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PUBLISH OR PROCREATE: THE EFFECT OF MOTHERHOOD ON ACADEMIC PERFORMANCE

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Abstract

Women are underrepresented in science and representation deficits are even greater for more senior positions and in STEM fields. The dominant explanation is that male and female scientists, even within the same field, publish at unequal rates.
Prior studies on select fields suggest that the gender gap in academic productivity reflects differential effects of childbearing on men and women, as women face tensions between the two greedy institutions of family and academia. We study the full population of STEM academics in Denmark and investigate parenthood penalties on scientific productivity of mothers and fathers, who are active in research after the birth of their first child.
We employ an event-study approach on annual research publications, an outcome especially relevant in the science domain, and rely on a unique combination of Danish registers and granular bibliometric data on publications from the database Scopus.
We find that, on average, the first childbirth results in an annual penalty of 24 percent on scientific productivity of mothers in STEM fields relative to fathers in the first 5 years after birth. This reflects a drop in annual research publications of mothers relative to their own pre-birth productivity. Hence, unequal impacts of parenthood may be an important driver of gender inequality in Science.

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1. INTRODUCTION

Women continue to be underrepresented in the scientific profession, particularly in the fields of science, technology, engineering and mathematics (STEM), and representation deficits are even greater in academia's highest echelons (Wolfinger, Mason, & Goulden, 2008). Across their careers, female scientists tend to earn fewer promotions (Ginther & Hayes, 1999; Ginther & Kahn, 2006) receive less funding (Witteman et al. 2017; Witteman et al., 2019) and win fewer prestigious prizes than their male peers (Meho, 2021)

This inefficient allocation and underutilization of female talent generates a loss to our society because we fail to take full advantage of the available talent pool. Fewer topics are studied, a smaller variety of products are developed (Koning et. al. 2021), and future generations of young girls lack important role models in science (Bettinger & Long 2005; Shannon et al., 2019; Porter & Serra, 2020).

One particular aspect of the gender gap in science stands out, namely the productivity puzzle. Numerous contributions have highlighted the fact that male and female researchers, even within the same research field, publish at unequal rates (Cole & Zuckerman, 1984; West et al., 2013; Mairesse & Pezzoni, 2015; Harriet Zuckerman, 1993; Xie & Shauman, 1998). This specific gender gap is particularly problematic because scientific productivity is one – if not the most – key factor explaining access to funding resources, career progress, and, more broadly, scientific success (Huang et al., 2020; Stephan, 2012; Bentley & Adamson, 2003).

Prior studies suggest that the gender productivity gap in academia may reflect differential effects on the part of childbearing and parenthood on male and female academics because women face heightened tensions between the two greedy institutions of family and research. While the gender productivity gaps in science may have decreased over time, having children still seems to represent one of the main factors explaining them (Xie & Shauman, 1998).

Gaining a better understanding of the potentially differential effects of parenthood on scientists is thus central to any discussion of equality and inclusion in science.

The majority of existing studies on gender gaps in science focus on the effect of childbearing on the likelihood of tenure, promotion, or survival in science (Wolfinger, Mason, & Goulden, 2008; Ginther & Kahn, 2006; Huang et al., 2020; Cech & Blair-Loy, 2019; Van Anders, 2004; Cheng, 2020; Wolfinger et al., 2009) while only a few studies prior to ours have analyzed the effect of childbirth on academic productivity in either selected fields or for historical populations (Kim & Moser, 2020; Stack, 2004; Mairesse et al., 2019; Morgan et al. 2021)

Early studies found mixed results due to data restrictions, e.g., a lack of controls and the use of cross-sectional methods (Zuckerman, 1993; Fox, 1981; Frank et al., 1985; Long & McGinnis, 1993). More recent studies based on historical and longitudinal data indicate that childbearing was already important for gender gaps in scientific productivity among scientists with childbearing during the baby-boom of the 1950s (Kim & Moser, 2020) and has remained important within specific fields, such as computer science and physics (Mairesse et al., 2019; Morgan et al., 2021).

In this study, we focus on the full population of STEM scientists in Denmark in the period from 1990 to 2018 and investigate parenthood effects on the scientific productivity of mothers as compared to fathers around the birth of their first child. Due to the combination of detailed register data on family dynamics and granular bibliometric data, we are able to precisely identify the effect of childbirth of scientists' productivity within the universe of STEM academics employed in Denmark, thus avoiding the issues of selection or representativeness that were present in earlier studies. This study makes several contributions to our current understanding of the gender gap in science. First, we offer a precise identification of the motherhood penalty in the full population of STEM academics affiliated in a single country over a period of 28 years, overcoming the focus on single discipline or institutions of previous studies. Additionally, we explore the heterogeneity of this penalty across different dimensions, such as the education level of partners, the number of children, and the type of research conducted (experimental vs. theoretical). Finally, by leveraging our findings, we suggest possible unintended consequences of current parental leave arrangements

2. METHODS

Data

We rely on two data sources, namely the Danish administrative registers and bibliometric data on publications from the Scopus database. The data sources are matched on researchers' name by Statistic's Denmark, such that bibliometric Scopus data on scientific publications are linked to a unique id in the Danish registers.

The registers we rely on contain high-quality administrative data on education, demographics, occupational status, workplace, family status and parental status, e.g. year of becoming a parent.

We study granular bibliometric data on individual researchers' publications. To ensure the quality of data on annual publications, we leave out publications with more than 10 coauthors from the count of annual publications. Moreover, we exclude star researchers, i.e. researchers with more than 10 publications per year across a period of 4 years from our sample. This restriction excludes 24 individuals.

Sample

Our sample consists of the full population of STEM scientists in Denmark in the period from 1990 to 2018. We include researchers in all STEM fields, including in Human and Veterinary Medicine, while excluding researchers in Economics, Business, Management and Accounting, Social sciences, Psychology, and Arts and Humanities.

We focus on academics based in Denmark around the birth of their first child. Hence, academics in our sample are all PhD students or PhD graduates, who were studying or working as researchers at a public research institution in Denmark, such as a university or a university hospital, one year before, one year after or in the exact year of birth of their first child. By conditioning on being in Denmark around childbirth, we ensure that individual academics face a similar institutional setting with regard to child leave and job security at the moment of childbirth.

We select individuals with an active research career over the full time period around childbirth. We follow their research publication activity from 1990 to 2018. Researchers in our sample become parents for the first time in the period from 1993 to 2011. This allows us to follow the researchers' academic productivity from 3 years before and 9 years after the event of having a first child. We set these criteria to secure representativeness of our sample. If we had aimed for a longer pre-birth publication period, our sample would be skewed towards individuals with very early publishing or very late childbearing.

Individuals in our sample are required to have published in the STEM fields during the 3 years before childbirth and to continue to publish no later than in years 7 to 9 after the birth of their first child. However, we do allow for temporary breaks in publishing activity around childbirth in years 0 to 5. If a child is born in November or December, we change their birth year to the following year. We count twins as one birth.

Individuals in our sample may have left Denmark for some time prior to birth or go on to leave Denmark in the period after birth. However, our data on publications allow us to continuously track their individual research activity. The only caveat is that we may not observe additional childbirths taking place outside Denmark, unless the individual returns to Denmark, and thus reappears in the registers.

Summary statistics

Even prior to parenthood, male and female academics publish at different rates. **Figure 1** shows cumulated number of publications for male and female academics in the years around the birth of their first child. From Figure 1 we see that the gender productivity gap widens after childbirth, and never starts to close in the observation period.

Insert Figure 1 here

Our data are summarized in **Tables 1, 2 and 3**. From **Table 1,** we see that males and females in our sample start publishing at similar ages, namely around age 29, and that both males and females have their first child around age 33. Hence, they are almost 3 years older than the general population, when starting a family.

The PhD-age of mothers and fathers at first birth differs by more than 1 year, as mothers pursue family formation earlier in their career, while men tend to delay parenthood. As a consequence male academics achieve higher productivity prior to having their first child.

Over the period of observation, males and females in our sample have a similar number of children (2.1 children). 92 percent of males and 87 percent of females have a second child within the 8 years after first birth. More females than males have an academic partner defined as a PhD graduate or a PhD student partner. Finally, 49 percent of females and 34 percent of males in our sample are PhD students, when they have their first child.

Table 2 shows that shares of male and female academics differ substantially across publication fields. 40 percent of female researchers publish in medical journals compared to 27 percent of males, and relative to males, very few females publish in computer science, engineering and physics.

Insert Table 2 here

From **Table 3,** we see that a majority of individuals in our sample (85 percent) have two children or more in the period of observation. Researchers, who have just one child over the period, are somewhat more productive than researchers with more children.

Insert Table 3 here

Even though male and female researchers are almost the same age, when they have their first child (see **Table 1**), results in **Table 4** show that female researchers tend to match with partners, who are older than they are, while the opposite is true for male researchers. Male academics are relatively more likely to have a partner with a Master's, Bachelor's or lower education, while female academics are relatively more likely to have another PhD as their partner. Moreover, male researchers are more likely to have a child with another younger PhD or PhD student. In the year before the birth of their first child, male researchers earn relatively more than their partners do, while female researchers earn a bit less than their partners do.

Insert Table 4 here

Empirical Strategy

Our empirical strategy follows the event study methodology of Kleven et al. (2019). The event in our set-up is the birth of the researcher's first child. The event is not exogenous, but following Kleven et al. (2019) we suggest that timing of birth is as good as random, when conditioning on year and age fixed effects. We expect the event, i.e. the birth of a first child, to cause sharp changes in the academic productivity measured as number of yearly publications. In addition to time, age and year fixed effects, we extend the model of Kleven et al. (2019) with PhD-age fixed effects to control for any trend in scientific productivity over career.

We index all years in relation to the year of the birth of the first child: $t = 0$. This implies that the year before the childbirth is denoted $t = -1$ and the year after is denoted $t = 1$. Individual researchers are observed from 3 years before the birth of the first child to 9 years after.

Model. We denote the number of yearly publications as U_{ist}^{g}, where i is the individual, s is the calendar year, g is the gender, m is the PhD-age and t is the time relative to the event time. We run the following regression to measure the impact of children on academic productivity relative to the year just before the event of having the first child.

$$U_{ist}^{g} = \sum_{j\neq-1} \alpha_j^g * \mathbb{1}[\mathbf{j} = \mathbf{t}] + \sum_{\mathbf{k}} \boldsymbol{\beta}_{\boldsymbol{k}}^{\boldsymbol{g}} * \mathbb{1}[\boldsymbol{k} = \boldsymbol{age}_{\boldsymbol{is}}] + \sum_{\boldsymbol{u}} \boldsymbol{\gamma}_{\boldsymbol{u}}^{\boldsymbol{g}} * \mathbb{1}[\boldsymbol{u} = \boldsymbol{s}] + \sum_{\boldsymbol{m}} \boldsymbol{\delta}_{\boldsymbol{m}}^{\boldsymbol{g}} * \mathbb{1}[\boldsymbol{m} = \boldsymbol{PhDage}_{\boldsymbol{is}}] + \boldsymbol{v}_{\boldsymbol{ist}}^{\boldsymbol{g}} \qquad (1)$$

Hence, we regress number of publications on a full set of dummies for age, calendar year, PhD age (number of years since finishing the PhD, negative if the researcher is a PhD student) and time relative to event, leaving out as reference category the event time dummy for t=-1, to ensure that α estimates the impact of childbirth relative to the year before entering parenthood conditional on age and calendar year. We predict number of publications in the absence of childbirth by omitting the contributions from the event time dummies:

$$\widetilde{U}_{ist}^{g} = \sum_{k} \hat{\beta}_k^g * \mathbb{1}\,[k = age_{is}] + \sum_{u} \hat{\gamma}_u^g * \mathbb{1}[u = s] + \sum_{m} \hat{\delta}_m^g * \mathbb{1}[m = PhDage_{is}]$$

Next, we use the estimated level effects to calculate the year-relative-to-event effect of the first child as a percentage of the predicted academic productivity in the absence of children, and then we use the gender specific event-time dummy estimates to define the child penalty on females relative to males as:

$$P_t = \frac{\hat{\alpha}_t^m - \hat{\alpha}_t^w}{E[\widetilde{U}_{ist}^w | t]} \qquad (2)$$

P_t measures how many percentage points female researchers' academic productivity falls behind their male counterparts' due to children at a time relative to the event of having a first child. Long run penalties will include the effects of later children, unless the individual has only one child.

The gender specific impacts of children on academic productivity are calculated as:

$$P_t^g = \frac{\widehat{\alpha}_t^g}{E[\widetilde{U}_{ist}^g|t]} \quad (3)$$

These are the estimates we plot in the main **Figures** of this paper.

3. RESULTS

Across STEM fields, we find that mothers, on average, suffer an annual child penalty on scientific productivity of 24 percent (*p=0.003*) relative to fathers in the first 5 years after birth, when measuring productivity by annual number of research publications, cf. **Figure 2**.

Insert Figure 2 here

The child penalty on mothers' productivity relative to fathers' is equivalent to a loss of 2.4 articles over the first five years after birth, when measuring the productivity penalty relative to own estimated productivity of 12.1 articles in the absence of children. Annual productivity losses of mothers relative to fathers in the first years after birth result in substantial cumulative productivity losses over time (cf. **Figure 1)**. As childbirth tends to happen in the early stages of women's academic career, a period that is central to future career progression, mothers face a substantial long-term disadvantage compared to their male peers with children.

From **Figure 2** we see that the gender gap in annual scientific productivity widens around year 2 after first childbirth and remains large until year 5. From year 6 after birth, annual productivity of female academics relative to own pre-birth productivity starts to converge back, seemingly reaching the pre-birth productivity level some time after year 8, and perhaps even exceeding prior productivity further ahead. This is in line with a study by Kim and Moser (2020) on historical data on patents and publications among US researchers in the 1950s. The authors find that conditional on survival in science, female academics with children experience productivity peaks much later than those of other scientists and eventually, after being married for 15 years, experience large and persistent increases in scientific output.(Kim & Moser, 2020)

However, convergence in productivity does not imply that female scientists on average catch up with their male peers in regards of rank, publications or other objective success criteria. They remain at a disadvantage throughout their careers as they fail to recover the ground lost around childbirth.

4. HETEROGENEITY

In the following, we investigate household characteristics and research environment specific factors that may aggravate or mitigate the effects of childbirth on productivity of mothers.

The role of partners

At the onset of parenthood, both fathers and mothers may feel time constrained. Providing care for a newborn requires both time and effort, while making progress in research depends crucially on the same ingredients. The intra-household division of child-related tasks after birth is therefore likely to influence the individual academics' trade-off between engaging in research and care work. In particular, having a partner that takes leave with the baby, a partner with flexible employment, or a partner that understands the challenges of doing research, may have a positive impact on the individual researcher's productivity after birth. (Sonnert & Holton, 1996) Particularly, having a partner in academia could mitigate the time pressure of inflexible childcare due to both a flexible work-schedule and a greater understanding of inherent challenges, while having a partner outside academia may exacerbate the impact of childbirth on scientific productivity of female academics.

In addition, partner's relative education, age and earnings are likely to influence bargaining over who will take leave or reduce their work hours after childbirth, and as such may, on average, result in unequal outcomes between mothers and fathers in academia. These ideas motivate splitting our sample into subgroups by having a partner with a PhD (or engaged in PhD-studies) and having a partner without a PhD-degree. In our sample 27 percent of female academics have their first child with an academic partner, while this is true for 15 percent of male academics. Female academics in our sample are more likely to match with an older partner of similar educational or professional rank, while male academics are more likely to match with a younger partner with a lower level of education and earnings.

Insert Figure 3 here

Panel A in **Figure 3** documents that child penalties on productivity among mothers in academia are driven by individuals with a partner outside of academia, i.e. a partner without a PhD degree (and not engaged in PhD-studies), while we find no significant gender differences in productivity trends around birth, when both parents are academics, cf. **Panel B in Figure 3.** This suggests that having an academic partner may alleviate some of the time pressure mothers experience in academia, resulting in improved scientific productivity.

Hence, partner's occupation affects male and female academics asymmetrically. This is likely to reflect wife's relative education and income, as well as gender norms on division of childcare and housework, and entitlements to and division of child leave among parents.

Family size

The fact that the initial productivity gap continues to widen after the birth of the first child is likely to reflect continued family formation. Indeed, the arrival of a second child in years 2 to 4 after the first birth is likely to exacerbate the child penalties experienced by mothers.

Insert Figure 4 here

In **Figure 4**, we see that, on average, the annual child penalty on productivity of female academics relative to males is higher at 31% *($p<0.001$)* in the first 5 years after childbirth among individuals who have more than one child during the observation period.

As documented in **Figure A in Appendix A**, average annual child penalties on productivity of female academics with no additional child following their firstborn are very limited.

Research environment

Researchers in different academic fields are likely to experience different working conditions and to rely on different research methods. Particularly, the so-called “wet fields”, such as chemistry and biology, rely heavily on applied methods, e.g. conducting experiments in laboratories, which requires the actual presence of researchers at research facilities. If we split the sample by typical working conditions, we get two sub-samples: 1) Researchers in laboratory-intensive fields, excluding medicine, and 2) Researchers in other non-laboratory intensive fields, including medicine. Publication fields requiring laboratory work are marked with an (*) in **Table 2.**

In **Figure 5,** we present results on motherhood penalties across laboratory intensive and other fields. We find that the motherhood penalty on female academics relative to males is larger among researchers, who depend on laboratory presence for conducting their research, relative to researchers in other fields. Female academics in laboratory-intensive fields face an average annual penalty of 31 percent (*p=0.003*) in the first 5 years after birth, while female academics in other fields, including in medicine, face a motherhood penalty of 16 percent (*p=0.184*). This implies that the laboratory-intensity of research field has a significant impact on the severity of penalties.

Insert Figure 5 here

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5. Robustness

In our analysis we include PhD age fixed effects, cf. **Section 3,** to account for an increasing trend in number of publications in early career. To validate the robustness of our main result, cf. **Figure 2**, in **Figure 6,** we present the results, when leaving out PhD-age fixed effects in the regression**.**

Insert Figure 6 here

The graph shows an upward shift of the child effect graph for both men and women relative to the graph in **Figure 2.** Most interestingly, we see a child premium for the fathers in **Figure 6,** which might be explained by productivity effects due to career progression. This career progression is what we aim to account for by including PhD-age fixed effects in our main analysis. In fact, as seen from **Figure 2,** the inclusion of PhD age cancels the unexplainable child premium of fathers.

In addition, our results are robust to splitting our sample into PhD-student and PhD-graduate academics, and into academics continuing their career either in Denmark or abroad. Hence, the overall conclusions are robust across subgroups based on career stage and location of academics.

6. DISCUSSION

Despite considerable gender convergence in the general labor market and reduced gender gaps in science in the last few decades, at the current speed many fields are looking at extended time horizons to achieve gender equality. This calls for attention and action from policy makers, grants agencies, university administrators and the science community at large. From a policy perspective, disentangling the mechanisms driving the persistence of gender inequality in science is important, as it could inform the design of effective interventions to mitigate the current gender gap.

Our study contributes to the on-going debate on gender inequality in science by suggesting that the disproportionate impact of parenthood on male and female academics may be an important driver of such inequality. This is unsurprising as mothers continue to take the lion's share of parental leave and childcare responsibilities at home compared to fathers. Up until today parental leave entitlements for women have been much more generous than those for men in Denmark, substantially creating inequality in the allocation of leave between parents and reinforcing gender stereotypes on task allocation in households. Parental leave entitlements targeted specifically at mothers may be a two-edged sword. On one hand, they provide income and job security for the individual, while ensuring that a child can enjoy the intimate care of a parent during infancy. On the other hand, the effects of leave-taking in scientific and other knowledge-intensive professions may be detrimental for one's career, given the idiosyncratic characteristics of such professions. Being successful in science requires continuous engagement in research and with scientific networks (for example by participating in international scientific conferences), making investments in updating one's frontier-knowledge, and applying for funding at a regular basis. All these activities require active presence and investments in terms of time, elements, which are lacking, while individuals are on parental leave. A child, no doubt, needs close care during the first year of life, but a mother and a father are equally disposed to provide it. Hence, policies ensuring equal and earmarked child leave entitlements across genders represent a low-hanging fruit to level the playing field in academia as well as in other knowledge-intensive professions. Moreover, public policies send a strong signal of societal expectations to parents in terms of a more equal division of work in the household. However, attention to detail is crucial, as gender equal tenure-clock stopping policies in the US are found to have very unequal effects across genders due to differential time allocations of mothers and fathers during tenure extensions.(Antecol, Bedard, & Stearns, 2018; Manchester, Leslie, & Kramer, 2013) Hence, symmetrical policies may have an asymmetric impact across genders.

In addition, when a parent returns to work after parental leave, specific actions may be needed to reinsert the researcher in the scientific work loop. In order to re-start their pipeline, new parents need to devote a large share of their time to research and applying for funding (which are activities idiosyncratic to them as individual researchers), rather than to administration and teaching, which are more fungible and therefore can be covered by other faculty members. However, policies alleviating new parents of their teaching responsibilities may also have gender-specific effects, if teaching obligations are exchanged for either childcare or research engagement according to gender. Additionally, quota policies may have a backlash on productivity, if each scientific committee needs a token female member, resulting in burdening female faculty with extensive faculty services.

One potential limitation of our work is that we focus on a relatively narrow measure of productivity, namely number of papers published, while we are not taking into account the quality of such output. If the scientific contributions of female scientists are on average more comprehensive or innovative than those of males, analyzing scientific quality rather than quantity may deliver new insights on the gender gap in science. Additionally, we are studying a very specific context, which may not generalize to other countries. Indeed, Scandinavian countries are often praised for their high rate of female participation in the labor force and their generous policies in support of families. However, we believe that our results are of interest to the broader scientific community for at least two reasons. First, as we are analyzing a context where families enjoy relatively generous support, we would expect our results to underestimate the actual penalty in terms of scientific productivity that academic mothers would face in countries where such support is lower or non-existent. Second, while gender norms are generally perceived to be more egalitarian in Scandinavia than elsewhere, it appears that in reality gender attitudes in Denmark are quite traditional, when it comes to the labor supply of women after having children (ISSP Research Group, 2016), and in line with prevalent values in countries such as the UK or the US. This suggest that Danish female researchers face similar pressures at home in terms of disproportionate allocation of childcare duties.

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TABLES AND FIGURES

Table 1. Summary statistics

	Males	**Females**
N	853	423
Mean number of publications the year before birth	2.1	1.5
Mean age at birth of first child	33.5	33.1
Mean age first year of publishing	28.4	28.90
Mean number of total publications by 2018	55.5	37.4
Mean number of publications 5 years after birth	3.1	1.8
Mean number of publications in year before birth	8.9	5.8
Mean number of children up to 8 years after the first	2.1	2.1
Share with additional childbirth(s) within 8 years of first birth	0.87	0.84
Share with PhD student or PHD graduate partner	0.15	0. 27
Share of PhD students	0.34	0.49
Mean PhD age year before birth	1.5	0.1
Number of researchers with a medical degree	229	

Table 2. Summary statistics – Males and females distributed on main fields

	Males		Females	
Publishing field	**Number**	**Share**	**Number**	**Share**
Agricultural and Biological Sciences*	82	10%	51	12%
Biochemistry, Genetics and Molecular Biology*	149	17%	87	21%
Chemistry*	34	4%	9	2%
Computer Science	68	8%	7	2%
Earth and Planetary Sciences	43	5%	13	3%
Energy	13	2%	-	-
Engineering	40	5%	6	1%
Environmental Science	36	4%	20	5%
Immunology and Microbiology*	20	2%	19	4%
Materials Science	23	3%	8	2%
Mathematics	16	2%	-	
Medicine	227	27%	169	40%
Neuroscience*	11	1%	9	2%
Pharmacology, Toxicology, Pharmaceutics*	9	1%	-	-
Physics and Astronomy	70	8%	7	2%
Veterinary*	-	-	10	2%

Note: Groups smaller than 5 persons are excluded.
(*) Laboratory intensive fields, excluding medicine

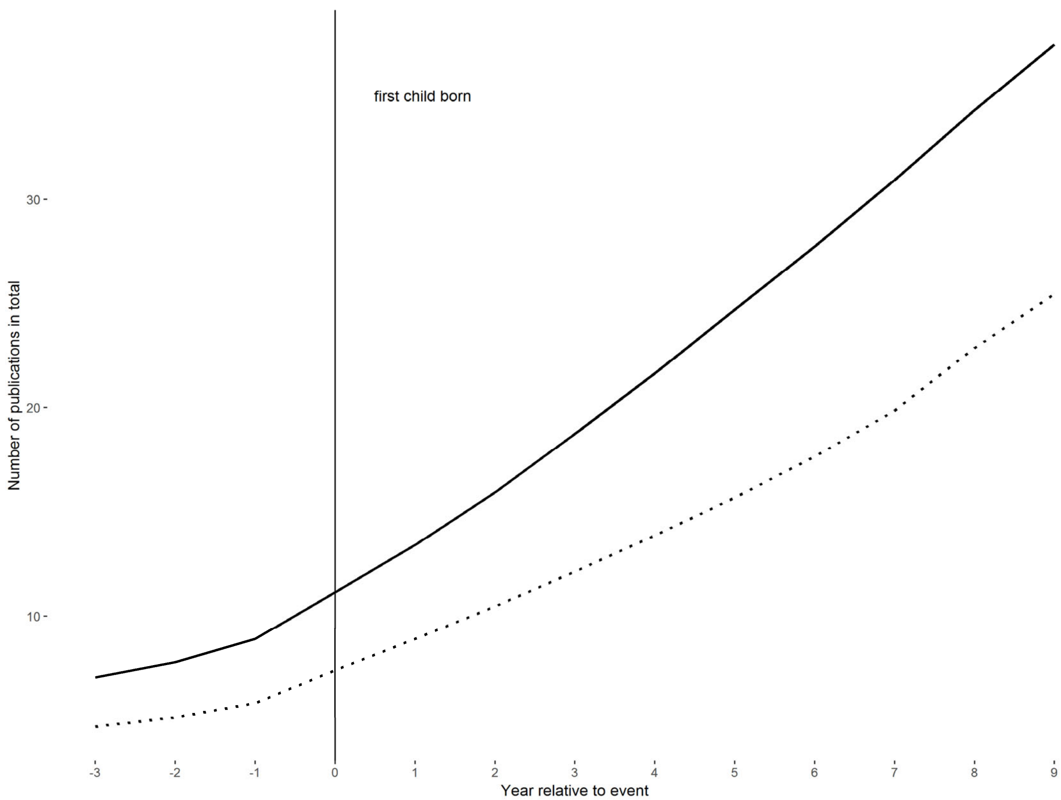
Table 3. Number of children and productivity prior to having children

	Males	Females
Share having 1 child in the period	0.13	0.16
Share having 2 children in the period	0.62	0.64
Share having 3 children in the period	0.22	0.19
Share having 4 children in the period	0.02	0.01
Avg. productivity in year -1 (1 child)	2.7	1.9
Avg. productivity in year -1 (2 children)	2.0	1.5
Avg. productivity in year -1 (3 children)	2.0	1.3
Avg. productivity in year -1 (4 children)	1.6	1.0
Avg. total production in year -1 (1 child)	12.8	7.8
Avg. total production in year -1 (2 children)	8.7	5.9
Avg. total production in year -1 (3 children)	7.1	4.1
Avg. total production in year -1 (4 children)	9.1	4.7

Table 4. Partner characteristics

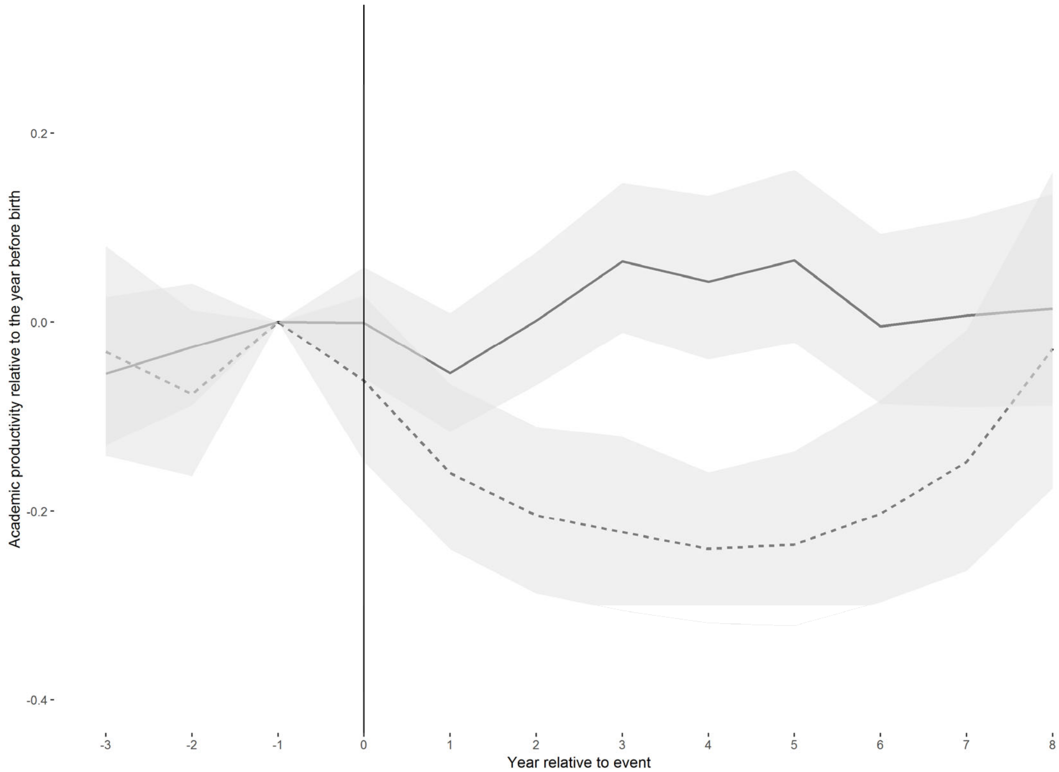
	Males	Females
More than 10 years younger than partner	-	5 %
6-10 years younger than partner	2 %	12 %
1-5 years younger than partner	20 %	48 %
Same age as partner	14 %	14 %
1-5 years older than partner	48 %	19 %
6-10 years older than partner	13 %	2 %
More than 10 years older than partner	3 %	-
Partner’s highest education: Primary school	1 %	2 %
Partner’s highest education: High school	2 %	3 %
Partner’s highest education: Vocational school	4 %	6 %
Partner’s highest education: Short higher education	3%	4 %
Partner’s highest education: Bachelor's degree	19 %	12 %
Partner’s highest education: Master’s degree	49 %	42 %
Partner’s highest education: PhD	22 %	31 %
Own average income, DKK, yearly	315,064	302,892
Partner’s average income, DKK, yearly	222,498	334,417

Figure 1. Cumulative publications of male and female academics across childbirth



Notes: The figure shows cumulated number of publications of male and female researchers working in STEM fields in Denmark around the birth of their first child. The sample consist of 423 female and 853 males.

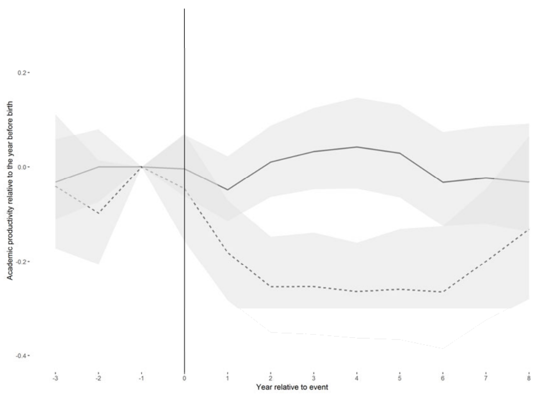
Figure 2. Impact of childbirth on the scientific productivity of researchers in STEM



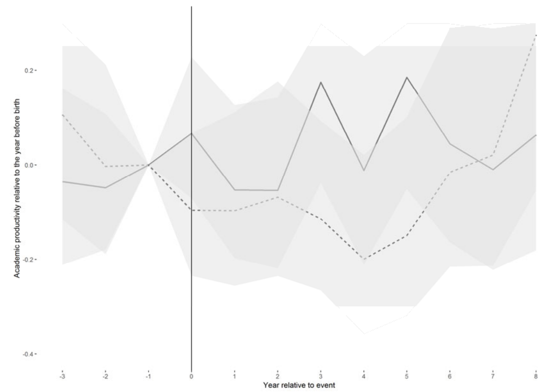
Notes: The figure shows the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. The estimated average annual child penalty is 24 percent (p<0.003) over the first 5 years after birth. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications). The sample consist of 423 female and 853 male STEM researchers.

Figure 3. Impact of childbirth on the scientific productivity by occupation of partner

Panel A: Non-PhD partner

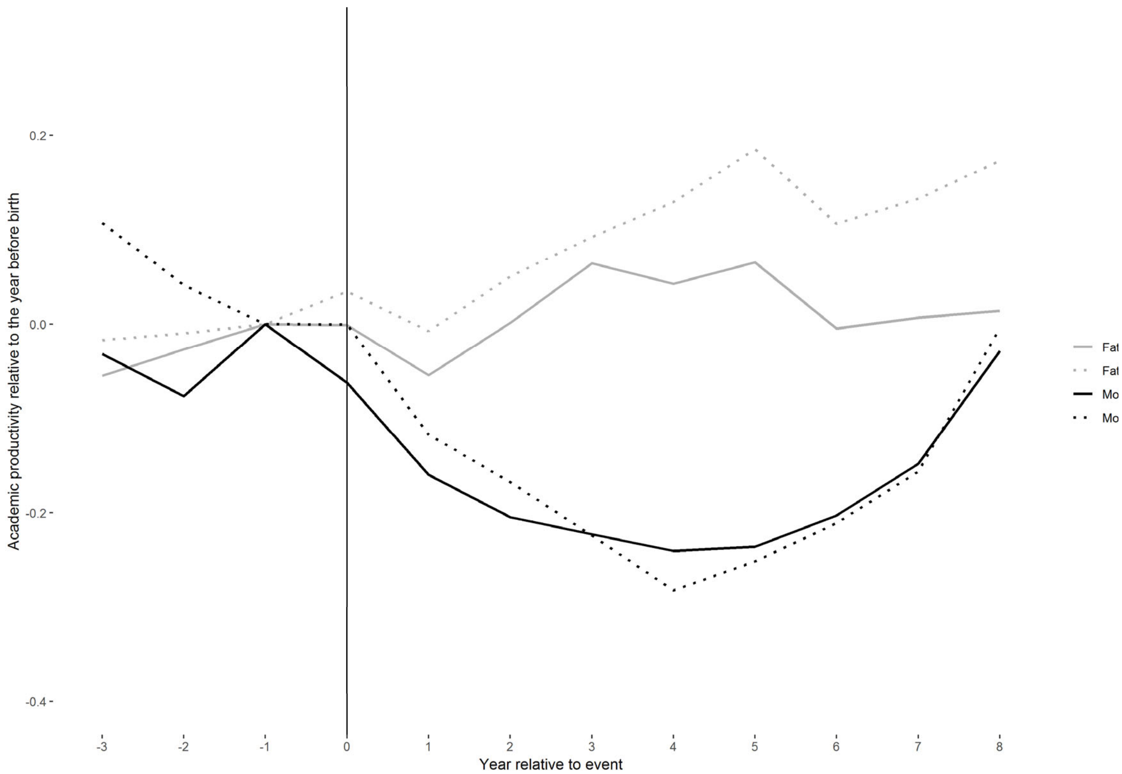


Panel B: PhD partner



Notes: The figures show the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications).
Panel A: The sample of researchers with a non-PhD partner consist of 294 female and 669 male STEM researchers. The estimated average annual child penalty is 26 percent (p<0.004) over the first 5 years after birth.
Panel B: The sample of researchers with a PhD partner consist of 113 female and 131 male STEM researchers. The estimated average annual child penalty is 19 percent (p=0.361) over the first 5 years after birth.

Figure 4. Impact of children on academic productivity of males and females with multiple births



Notes: The figure shows the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. The estimated average annual child penalty on mothers with more than one birth is 31 percent (p=0.001) over the first 5 years after birth. The sample consist of 423 female and 853 male STEM researchers. The child penalty on mothers with only one child is shown in Appendix A. Figure A.

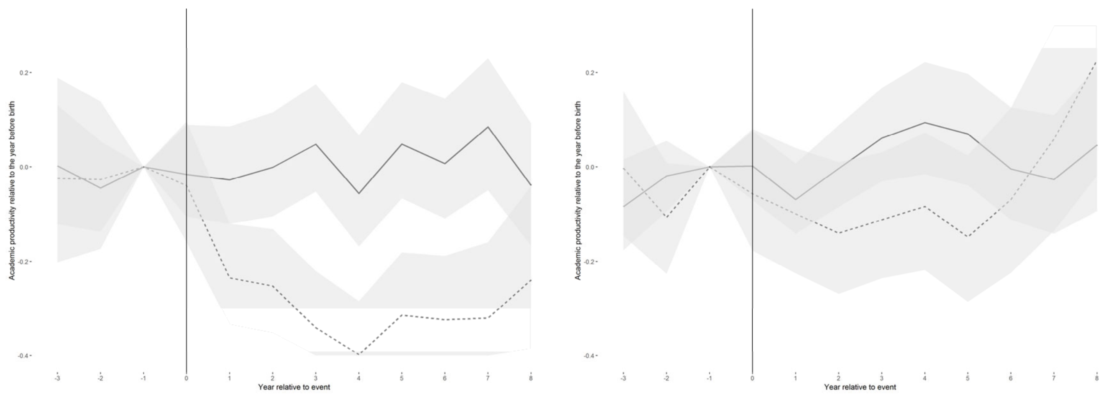
Figure 5. Field specific impact of children on academic productivity

Panel A:

Laboratory intensive fields

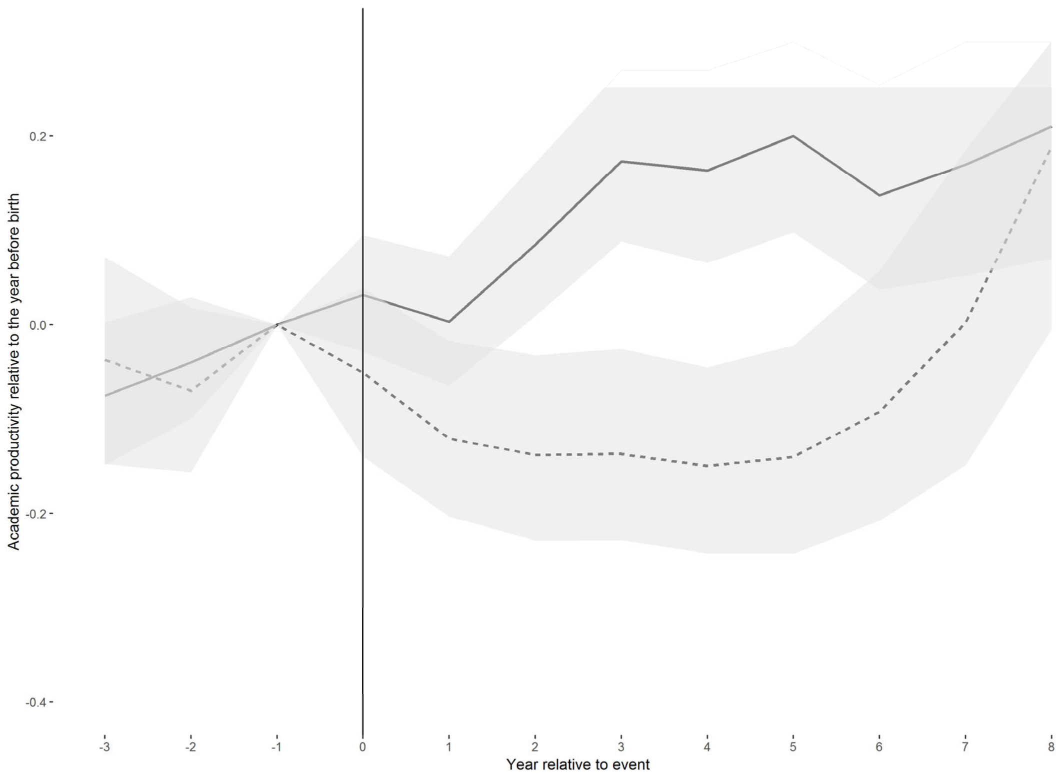
Panel B:

Other fields



Notes: The figures show the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications).
Panel A: The sample of researchers publishing in laboratory intensive field consists of 192 female and 314 male STEM researchers. The estimated average annual child penalty is 31 percent (p=0.003) over the first 5 years after birth.
Panel B: The sample of researchers publishing in other fields consist of 231 female and 539 male STEM researchers. The estimated average annual child penalty is 16 percent (p=0.184) over the first 5 years after birth.

Figure 6. Main figure excl. PhD-age FE



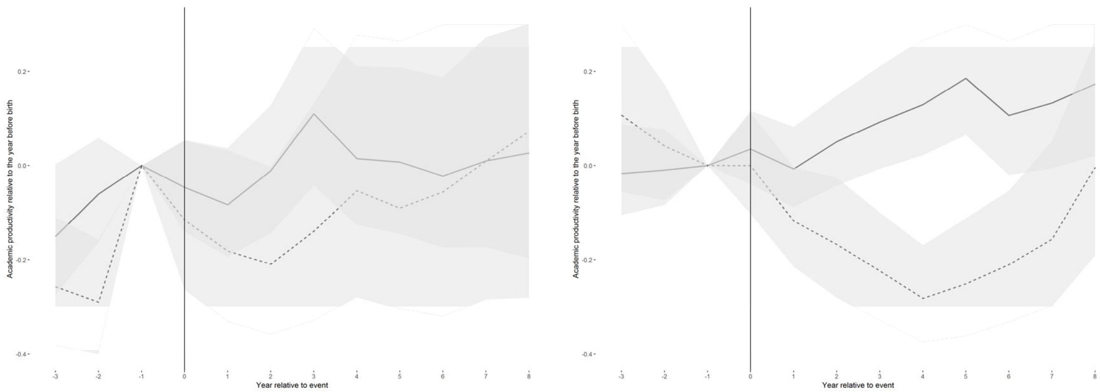
Notes: The figure shows the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. The estimated average annual child penalty is 29 percent (p<0.001) over the first 5 years after birth. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications). The sample consist of 423 female and 853 male STEM researchers.

8. Appendix

Appendix A. Family size

Figure A.

Panel A: One child in the period **Panel B: Multiple children in the period**



Notes: The figures show the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications).
Panel A: The sample of researchers with only one child consists of 139 female and 285 male STEM researchers. The estimated average annual child penalty is 14 percent (p=0.435) over the first 5 years after birth.
Panel B: The sample of researchers with more than one child consist of 284 female and 568 male STEM researchers. The estimated average annual child penalty is 31 percent (p<0.001) over the first 5 years after birth.

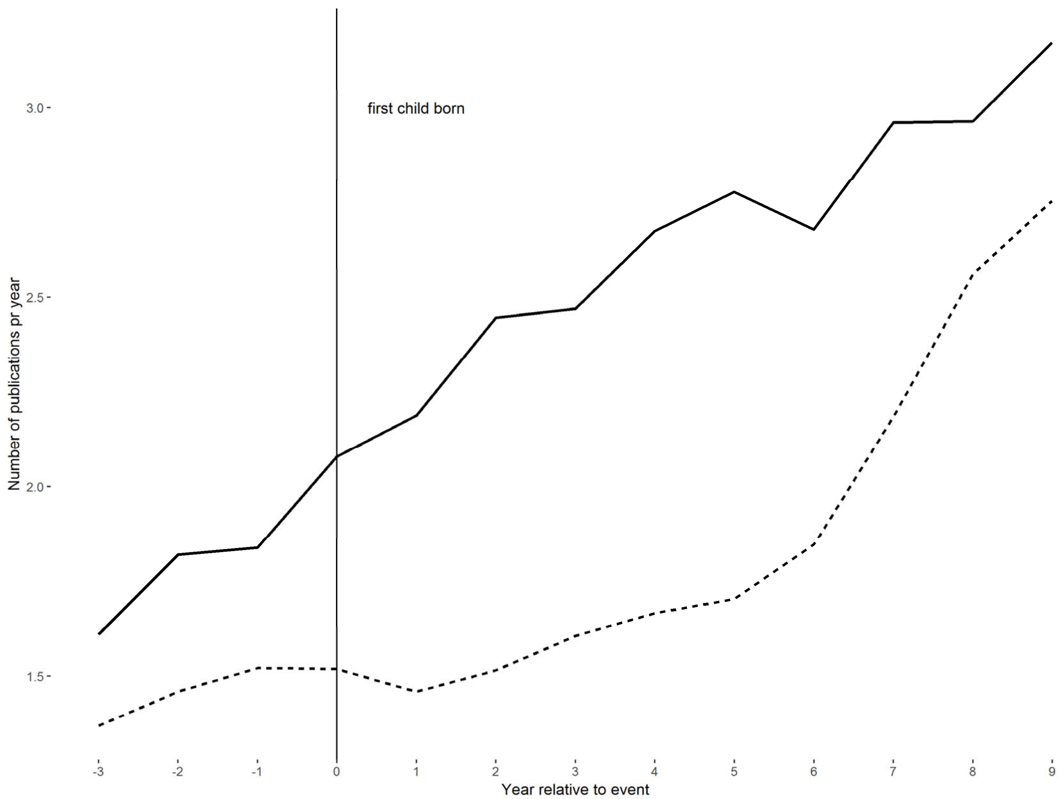
Appendix B. Do researchers accelerate publication activity in anticipation of motherhood?

To test if academic researchers accelerate their publication activity prior to birth, which would impose a bias on our estimates, we match male and female researchers in the year before birth of their first child. Males and females are matched on PhD-age, field, including laboratory-intensive (e.g. chemistry and biology), medicine and other (e.g. physics and computer science), Danish or other origin, and year of first birth in 1990s, mid-2000s (2000-2004) or late 2000s (2005-2010), and finally on 5-year age groups. As our sample contains more males than females, we match multiple males to the same female. We are able to match 320 of the 423 female researchers to 485 of the 853 male researchers. This allows us to compare growth in number of publications by gender across event-time, where the event is the birth of a first child.

From **Figure B**, we see that female academics have lower publication levels per year relative to male academics across childbearing, in both pre- and post-birth periods. There is no shift in yearly productivity levels prior to the birth of a first child. Females experience an increase in number of annual publications of 4 percent on average from year -3 to year 0, compared to annual growth of 5 percent on average from year 1 to year 4 after birth. Meanwhile, males experience an increase in yearly publications of 9 percent on average from year -3 to year 0, and an annual increase of 7 percent on average from year 1 to year 4 after birth.

Hence, we find no evidence that our main findings reflect accelerated publication rates prior to birth.

Figure B. Academic productivity in years relative to birth. Matching approach.



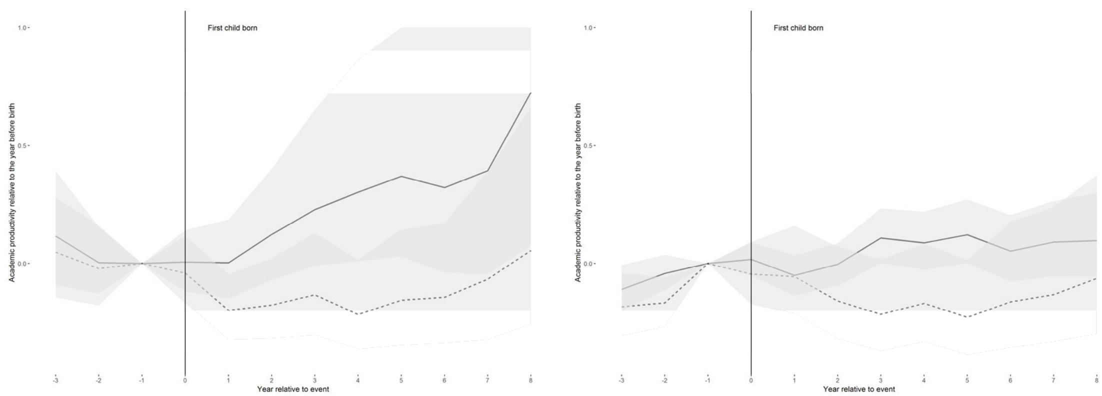
Notes: The Figure shows average annual number of publications relative to year of birth. The sample consists of 320 females, who are exactly matched to 485 males in the main sample in the year before the birth of their first child (t=-1).

Appendix C. Is the effect driven by PhD-students?

Figure C splits the sample into researchers, who have their first child during their PhD and continue in research after PhD graduation, cf. Panel A, and researchers, who have their first child after finishing their PhD. The figure shows that the child penalty on productivity of female academics is neither driven exclusively by PhD students nor by established researchers.

Figure C. Impact of children on the academic productivity by career stage

Panel A: PhD students **Panel B: Finished a PhD**



Notes: The figures show the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications). The range of the y-axis is different from other graphs in the paper.
Panel A: The sample of researchers who were PhD students when becoming parents for the first time consists of 209 female and 293 male STEM researchers. The estimated average annual child penalty is 40 percent (p=0.051) over the first 5 years after birth.
Panel B: The sample of researchers who finished their PhD before becoming parents for the first time consist of 178 female and 459 male STEM researchers. The estimated average annual child penalty is 22 percent (p=0.092) over the first 5 years after birth.

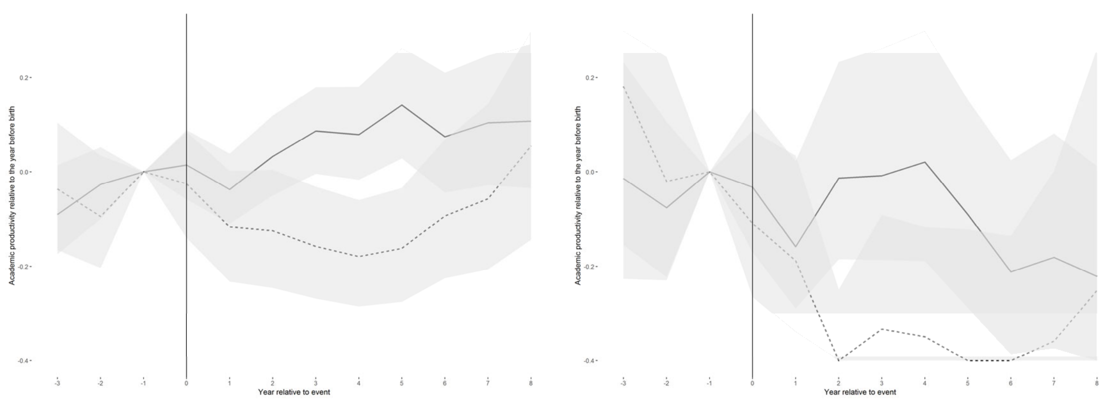
Appendix D. Are results driven by researchers who leave Denmark?

Researchers, who leave Denmark after having their first child, may face different working conditions, which could in turn affect their child penalties. This motivates us to split the sample by post-birth country of occupation, separating researchers who conduct research in Denmark in at least 5 out of 8 years after first birth, and researcher who work abroad after first birth.

Figure D. Impact of children on the academic productivity by location

Panel A: **Researchers who work in Denmark**

Panel B: **Researchers who work abroad**



Notes: The figures show the impact of childbirth on academic productivity (P_t) of male and female researchers working in Denmark around the birth of their first child. 90%-confidence intervals are based on bootstrapped standard errors (1000 replications).
Panel A: The sample of researchers who work in Denmark in at least 5 out of 8 years following first birth consists of 244 female and 558 male STEM researchers. The estimated average annual child penalty is 22 percent (p=0.022) over the first 5 years after birth.
Panel B: The sample of researchers who work abroad after having their first child consists of 85 female and 136 male STEM researchers. The estimated average annual child penalty is 28 percent (p=0.154) over the first 5 years after birth. The plotted Pt of females in Panel B is censored in years 2, 5 and 6 to keep the scale comparable to other graphs in the paper. The correct value of Pt in years 2, 5 and 6 for the females in panel B is -41, -42 and -43 percent, respectively.

In **Figure D,** we present results on motherhood penalties of researchers working in and outside Denmark. We find that the motherhood penalty on female academics relative to male academics is broadly similar across subgroups. Female academics conducting their research primarily in Denmark in the 8 years after first birth face an average annual penalty of 22 percent (*p=0.022*) in the first 5 years after birth, while female academics, who do research abroad, face a somewhat larger motherhood penalty of 28 percent (*p=0.154*), however the latter sub-sample is quite small reducing the precision of our estimate.