compare the effect sizes of Models 5 and 6 as well as 7 and 8).

This result fits the mechanisms discussed above, suggesting that, on average, men seem to benefit from traditional gender roles in the household, which allow them to concentrate on their career after the birth of a child. Women, by contrast, experience a decline of their publication output after childbirth.

That the effect of having children on publication productivity changes after controlling for prior academic achievements suggests that women with lower academic achievements experience a stronger productivity decline after childbirth compared with women that have relatively high levels of academic achievement. Table 4 tests the interaction between the effect of having children and seven measures of prior academic achievement, specifically the accumulated number of SSCI journal articles (1), published books (2), book chapters (3), academic awards (4), international publications (5), DFG grants (6), and lastly mobility (7). Since we have not mean-centered these predictor variables

Table 3 Fixed–effects regression on SSCI productivity

| | (1) Women only | (2) Men only | (3) Women only | (4) Men only | (5) Women only | (6) Men only | (7) Women only | (8) Men only |
|---|---|---|---|---|---|---|---|---|
| No. of children (ln), $_{t-1}$ | 0.067* | 0.119** | –0.062+ | –0.031 | –0.080* | –0.030 | –0.079* | –0.035 |
| | (2.52) | (3.04) | (–1.78) | (–0.62) | (–2.07) | (–0.57) | (–1.98) | (–0.67) |
| Doctorate, $_{t-1}$ | | | 0.098*** | 0.120*** | 0.105* | 0.127*** | 0.102* | 0.112** |
| | | | (3.59) | (3.71) | (2.54) | (3.58) | (2.53) | (3.19) |
| Habilitation, $_{t-1}$ | | | –0.059 | –0.065 | –0.050 | –0.037 | –0.035 | –0.018 |
| | | | (–1.22) | (–1.21) | (–0.83) | (–0.61) | (–0.52) | (–0.30) |
| Years in academia (ln), $_{t-1}$ | | | 0.043*** | 0.058*** | 0.039* | 0.075*** | 0.035* | 0.068** |
| | | | (3.48) | (4.69) | (2.40) | (3.34) | (2.22) | (3.04) |
| SSCI journal articles (ln), $_{t-1}$ | | | | | –0.206*** | –0.138*** | –0.207*** | –0.134*** |
| | | | | | (–4.06) | (–3.73) | (–4.02) | (–3.54) |
| Books (ln), $_{t-1}$ | | | | | 0.022 | –0.016 | 0.019 | –0.010 |
| | | | | | (0.47) | (–0.40) | (0.40) | (–0.26) |
| Book chapters (ln), $_{t-1}$ | | | | | –0.018 | –0.061* | –0.012 | –0.067* |
| | | | | | (–0.74) | (–2.23) | (–0.50) | (–2.32) |
| Awards (ln), $_{t-1}$ | | | | | 0.152 | 0.111 | 0.140 | 0.111 |
| | | | | | (1.09) | (1.26) | (1.00) | (1.23) |
| Co-authors (ln), $_{t-1}$ | | | | | 0.029 | 0.022 | 0.030 | 0.022 |
| | | | | | (1.31) | (1.09) | (1.37) | (1.10) |
| International publications (ln), $_{t-1}$ | | | | | 0.062* | 0.087*** | 0.051+ | 0.074** |
| | | | | | (2.13) | (3.32) | (1.75) | (2.94) |
| DFG grants (ln), $_{t-1}$ | | | | | 0.076 | 0.222 | 0.094 | 0.222 |
| | | | | | (0.87) | (0.90) | (1.05) | (0.91) |
| Months abroad (ln), $_{t-1}$ | | | | | | | 0.037* | 0.031 |
| | | | | | | | (2.07) | (1.43) |
| Mobility (ln), $_{t-1}$ | | | | | | | –0.038 | 0.061 |
| | | | | | | | (–1.01) | (1.61) |
| Interim professor (ln), $_{t-1}$ | | | | | | | –0.074 | –0.105* |
| | | | | | | | (–0.77) | (–2.09) |
| Constant | 0.139*** | 0.196*** | 0.132*** | 0.197*** | 0.101*** | 0.197*** | 0.095*** | 0.196*** |
| | (10.59) | (12.61) | (10.23) | (12.24) | (5.28) | (11.46) | (5.02) | (11.33) |
| *$R^2$-overall* | 0.001 | 0.000 | 0.027 | 0.020 | 0.000 | 0.018 | 0.006 | 0.020 |
| *$R^2$-within* | 0.002 | 0.006 | 0.028 | 0.031 | 0.053 | 0.049 | 0.058 | 0.053 |
| *$R^2$-between* | 0.000 | 0.001 | 0.045 | 0.017 | 0.028 | 0.000 | 0.001 | 0.002 |
| *N (persons)* | 297 | 432 | 297 | 432 | 297 | 432 | 297 | 432 |
| *N (person-years)* | 2,592 | 4,254 | 2,592 | 4,254 | 2,592 | 4,254 | 2,592 | 4,254 |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

for the models in Table 4, the main effects of the number of children in Table 4 show, due to the inclusion of the interaction terms, the effect of childbirth on productivity for women (Model 1) or men (Model 2) who have low academic productivity (zero on all measures).

The results indicate that the negative effect of children on publication output is larger and more significant for a woman with low academic acclaim (no SSCI articles, books, book chapters, awards, international publications, DFG grants, and changes of place). The main effect in Model 1 shows that a woman's annual number of SSCI publications decreases by 0.147 with each log increase in the number of children. To put this effect into perspective, the main effect of Table 3 showed that a woman with average mea-

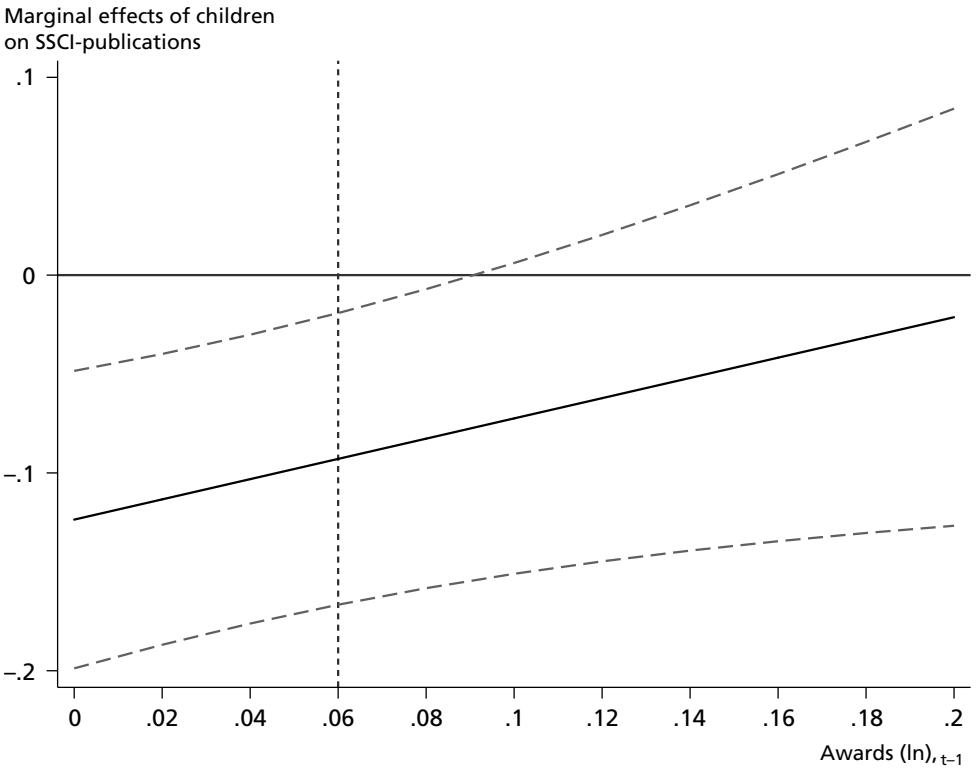
Table 4 Fixed-effects regression SSCI productivity, testing effects of prior academic performance

| | (1) Women | | (2) Men | |
|---|---|---|---|---|
| No. of children (ln), $_{t-1}$ | –0.147** | (–2.74) | 0.041 | (0.63) |
| Doctorate, $_{t-1}$ | 0.110** | (2.67) | 0.096** | (2.77) |
| Habilitation, $_{t-1}$ | –0.036 | (–0.53) | –0.037 | (–0.72) |
| Years in academia (ln), $_{t-1}$ | 0.037* | (2.24) | 0.052** | (2.86) |
| SSCI journal articles (ln), $_{t-1}$ | –0.207** | (–3.23) | –0.139** | (–2.70) |
| Books (ln), $_{t-1}$ | 0.021 | (0.36) | 0.013 | (0.34) |
| Book chapters (ln), $_{t-1}$ | –0.009 | (–0.32) | –0.051+ | (–1.86) |
| Awards (ln), $_{t-1}$ | –0.017 | (–0.10) | 0.132 | (1.21) |
| Co-authors (ln), $_{t-1}$ | 0.037+ | (1.66) | 0.019 | (0.97) |
| International publications (ln), $_{t-1}$ | 0.039 | (1.10) | 0.081** | (3.05) |
| DFG grants (ln), $_{t-1}$ | 0.034 | (0.15) | 0.626 | (1.63) |
| Months abroad (ln), $_{t-1}$ | 0.036* | (2.03) | 0.023 | (1.16) |
| Mobility (ln), $_{t-1}$ | –0.048 | (–1.13) | 0.062+ | (1.65) |
| Interim professor (ln), $_{t-1}$ | –0.073 | (–0.74) | –0.099+ | (–1.96) |
| No. children (ln), $_{t-1}$ * SSCI journal articles (ln), $_{t-1}$ | –0.015 | (–0.16) | –0.012 | (–0.17) |
| No. children (ln), $_{t-1}$ * Books (ln), $_{t-1}$ | –0.013 | (–0.23) | –0.014 | (–0.21) |
| No. children (ln), $_{t-1}$ * Book chapters (ln), $_{t-1}$ | –0.015 | (–0.40) | 0.001 | (0.02) |
| No. children (ln), $_{t-1}$ * Awards (ln), $_{t-1}$ | 0.512* | (2.13) | –0 | (–0.00) |
| No. children (ln), $_{t-1}$ * International publications (ln), $_{t-1}$ | 0.033 | (0.56) | –0.008 | (–0.20) |
| No. children (ln), $_{t-1}$ * DFG grants (ln), $_{t-1}$ | 0.088 | (0.34) | –0.570+ | (–1.66) |
| No. children (ln), $_{t-1}$ * Mobility (ln), $_{t-1}$ | 0.034 | (0.55) | –0.016 | (–0.25) |
| Constant | 0.022 | (0.91) | 0.016 | (0.76) |
| *$R^2$-overall* | 0.005 | | 0.030 | |
| *$R^2$-within* | 0.065 | | 0.068 | |
| *$R^2$-between* | 0.005 | | 0.002 | |
| *N (persons)* | 297 | | 432 | |
| *N (person-years)* | 2,592 | | 4,254 | |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

sures of academic achievement (mean values on each variable) can expect a decrease of 0.079 annual SSCI publications with each log increase of children. This means that parenthood decreases the number of publications twice as much for a woman with low academic achievements as it does for a woman with average performance. By calculating margins, we can compute that a woman who has one (instead of zero) SSCI article, book, book chapter, award, international publication, DFG grant, and change of place at the same career stage, publishes 0.038 fewer articles annually after having a child. In contrast, a woman who has zero on all of these metrics and thus relatively low measures of academic achievement has a much higher decline in publications during parenthood, namely of 0.147 articles. In this sense, the margins from the regression show that the number of publications by a mother with lower measures of academic achievement declines almost four times as much as that of a mother who has higher measures of academic achievement. For a typical man, the effect of parenthood hardly depends on prior academic success. Regardless of whether a typical man shows higher or lower signals of academic success, his publication output does not decrease by having children. This is in line with theoretical expectations based on male benefits from traditional gender roles within the household.

Figure 1 Marginal effects of the number of children on SSCI publications (y-axis), conditional on the number of awards (x-axis) (women only; based on Model 1 in Table 4)




Notes: All covariates fixed at their means. Dashed vertical line: women's mean number of awards. Dashed curves: lower and upper limits of the effect's 95 percent confidence interval.

None of the interaction effects are significant, with the exception of academic awards for females (see Model 1). This means that the detrimental effect of having children on productivity is substantially reduced when women have accumulated a higher number of academic awards, which suggests that the signaling function of academic awards may encourage female researchers to maintain publications after childbirth. To facilitate the interpretation of this interaction effect, Figure 1 shows the effect of having children on the number of SSCI publications (y-axis), conditional on the number of awards women have received (x-axis, based on Model 1 in Table 4). The figure also displays the lower and upper limits of the effect's 95 percent confidence interval. Effects are significant at the five-percent level when the interval does not cover the y-zero line. The dashed vertical line plots the women's mean of the log number of awards. As can be seen, having children is negatively associated with publication output if women have received below-average awards. If, by contrast, women have obtained more than an above-average number of awards, then the effect of children on publication output becomes insignificant.

This may indicate that women keep up their rate of publication after childbirth when award-giving committees have encouraged them to believe in their potential for a scientific career.

## Robustness checks

Tables A1–A3 (appendix) present several alternative specifications as robustness checks. Table A1 replicates the main results (Models 7 and 8 in Table 3) from the fixed-effects analysis using a two-year lag of the number of children variable (see Models 1 and 2 in Table A1). As can be seen, using a two-year lag creates even stronger negative effects for women (Model 1), while the effect for men remains nonsignificant. This suggests that an increase in the number of children imparts negative effects on publishing for at least two years. We also tested a three-year lag (not shown but available upon request). The effects remained negative but were not significant anymore. We conclude from this that the effect of children on research productivity operates most strongly with a two-year lag, as differences in productivity may need some time to express themselves in measurable output.

The subsequent models use a logged dependent variable for a one-year lag (Models 3 and 4) and a two-year lag (Models 7 and 8). For women, an increase in the number of children by one child corresponds to a decrease in annual SSCI publications by about 5.2 percent in the following year (Model 3), or by about 6.7 percent two years later (Model 5).

Table A2 replicates the main results (Models 7 and 8 of Table 3) using fixed-effects individual-specific slopes (FEIS) regression. As has been argued by Ludwig and Brüderl (2018), conventional fixed-effects models do not take into account differences in growth of career performance, which in our case are differences in the growth of academic performance within careers. Since this might be an important selection criterion, we estimate FEIS models to test the robustness of the main regressions. FEIS models need to specify a slope function that is supposed to model the selection process and interacts with time-constant individual heterogeneity. We base the function on two of the most significant measures of prior performance, the total number of SSCI publications and the number of awards. The models in Table A2 estimate the one-year and two-year lags of the children variable both for the non-logged (Models 1–4) as well as the logged dependent variable (Models 5–8). As can be seen, the FEIS models replicate the children effect both with regard to similar effect sizes as well as statistical significance.

Table A3 replicates Table 3 using the children variable coded as dummy variables (and lagged by two years). The dummy coding shows the nonlinearity of the effect (see Model 7): Women who give birth to their first child will have about 0.068 fewer SSCI articles published two years later, as compared with childless women, all else being equal.

Women who give birth to a second child will face a decline in output by about 0.126, compared with childless women. Having three or more children, finally, points to a decline as well, but is not significant anymore (probably due to the very small number of women in the sample with three or more children). For male productivity, according to Model 8, children generally make no difference at all.

## 5 Conclusions

This study has analyzed how parenthood affects the academic publications of men and women differently. We obtain four main results, which contribute to the existing literature in four ways. Our first main result is that the estimates from random- and fixed-effects regressions point in different directions. Random-effects models (which mix between- and within-effects) indicate that children depress the publications of men and women similarly. Using fixed-effects regressions, which isolate the within-effect, we find that children depress the publications of women, but not of men. This result advances prior research, which mainly drew on between-level effects and thus focused on differences between the groups of parents and nonparents, while being unable to show how children affect the publications of the same researcher. Our mixed between-effects indicate that men and women with children each have fewer publications than otherwise similar childless academics. However, the within-effect indicates that a statistically typical father maintains his level of publication productivity, while a statistically average mother does not. Mothers who have been granted academic awards are also able to maintain their prior level of publications; in this sense, an intra-female "Matilda" effect may exist, since women who received more awards experience a smaller decline in the number of publications as parents (Lincoln et al. 2012; Rossiter 1993).

Second, while we find that, after controlling for career stage and prior research achievement, children have a negative effect on productivity, parents do indeed have more, not fewer, publications than childless men and women on a purely descriptive level. In essence, this means that mothers and fathers publish more than childless women and men, but less than childless women and men at similar career stages and less than would be expected given their pre-childbirth achievements and career stage. Therefore, we can refute the prominent finding in the literature that there is "no significant relationship between publications and child rearing for academic women" (also cf. Cole and Zuckerman 1987, 125; Hamovitch and Morgenstern 1977, 643; Sax et al. 2002: 43). Indeed, we find that exactly such a relationship exists and suggest that prior studies overlooked it because they have not adequately controlled for career stage, prior achievements, and between- versus within-effects (cf. the models in Joecks, Pull, and Backes-Gellner 2014, 528; Sax et al. 2002, 433f.; Stack 2004, 911f.).

Third, many studies that do not find a relationship between childrearing and publication productivity argue that this is because, in order to publish, highly motivated women eliminate everything except work and children from their lives (Cole and Zuckerman 1987, 125; Fox 2005, 145; Joecks, Pull, and Backes-Gellner 2014, 520). This explanation is compatible with our results, which show that women who have received more academic acclaim do not in fact experience a decline in research output when having children. It is likely that existing studies do not find any such effect, because they have focused on a select sample of those who already "survived" a longer career in academia, which may have led to a pool of exceptionally motivated or otherwise positively selected women.

Fourth, while our results show that parenthood depresses the research output of women, as mentioned above, they also show that the gendered effect of children on the number of SSCI publications explains only some of the female publication gap. After controlling for seniority and prior performance, we found that women publish 23.7 percent fewer annual SSCI journal articles than men do (Model 5 of Table 2). After additionally controlling for the differential effect of children on the publication output of men and women, we show that this difference drops by about 15 percent to a publications gap of 20.5 percent (Model 6 of Table 2). Remarkably, this magnitude of the gender gap is similar to what studies found forty years ago (Hamovitch and Morgenstern 1977, 643).

Our results are in line with studies showing that the effect of children on women cannot fully account for observed gender gaps in research productivity (Hargens, McCann, and Reskin 1978, 159; Stack 2004, 912). Our results do not concur with studies that argue that no significant gender gap exists, after gender-specific effects of children on publication output are taken into account (Hunter and Leahey 2010: 447). Overall, we observe that women publish less than men each year, even if we compare men and women at the same career stage and with similar prior academic achievements. We initially supposed that this is because children lower the productivity of women more than of men. However, this only explains a small part of the female publication gap, meaning that the lower number of publications by women cannot be explained entirely by arguing that these women are trapped in earlier career stages or that female productivity suffers much more from childrearing than male productivity does. From these results, it therefore appears to be somewhat of a puzzle why women publish less than men. While we do observe that women have less access to higher career levels and that women are more burdened through childcare, neither of these two effects can fully explain their lower level of publication output relative to men. To advance the productivity and therefore success of women in labor markets, it is apparently not enough to help women with childrearing and to make sure that they have the same access to each career stage as men. We therefore suggest that future studies focus on other factors apart from parenthood, which might explain the female publications gap, as the latter only seems to be one part of the puzzle.

While our findings answer some important questions of the research literature, they also suffer from some shortcomings, which mainly consist of unobservable heterogeneity in the data. First, our research design cannot explicitly test the causal mechanisms that may explain why mothers experience stronger declines in publication output than fathers. Gender may be a proxy for hours spent on childcare, which could be a more direct measure to explain the female publication gap in academia.

Second, we can show that parenthood lowers publication output especially for women with fewer academic awards. However, researchers with fewer publications were probably disproportionately likely to have left academia before we could sample them. It is thus possible that childbirth decreases publication output to an even stronger degree if we had included those researchers as well. In this sense, it is possible that our data underestimates how much children depress female productivity, so that the effect we report is conservative.

These problems of our study underscore the need for future research. We showed that parenthood lowers the publication output of a typical woman, but not of a typical man. It may be that women have less time after childbirth or that they experience a stronger role conflict. It is also possible that women are integrated in research networks of lesser status (Ibarra 1992) and that this "closure penalty" (Lutter 2015) in their networks intensifies with children. Future research could compare professional networks of male and female academics to explain the gendered effect of children on academic publications.

## Appendix

Table A1 Replication of Table 3, Models 7 and 8, using number of children lagged by two years (Models 1+2, 5+6) and using logged dependent variable (Models 3–6)

| | (1) Women only | (2) Men only | (3) Women only (logged DV) | (4) Men only (logged DV) | (5) Women only (logged DV) | (6) Men only (logged DV) |
|---|---|---|---|---|---|---|
| No. of children (ln), $_{t-1}$ | | | –0.052* | –0.011 | | |
| | | | (–2.04) | (–0.35) | | |
| No. of children (ln), $_{t-2}$ | –0.100* | 0.013 | | | –0.067* | 0.018 |
| | (–2.27) | (0.23) | | | (–2.40) | (0.57) |
| Doctorate, $_{t-1}$ | 0.088* | 0.099** | 0.063* | 0.068*** | 0.054* | 0.059** |
| | (2.10) | (2.61) | (2.54) | (3.39) | (2.08) | (2.79) |
| Habilitation, $_{t-1}$ | –0.049 | –0.011 | –0.017 | –0.018 | –0.026 | –0.013 |
| | (–0.70) | (–0.19) | (–0.38) | (–0.56) | (–0.56) | (–0.43) |
| Years in academia (ln), $_{t-1}$ | 0.057* | 0.056 | 0.025* | 0.040** | 0.041* | 0.027 |
| | (2.06) | (1.47) | (2.48) | (3.22) | (2.30) | (1.31) |
| SSCI journal articles (ln), $_{t-1}$ | –0.229*** | –0.204*** | –0.134*** | –0.099*** | –0.148*** | –0.142*** |
| | (–4.47) | (–4.60) | (–4.17) | (–4.39) | (–4.55) | (–5.34) |
| Books (ln), $_{t-1}$ | 0.040 | 0.002 | 0.018 | –0.001 | 0.028 | 0.009 |
| | (0.81) | (0.05) | (0.59) | (–0.04) | (0.89) | (0.36) |
| Book chapters (ln), $_{t-1}$ | –0.013 | –0.063+ | –0.010 | –0.039** | –0.009 | –0.037* |
| | (–0.46) | (–1.94) | (–0.63) | (–2.67) | (–0.50) | (–2.26) |
| Awards (ln), $_{t-1}$ | 0.076 | 0.104 | 0.095 | 0.067 | 0.058 | 0.066 |
| | (0.36) | (1.03) | (1.47) | (1.18) | (0.61) | (1.05) |
| Co-authors (ln), $_{t-1}$ | 0.037 | 0.028 | 0.018 | 0.018 | 0.022 | 0.023 |
| | (1.38) | (1.20) | (1.28) | (1.51) | (1.32) | (1.63) |
| International publications (ln), $_{t-1}$ | 0.046 | 0.078** | 0.033+ | 0.049** | 0.029 | 0.052** |
| | (1.47) | (2.77) | (1.75) | (3.10) | (1.44) | (2.92) |
| DFG grants (ln), $_{t-1}$ | 0.082 | 0.233 | 0.057 | 0.088 | 0.054 | 0.094 |
| | (1.05) | (0.96) | (1.18) | (0.89) | (1.18) | (0.95) |
| Months abroad (ln), $_{t-1}$ | 0.036+ | 0.033 | 0.025* | 0.014 | 0.024* | 0.015 |
| | (1.86) | (1.45) | (2.17) | (1.19) | (1.97) | (1.20) |
| Mobility (ln), $_{t-1}$ | –0.047 | 0.077+ | –0.022 | 0.034 | –0.028 | 0.048+ |
| | (–1.14) | (1.77) | (–0.96) | (1.49) | (–1.11) | (1.80) |
| Interim professor (ln), $_{t-1}$ | –0.057 | –0.110* | –0.051 | –0.060* | –0.042 | –0.065* |
| | (–0.61) | (–2.24) | (–0.84) | (–1.96) | (–0.71) | (–2.11) |
| Constant | 0.087*** | 0.198*** | 0.064*** | 0.126*** | 0.059*** | 0.128*** |
| | (4.32) | (10.13) | (5.23) | (12.05) | (4.50) | (10.57) |
| *$R^2$-overall* | 0.000 | 0.000 | 0.006 | 0.007 | 0.000 | 0.002 |
| *$R^2$-within* | 0.057 | 0.047 | 0.063 | 0.054 | 0.062 | 0.049 |
| *$R^2$-between* | 0.020 | 0.027 | 0.001 | 0.006 | 0.016 | 0.070 |
| *N (persons)* | 282 | 411 | 297 | 432 | 282 | 411 |
| *N (person-years)* | 2,295 | 3,822 | 2,592 | 4,254 | 2,295 | 3,822 |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A2 Replication of Table 3, Models 7 and 8, using fixed-effects individual slopes regression

| | (1) Women only | (2) Men only | (3) Women only | (4) Men only | (5) Women only | (6) Men only | (7) Women only | (8) Men only |
|---|---|---|---|---|---|---|---|---|
| No. of children (ln), $_{t-1}$ | –0.092* | –0.059 | | | –0.063* | –0.030 | | |
| | (–2.08) | (–1.14) | | | (–2.25) | (–1.00) | | |
| No. of children (ln), $_{t-2}$ | | | –0.121** | –0.020 | | | –0.081** | –0.008 |
| | | | (–2.71) | (–0.36) | | | (–2.79) | (–0.25) |
| Doctorate, $_{t-1}$ | 0.094** | 0.079* | 0.062+ | 0.083* | 0.061** | 0.050* | 0.045* | 0.051* |
| | (2.69) | (2.27) | (1.81) | (2.18) | (2.74) | (2.48) | (2.01) | (2.37) |
| Habilitation, $_{t-1}$ | –0.084+ | –0.074 | –0.091+ | –0.077+ | –0.051 | –0.049+ | –0.055 | –0.050+ |
| | (–1.69) | (–1.63) | (–1.69) | (–1.68) | (–1.52) | (–1.92) | (–1.51) | (–1.93) |
| Years in academia (ln), $_{t-1}$ | 0.045** | 0.105*** | 0.082*** | 0.125*** | 0.032*** | 0.068*** | 0.058*** | 0.080*** |
| | (3.08) | (5.04) | (3.56) | (3.66) | (3.34) | (5.35) | (3.83) | (3.84) |
| Books (ln), $_{t-1}$ | –0.008 | 0.012 | –0.007 | 0.012 | –0.004 | 0.012 | –0.006 | 0.015 |
| | (–0.20) | (0.33) | (–0.14) | (0.30) | (–0.17) | (0.53) | (–0.21) | (0.61) |
| Book chapters (ln), $_{t-1}$ | –0.006 | –0.053* | 0.002 | –0.060* | –0.007 | –0.037** | –0.002 | –0.042* |
| | (–0.26) | (–2.26) | (0.09) | (–2.21) | (–0.43) | (–2.64) | (–0.10) | (–2.58) |
| Co-authors (ln), $_{t-1}$ | 0.035+ | 0.030 | 0.028 | 0.033 | 0.023+ | 0.025+ | 0.017 | 0.027+ |
| | (1.73) | (1.33) | (1.15) | (1.32) | (1.76) | (1.81) | (1.10) | (1.79) |
| International publications (ln), $_{t-1}$ | 0.102** | 0.094*** | 0.107** | 0.094*** | 0.067** | 0.061*** | 0.070** | 0.061*** |
| | (3.20) | (3.81) | (2.99) | (3.64) | (3.15) | (4.01) | (2.95) | (3.81) |
| DFG grants (ln), $_{t-1}$ | 0.016 | 0.144 | 0.051 | 0.161 | 0.023 | 0.075 | 0.046 | 0.092 |
| | (0.22) | (0.92) | (0.69) | (1.03) | (0.55) | (0.96) | (1.04) | (1.12) |
| Months abroad (ln), $_{t-1}$ | 0.016 | 0.006 | 0.018 | 0.009 | 0.010 | 0.001 | 0.010 | 0.004 |
| | (1.03) | (0.34) | (0.98) | (0.48) | (0.99) | (0.12) | (0.89) | (0.34) |
| Mobility (ln), $_{t-1}$ | –0.042 | 0.044 | –0.042 | 0.052 | –0.022 | 0.024 | –0.021 | 0.029 |
| | (–1.15) | (1.07) | (–1.01) | (1.13) | (–0.97) | (0.98) | (–0.82) | (1.05) |
| Interim professor (ln), $_{t-1}$ | –0.027 | –0.084+ | –0.022 | –0.087+ | –0.021 | –0.043 | –0.017 | –0.045 |
| | (–0.42) | (–1.72) | (–0.29) | (–1.79) | (–0.51) | (–1.48) | (–0.35) | (–1.52) |
| $R^2$-*within* | 0.062 | 0.054 | 0.064 | 0.051 | 0.069 | 0.066 | 0.072 | 0.063 |
| *N (persons)* | 233 | 347 | 212 | 315 | 233 | 347 | 212 | 315 |
| *N (person-years)* | 2,451 | 4,070 | 2,155 | 3,627 | 2,451 | 4,070 | 2,155 | 3,627 |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

Table A3 Replication of Table 3 using dummy variables for number of children

| | (1) Women only | (2) Men only | (3) Women only | (4) Men only | (5) Women only | (6) Men only | (7) Women only | (8) Men only |
|---|---|---|---|---|---|---|---|---|
| No. of children=1, $_{t-2}$ | 0.039 | 0.091* | –0.053 | 0.022 | –0.069+ | 0.034 | –0.068+ | 0.032 |
| | (1.28) | (2.06) | (–1.52) | (0.44) | (–1.79) | (0.60) | (–1.80) | (0.58) |
| No. of children=2, $_{t-2}$ | 0.020 | 0.116* | –0.108* | 0.012 | –0.129* | 0.016 | –0.126* | 0.014 |
| | (0.61) | (2.12) | (–2.47) | (0.19) | (–2.37) | (0.21) | (–2.22) | (0.18) |
| No. of children >=3, $_{t-2}$ | 0.129 | 0.112+ | –0.070 | –0.032 | –0.065 | –0.017 | –0.045 | –0.024 |
| | (0.59) | (1.80) | (–0.30) | (–0.42) | (–0.29) | (–0.18) | (–0.21) | (–0.26) |
| Doctorate, $_{t-1}$ | | | 0.086** | 0.108** | 0.090* | 0.115** | 0.089* | 0.098* |
| | | | (2.67) | (2.79) | (2.15) | (2.75) | (2.16) | (2.34) |
| Habilitation, $_{t-1}$ | | | –0.065 | –0.061 | –0.053 | –0.030 | –0.043 | –0.012 |
| | | | (–1.25) | (–1.14) | (–0.80) | (–0.51) | (–0.58) | (–0.20) |
| Years in academia (ln), $_{t-1}$ | | | 0.061* | 0.041+ | 0.064+ | 0.068 | 0.059 | 0.055 |
| | | | (2.41) | (1.80) | (1.65) | (1.16) | (1.55) | (0.94) |
| SSCI journal articles (ln), $_{t-1}$ | | | | | –0.229*** | –0.209*** | –0.231*** | –0.205*** |
| | | | | | (–4.27) | (–3.98) | (–4.25) | (–3.86) |
| Books (ln), $_{t-1}$ | | | | | 0.041 | –0.005 | 0.038 | 0.001 |
| | | | | | (0.79) | (–0.09) | (0.74) | (0.02) |
| Book chapters (ln), $_{t-1}$ | | | | | –0.021 | –0.054 | –0.015 | –0.060 |
| | | | | | (–0.61) | (–1.34) | (–0.46) | (–1.48) |
| Awards (ln), $_{t-1}$ | | | | | 0.091 | 0.109 | 0.080 | 0.108 |
| | | | | | (0.70) | (1.04) | (0.61) | (1.02) |
| Co-authors (ln), $_{t-1}$ | | | | | 0.033 | 0.028 | 0.037 | 0.027 |
| | | | | | (1.20) | (1.06) | (1.29) | (1.05) |
| International publications (ln), $_{t-1}$ | | | | | 0.056+ | 0.090** | 0.044 | 0.077* |
| | | | | | (1.68) | (2.80) | (1.38) | (2.46) |
| DFG grants (ln), $_{t-1}$ | | | | | 0.067 | 0.237 | 0.086 | 0.236 |
| | | | | | (0.59) | (0.90) | (0.74) | (0.91) |
| Months abroad (ln), $_{t-1}$ | | | | | | | 0.037+ | 0.033 |
| | | | | | | | (1.76) | (1.38) |
| Mobility (ln), $_{t-1}$ | | | | | | | –0.047 | 0.078 |
| | | | | | | | (–1.01) | (1.58) |
| Interim professor (ln), $_{t-1}$ | | | | | | | –0.054 | –0.108* |
| | | | | | | | (–0.53) | (–2.26) |
| Constant | 0.128*** | 0.170*** | 0.152*** | 0.194*** | 0.124*** | 0.189*** | 0.118*** | 0.191*** |
| | (8.27) | (7.72) | (9.09) | (8.01) | (4.89) | (6.88) | (4.92) | (6.90) |
| *$R^2$-overall* | 0.000 | 0.000 | 0.021 | 0.012 | 0.003 | 0.000 | 0.000 | 0.000 |
| *$R^2$-within* | 0.001 | 0.005 | 0.026 | 0.018 | 0.053 | 0.043 | 0.058 | 0.047 |
| *$R^2$-between* | 0.001 | 0.002 | 0.036 | 0.028 | 0.077 | 0.056 | 0.021 | 0.027 |
| *N (persons)* | 282 | 411 | 282 | 411 | 282 | 411 | 282 | 411 |
| *N (person-years)* | 2,295 | 3,822 | 2,295 | 3,822 | 2,295 | 3,822 | 2,295 | 3,822 |

Notes: *t* statistics in parentheses; + $p<0.1$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

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