

SCIENTIFIC COMMUNITY

The unequal impact of parenthood in academia

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Across academia, men and women tend to publish at unequal rates. Existing explanations include the potentially unequal impact of parenthood on scholarship, but a lack of appropriate data has prevented its clear assessment. Here, we quantify the impact of parenthood on scholarship using an extensive survey of the timing of parenthood events, longitudinal publication data, and perceptions of research expectations among 3064 tenure-track faculty at 450 Ph.D.-granting computer science, history, and business departments across the United States and Canada, along with data on institution-specific parental leave policies. Parenthood explains most of the gender productivity gap by lowering the average short-term productivity of mothers, even as parents tend to be slightly more productive on average than nonparents. However, the size of productivity penalty for mothers appears to have shrunk over time. Women report that paid parental leave and adequate childcare are important factors in their recruitment and retention. These results have broad implications for efforts to improve the inclusiveness of scholarship.

INTRODUCTION

Several decades of research, across many fields, show that men typically publish more papers than women (1–3), but the reasons for and consequences of this difference remain uncertain. Explanations are numerous and include the hiring of women at lower-ranked and less-productive institutions (4–6), higher teaching and service loads (2, 7, 8), differences in research or task specialization (9, 10), more time invested in drafting initial results (11, 12), shorter career lengths (13), and the greater impact of childbearing and parenthood on women. Of these factors, parenthood affects a majority of faculty, both women and men, yet studies of its effect on scientific productivity are contradictory, finding negative (14–16), positive (17), or no relationship (11, 18, 19). During the COVID-19 pandemic, the impact of parenthood on researcher productivity has received much more attention, with early results indicating a relatively greater loss of productivity for women (20) and increase in domestic labor (21). Nonetheless, establishing the causal impact of parenthood on productivity has been difficult because studies often lack detailed information on career age, longitudinal productivity, the timing of parenthood, or changing social norms.

Parenthood can cause many changes to careers. For one, parenthood creates a new demand to allocate time to childcare and, for birth mothers, to recover from childbirth. In academia, women report more time spent on housework and childcare than men (22, 23). Among parents, while both men and women may decrease their work hours around parenthood, how they do can reflect gendered imbalances. Fathers often protect their research time, which is typically more important for career advancement, while mothers often protect their teaching (24). Hence, parenthood may decrease the available research time for women, more so than for men (16, 25). Parenthood may also change work preferences. For faculty who seek both parenthood and career advancement, having a child may drive them to become more productive and organized to

achieve both (16, 25, 26). Parenthood may also shape the population of faculty through self-selection, because women are more likely to perceive academia as unwelcoming toward parents and thus seek careers outside academia (27–30).

Here, we quantify the productivity gap between early-career faculty who became parents and those who did not, and we directly measure parenthood's differential effects on men and women. We leverage a survey from 2017 to 2018 of 3064 tenure-track faculty at 450 Ph.D.-granting computer science, history, and business departments across the United States and Canada that provides detailed information on faculty career age, the timing of parenthood, and research expectations (section SA). These three disciplines were chosen for their variation in gender representation and diversity in scholarly practices, which may correlate with the impact of parenthood (14, 31). The disciplines exhibit a relatively broad range of gender representation, with women representing just 15% of tenure-track faculty in computer science and 37% in history. The rates of collaboration and types of publications valued also vary across these fields. History faculty often write books and monographs with few, if any, coauthors, whereas computer science faculty publish in juried conference proceedings with many coauthors (section SB). These differences in scholarship and gender representation may influence the impact of parenthood on researcher productivity and provide our analysis some generality across field-specific characteristics.

In our analysis, we refer to faculty who self-identified as women and men and who had children by the time of our survey as mothers and fathers, respectively. We combine this survey with longitudinal data on 100,972 publications by these faculty and data on their institution-specific parental leave policies (sections SB and SC). Our study allows us to distinguish the impact of parenthood from known correlates of productivity, such as differences in career age (32), institutional prestige (33, 34), and changing publication rates over time (35), and to make within-gender comparisons, while accounting for factors that may differentially affect women or men in academic careers (e.g., higher service loads). In particular, we are interested in how gender roles and parenthood status, especially around the birth of their first child, intersect to shape academic careers.

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RESULTS

Impact of parenthood on productivity

Across all three disciplines, among faculty who were at least 40 years old, a large majority (78.7%) reported having children, with lower rates among women compared to men (71.0 versus 82.2%, respectively; $z = 6.00$, $P < 10^{-8}$). Men and women in our survey both become parents, on average, at the age of 33 years old ($t = -1.04$, $P = 0.30$). In contrast, the average ages of parenthood in the general U.S. population are 31 for men and 26 for women (36, 37), indicating that faculty, especially women, tend to delay their transition to parenthood (38). Consistent with this well-known trend in the general population toward reproducing later, we find that the age at which faculty become parents has also been increasing slowly (fig. S2). This age correlates only weakly with the prestige of the faculty member's current institution (5), such that improving their institution's rank by 100 corresponds to an additional delay of only 1 year ($\beta = -0.01$, $t = -2.73$, $P = 0.01$). Parents did not differ significantly from nonparents in the prestige of their appointments (Kolmogorov-Smirnov test, $D = 0.03$, $P = 0.59$). Less than half (39.5%) of faculty became parents before starting their first faculty position, and mothers tend to have fewer children than fathers (averages of 1.8 versus 2.2; $t = 7.17$, $P < 10^{-11}$).

If the productivity gap between men and women is entirely caused by gendered parenthood effects, then the productivity trends of men and women without children should be indistinguishable. To investigate this hypothesis, we examined each professor's publication history and calculated their cumulative productivity over the 5 years before and 10 years after beginning their first assistant professor position. We find that the differences in cumulative time-adjusted productivity over this period (section SB) between men and women without children are 5.2, 0.8, and 1.5 papers over the 10 years on the tenure-track for computer science, business, and history faculty (insets of Fig. 1). That is, women without children produce on average 87.6 to 95.6% of the total number of papers than men without children produce. The residual (4.4 to 12.4%) remains unexplained by career age and parenthood and bears only on faculty like those we surveyed, i.e., tenure-track faculty at Ph.D.-granting departments.

Among parents from computer science, business, and history, mothers produced 13.1, 3.5, and 3.1 fewer papers (between 73.6 and

82.9%) compared to fathers over the same early-career period. This larger gap implies that gender differences associated with parenthood have a large effect on faculty productivity. If parenthood's effect is gendered, then we would expect a productivity gap to emerge only after parenthood, not before, and its impact should be larger for mothers than for fathers. To isolate the effect of parenthood from gender, we used a comparative interrupted time series (CITS) analysis to directly compare the productivity of faculty with and without children around the event of parenthood. CITS has been used to study the impact of childbirth on men and women's employment and wages (39, 40) but not previously to study academic careers. This comparison assigns counterfactual parenthood events to faculty without children, which we accomplish by drawing the timing of such an event from the empirical parenthood age distribution, stratified by parents' gender, birth year, and field (section SD) (41). This procedure results in parents and counterfactual parents being statistically similar with respect to biological age, career age, and institutional prestige before their real or counterfactual event (table S6).

Before children, the annual productivity rates of men and women are similar, but even in this period of time, faculty of both genders who go on to have children are slightly more productive, on average, than those faculty who do not ($t = 4.89$ and $t = 4.47$, $P < 0.01$ for computer science and business and $P > 0.1$ for history; Fig. 2 and table S6). However, the annual productivity of mothers decreases immediately after childbirth, compared to nonmothers or men. The estimated CITS parameters indicate that the event of parenthood sharply decreases short-term productivity for mothers (-48.3 to -17.3%) but generally not for fathers with the exception of the field of history ($t = 68.8$, $P < 0.01$; section SD).

Although we cannot say whether collaboration causally affects this impact, we see that the magnitude of the effect is correlated with disciplinary rates of collaboration (table S4): The short-term impact of motherhood is greatest among history faculty, where there is less collaboration, and smallest among computer science, where there is more. Furthermore, because parenthood may drive individuals to leave academia before being observed by our sample—a selection effect that may be stronger for those individuals who experience larger parenthood productivity losses—these estimates are likely lower bounds of the true effect size.

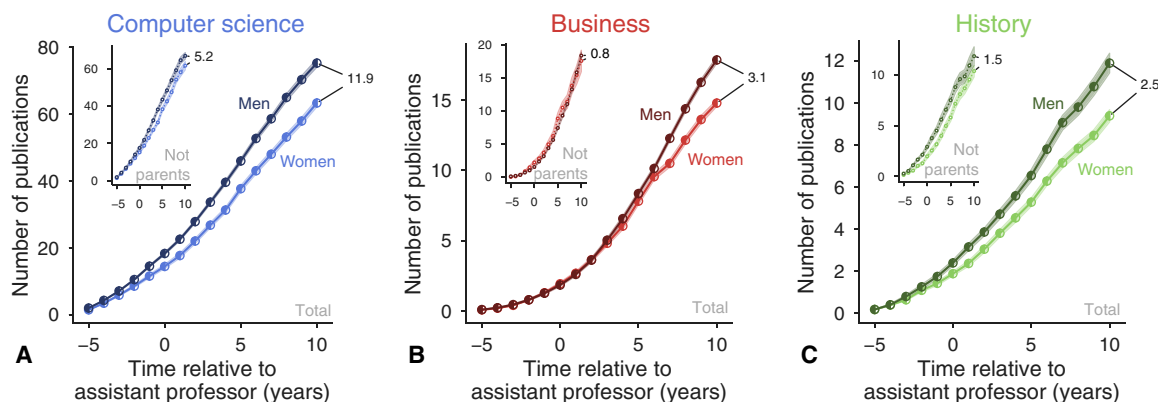


Fig. 1. Cumulative productivity of men and women over their careers. Average cumulative productivity relative to first tenure-track position and corresponding gender productivity gaps for (A) computer science faculty (blue; $N = 1006$), (B) business faculty (red; $N = 491$), and (C) history faculty (green; $N = 285$) with and without children. Insets show the same for faculty without children. Shaded regions denote the bootstrapped interval around the mean. Darker colors denote trends for men and brighter colors for women. Publications from computer science have been time-adjusted (section SB)

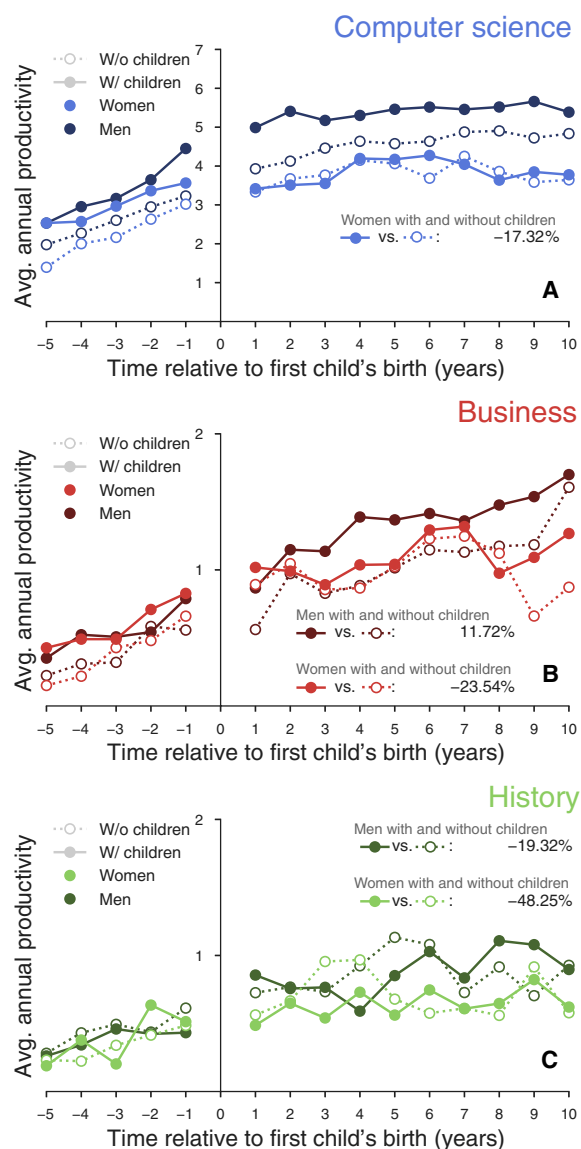


Fig. 2. Annual productivity of faculty with and without children. Average annual productivity for men and women, relative to the birth of their first child (dark) or a counterfactual first child (light), for (A) computer science, (B) business, and (C) history. Values shown are the immediate productivity changes between parents and faculty without children, relative to the expected productivity of that group ($\beta_6/\hat{\gamma}_0$). Estimates are adjusted for institutional prestige (section SD).

Our results are inconclusive as to whether long-term publication rates are affected by parenthood. We also find no clear evidence that parenthood causes a short-term productivity increase for fathers, in contrast to previous suggestions that fathers may tend to use gender-neutral parental leave policies to increase their productivity relative to women (42).

Importance and usage of parental leave

Previous research indicates that early-career women often perceive academic careers as unfriendly to parenthood (27, 28), which contributes to women leaving academia at higher rates than men, a pattern sometimes called “the leaky pipeline” (13, 29, 30). Parental leave policies may help mitigate this effect by improving the recruitment

and retention of parents, especially women. Consistent with prior work (43), women and men in our study used parental leave at different rates: Among leave-eligible parents, 91.8% of mothers but just 62.1% of fathers took parental leave at least once ($z = 9.24$, $P < 10^{-19}$; Fig. 3D). Reflecting this gendered difference in behavior, nearly half of women (45.9%) indicated that parental leave policies were somewhat or very important in choosing their current faculty position, compared to 20.6% of men ($\chi^2 = 141.81$, $P < 10^{-30}$; Fig. 3C). On the other hand, women and men placed similar and substantial value on the prestige of their current or a future position, rating prestige as somewhat or very important (89.9 or 56.9% of women and 89.3 or 57.6% of men; $\chi^2 = 0.77$, $P = 0.68$ and $\chi^2 = 0.35$, $P = 0.84$).

Among computer science faculty, early-career women with children reported less satisfaction with their current positions than women without children (58.3 versus 70.0%; $t = -2.04$, $P = 0.05$), suggesting parenthood as a potentially important factor in retention, although no such differences exist in the other fields we surveyed. Across all fields, 67.2 versus 72.7% of early-career women, with and without children, said that they were somewhat or very satisfied ($t = -0.86$, $P = 0.39$). Differences in job satisfaction remain insignificant when we compare men with and without children and older women with and without children. Among early-career men, 78.0% of those with children, versus 79.0% of those without children, indicated that they were satisfied at their current position. Among older women, overall job satisfaction was comparable among mothers and nonmothers (73.2 versus 72.2%). The availability of parental leave was not correlated with job satisfaction. Mothers at institutions that offered either more than or less than 10 weeks of parental leave indicated similar levels of satisfaction (72.1 versus 71.0%).

Parenting represents a threat to the ideal worker norm (44–46), an expectation of complete dedication to the workplace without responsibilities at home. While women and men are both subject to this expectation, women typically bear more childcare responsibilities than men (24) and thus are less likely to meet this ideal (45). To understand such norms, our survey asked respondents to estimate the likely and expected levels of productivity of others, as well as their personal productivity goals. Consistent with the belief that parenting violates the ideal worker norm, faculty estimate that mothers and fathers will likely publish fewer papers than faculty without children, and they expect decreases that are greater for women than for men (Table 1). Faculty also believe that women with children are likely to produce fewer papers than is expected of them (54.2% fewer of women and 37.2% of men, across all fields; $\chi^2 = 77.75$, $P < 10^{-17}$; Table 1). To appear devoted to their work while being a parent, under an ideal worker norm, we might also expect fathers to aim for relatively high productivity. Despite faculty adjusting their expectations of parents’ productivity, we find little evidence that parenthood changes faculty’s expectations of their own productivity. Early-career faculty with children under the age of 10 reports similar publishing aspirations as those without children (Table 1). For example, in computer science, women with children aimed for 8.2 papers over a 2-year period versus 9.2 papers for those without children, and men with children aimed for 9.5 papers versus 8.5 papers for those without children ($t = -0.95$, $P = 0.35$ and $t = 1.78$, $P = 0.08$). These norms appear to be shaped by broad cultural forces, as the availability of generous parental leave policies, defined here as at least 10 weeks of paid leave, does not appear to affect faculty expectations of others’ productivity or their own productivity.

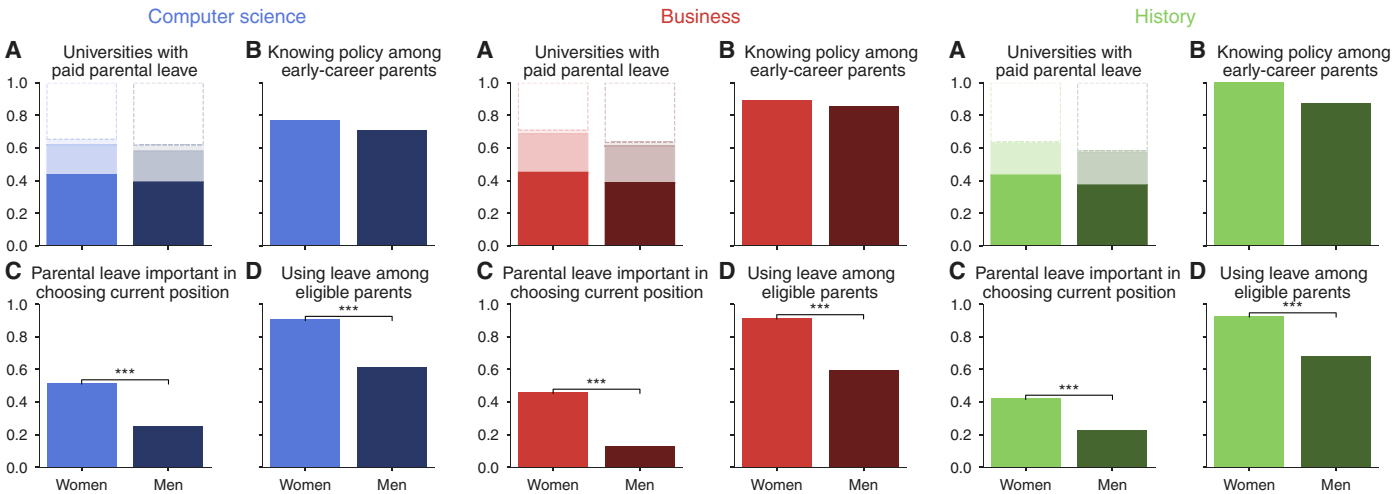


Fig. 3. Parental leave policy availability, knowledge, importance, and usage for faculty. Proportions of (A) universities with parental leave policies, (B) early-career parents with knowledge of those policies, (C) faculty who reported that parental leave was important in choosing their current position, and (D) eligible parents' usage of those policies, for faculty in computer science (blue), business (red), and history (green) faculty. Parental leave policies are coded as either at least 10 weeks long (roughly a semester; solid), more than 0 and less than 10 weeks (lighter), unknown policy (lightest), or no paid leave (empty). Pairwise hypotheses tests across gender with *** $P < 0.01$.

Table 1. Research expectations among faculty with and without children. Beliefs about the likely and expected numbers of papers each demographic group will publish in the next 2 years (Likely and Expected). Average goals from each group for the number of papers that they hope to produce in the next 2 years (Aim avg.). Demographic groups are among young faculty, who currently have a young child (10 or younger) or do not (either had no children or have a child older than 10).			
Computer science	Likely	Expected	Aim avg.
Women with child	5.72	6.53	8.18
Women with no child	7.05	7.10	9.21
Men with child	6.81	7.01	9.45
Men with no child	7.78	7.54	8.45
Business	Likely	Expected	Aim avg.
Women with child	1.59	2.40	3.51
Women with no child	2.13	2.58	3.62
Men with child	2.15	2.53	3.91
Men with no child	2.40	2.63	3.74
History	Likely	Expected	Aim avg.
Women with child	1.28	2.08	2.80
Women with no child	2.00	2.44	3.05
Men with child	2.00	2.30	3.09
Men with no child	2.40	2.54	3.27

Trends in the impact of parenthood

The policy implications of these findings depend strongly on whether they will hold in the future. Longitudinal studies indicate a decade-long trend of fathers becoming more involved in parenting (47), leading to the hypothesis that the productivity gap studied here has been narrowing over time. We find evidence for increased parental involvement among men. For instance, of men who were eligible to take parental leave before the year 2000, only 38.7% took that leave, compared to 67.6% of those who first became eligible after ($z = 4.64$,

$P < 10^{-5}$). Despite this marked increase in the rate at which men are taking parental leave, their overall productivity has not decreased (Fig. 4). Concurrently, mothers increased their productivity, which shrank the productivity gap between mothers and fathers. Among faculty who had their first child before the year 2000, the 10-year cumulative productivity of women ranges from 61.4 to 82.0% of comparable men, whereas it rises to 75.7 to 110.0% for those who became parents after (Fig. 4). In parallel with the narrowing of this productivity gap, we note that there were concurrent increases in rates of collaboration (48), as well as the number of paid parental leave policies and gender-neutral tenure clock-stoppage policies (42, 49). However, as of 2018, only 42.9% of universities in our sample offered such policies (50).

Among institutions that offered any paid parental leave (63.6%), the average length of leave was 14.7 and 12.2 weeks for women and men, respectively, which is roughly equivalent to one academic term (Fig. 3A). A slight majority of policies (54.8%) did not clearly specify whether the leave applied only to teaching, teaching and service, teaching and research, etc. In our survey, most men and women express a preference for a parental leave policy that is gender neutral (48.1% of responses) with full relief for teaching and service (68.4%). However, ignorance of their institution's current parental leave policy was not uncommon: 17.2% of early-career faculty with children reported not knowing whether their institution offered any parental leave benefits (Fig. 3B). This lack of knowledge about parental leave policies may suggest an overall lack of concern about those policies or the impact of parenthood on productivity. It may also reflect the often complex nature and convoluted language of these policies, which can include ad hoc negotiations with supervisors, leave-sharing requirements between parents, medical certifications, and more (51).

DISCUSSION

Our results inform the longstanding puzzle of the ubiquitous productivity gap between tenure-track men and women at research-intensive institutions by indicating that the majority of the extant gap (between 87.6 and 95.6%) is caused by a gendered effect of

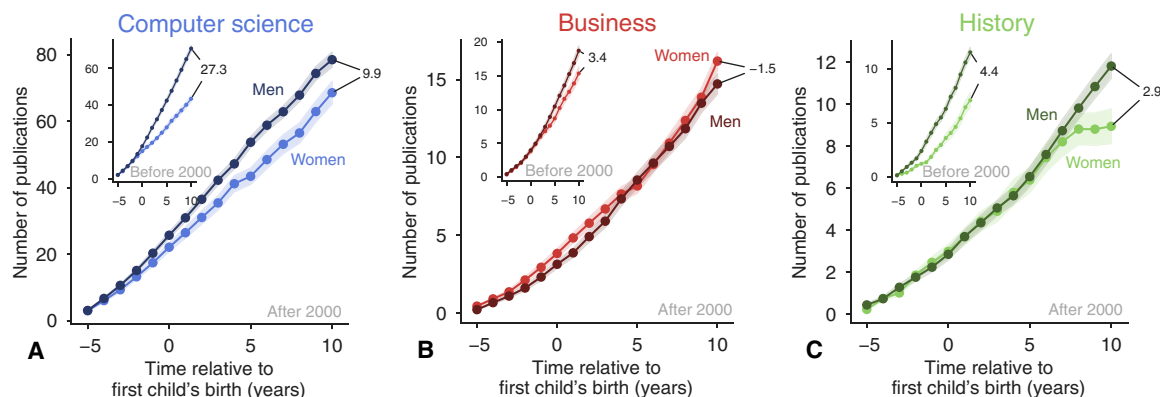


Fig. 4. Cumulative career productivity of fathers and mothers before and after 2000. Average cumulative productivity relative to their first child's birth and corresponding gender productivity gaps for (A) computer science (blue; $N = 724$), (B) business (red; $N = 366$), and (C) history (green; $N = 185$) faculty who became parents after the year 2000; insets show the same for faculty who became parents before 2000.

parenthood: Among computer science faculty, over the 10 years after the birth of their child, mothers produce on average 17.6 fewer papers than fathers—a gap that would take roughly 5 years of work for mothers to close (section SB). The effect of the parenthood penalty for mothers appears most concentrated in the years immediately following parenthood, with relatively little impact on long-term productivity rates (section SD). Our results are consistent with a simple causal relationship between time available for research and overall productivity, in which parenthood specifically reduces the latter for women much more so than for men. Hence, policies aimed at providing more workplace flexibility for parents, such as accessible lactation rooms and affordable childcare, are likely to lessen the impact of parenthood on research time.

At the same time, the magnitude of the parenthood penalty appears to be shrinking over time, not because men are becoming less productive (despite increasing rates of fathers' leave usage) but because women have increased their productivity (Fig. 4), e.g., since 2000, mothers in computer science produce on average only 5.4 fewer papers than fathers, a gap equivalent to only 1 year of work (table S5). This trend may reflect broader changes in gender roles, possibly driven by the increasing proportions of women (4), or the growing prevalence of paid gender-neutral parental leave policies. Our survey indicates broad support for such policies among faculty and points to the role these policies play in the recruitment and retention of women. Moreover, the fact that parental leave policies were important in choosing a position and that a large fraction of faculty have children before their first faculty position (39.4%) suggests that strong childcare benefits during their early professional careers may be an underutilized tool for recruitment and retention (52), especially for women. Barriers to balancing parenthood and research for graduate students and postdoctoral fellows, such as expensive childcare options or the lack of health care coverage of dependents, may also discourage early-career parents from pursuing tenure-track employment altogether. Although unobservable in our study, the effects of these policies remain an important topic of future research.

In the absence of randomized treatments, our observational study estimates the effect of parenthood on productivity by using causal inference methods and thus comes with caveats. For instance, women in academia are more likely to have partners working in academia than men (3, 53, 54), and women are more likely to be single parents (55). This tendency may explain why fathers experience

less of a parenthood penalty than mothers, because men may have nonacademic partners, leading to more practical flexibility in adapting to an abrupt change in time available for research due to caregiving. Understanding how partnerships mediate the impact of parenthood on researcher productivity remains an important direction of future work. Furthermore, our sample frame was restricted to current faculty. This requirement may have induced a selection bias in which less productive researchers, or those who experienced larger productivity penalties, were not observed, which may have contributed to faculty with children appearing slightly more productive than faculty without children (Fig. 2). While parenthood appears to adversely affect mothers' productivity across all three fields, further research is needed to understand why the magnitudes of these shocks vary across the fields and if the event of parenthood affects men's academic careers in a more nuanced way. Last, our analysis computes only average effects, which may conceal substantial variability in individual productivity patterns (32).

Our results indicate that the productivity penalty paid by mothers explains the vast majority of the observed productivity gap between men and women at research-intensive universities. However, a small-to-modest gendered productivity gap remains unexplained by the effects of parenthood and hence is attributable to other effects, ranging from bias in peer review (56, 57) to discrimination (58), differences in service loads (7), or approaches to research (9, 59), among others. Untangling the relative importance of these factors is an important direction for future work.

Although women reported valuing paid parental leave policies more than men, men are increasingly likely to use them, albeit still at rates much lower than women. To date, policy changes have been focused on availability and gender neutrality (42, 51), yet usage patterns remain complicated. For instance, Canadian fathers reported using parental leave at significantly lower rates than U.S. fathers in our sample (44.5 versus 63.9%; $z = 2.29$, $P = 0.02$) despite its universal availability in Canada. These perceptions and patterns suggest a complicated and evolving relationship between parental leave, gender, and productivity, and future work is needed to better understand their interactions.

Our results are consistent with the idea that gender norms around parenting and who allocates more time to childcare ultimately drive a differential and larger impact on women's careers and their ability to contribute equally in scholarship. We expect this differential impact

to appear whenever an event occurs that is filtered through these norms, such as a sudden loss of outside childcare or a sudden need for homeschooling, as has occurred recently. During the COVID-19 pandemic, women have borne a relatively greater share of increased childcare needs (21, 60), in addition to their extra service and teaching efforts (7, 61), while still earning substantially less despite broadly increased financial pressure (62, 63).

In the long run, social policies aimed at mitigating the impact of parenthood on faculty should do more than narrowly focus on optimizing near-term scholarly productivity. Prior work considering how scientific careers affect families and family formation suggests that dissatisfaction with having fewer children than desired correlates with job satisfaction (64) and that women are more likely to be single without children than men (65). Good policies should also recognize the long-term social, scholarly, and individual value of supporting work-life balance for both mothers and fathers.

MATERIALS AND METHODS

Our study relies on a large survey of tenure-track faculty at research-intensive universities. We collected names and email address from the publicly available online directories of 205 computer science, 112 business, and 144 history departments in the United States and Canada (section SA) (66). We then emailed 5792 computer science faculty, 9573 business faculty, and 4336 history faculty between summer 2017 and fall 2018 to participate in our survey. In our invitation, our survey did not reference parenthood, and questions about parenthood were just a few out of many. In total, 3064 faculty responded (15.6%). Although women were slightly more likely to respond to our survey than men, our survey constitutes a representative sample by faculty rank and departmental prestige.

To analyze how productivity changes in response to the presence or absence of the initial parenthood event, we linked survey responses to the number of papers each researcher published in a given year (section SB). For computer science faculty, we linked responses to publications listed in DBLP (<https://dblp.uni-trier.de>), an online database of computing publications. A comparison of publications indexed by DBLP with those on individuals' CVs (*curricula vitae*) shows time-varying coverage within DBLP. To account for this variation and the overall increasing publishing rate in computer science (fig. S1), we apply two linear adjustments to publication counts (32), which allows us to compare faculty across time. For history and business faculty, we manually counted publications from respondents' CVs. In general, respondents that we could link to publication data are a representative sample of our total population (table S3). In total, we recorded 79,274, 15,352, and 6346 scholarly works for 1061 faculty in computer science, 525 in business, and 294 in history departments, respectively.

To understand the impact of parenthood on faculty productivity, we use matching to align the publishing trends of parents and nonparents. To align these trends according to when faculty had their first child or, in the case of nonparents, could have had their first child, we match parents with nonparents in the same field, of the same gender, and who were born in the same year and assign a year of a counterfactual birth to the nonparent individual. This approach accounts for the rising age at which faculty are having their first child (fig. S2), and our matching means that parents and counterfactual parents are similar with respect to biological age, career age, and institutional prestige before becoming parents (table S6).

Given such an alignment, we then use a regression-based model called CITS to estimate the changes in productivity as a result of parenthood, relative to our nonparent group

$$Y_{i,t} = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot I[t > 0] + \beta_3 \cdot t \times I[t > 0] + \beta_4 \cdot T_i + \beta_5 \cdot T_i \times t + \beta_6 \cdot T_i \times I[t > 0] + \beta_7 \cdot T_i \times I[t > 0] \times t + \beta_8 \cdot \Pi_i \quad (1)$$

where $Y_{i,t}$ is the outcome of interest (annual number of papers published) for an individual i , at time relative to their first child's birth t . The indicator variable $T_i = 1$ if an individual is in our treatment group (parents) and 0 if they are a control (counterfactual parents). The variable Π_i controls for the prestige of an individual's institution. Our effect of interest is β_6 , describing how the productivity of parents changes immediately after becoming a parent, controlling for their pre-parenthood levels, and accounting for the secular trend among the nonparent group (Fig. 2). The remaining coefficients are described in more detail in section SD.

Our methods for estimating the impact of parenthood have limitations. Matching assumes that there are no unobserved confounding variables that may explain the year when faculty become parents. For example, possible confounders here may include relationship status and its differences by gender (65). In section SD, we examine two alternatives to our nonparametric matching. Our CITS approach rests on the idea that the nonparent cohort is an appropriate control for what would have happened to parents in the absence of parenthood. This assumption may not be entirely true. For instance, childbirth and expectations of subsequent productivity losses may drive some individuals to leave academia altogether, potentially more so for women (30). This type of selection effect on academic parents likely means that the effects that we observe are underestimates of the true effect sizes.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at <http://advances.sciencemag.org/cgi/content/full/7/9/eabd1996/DC1>

REFERENCES AND NOTES

1. J. R. Cole, H. Zuckerman, The productivity puzzle, in *Advances in Motivation and Achievement. Women in Science* (JAI Press, 1984).
2. Y. Xie, K. A. Shauman, Sex differences in research productivity: New evidence about an old puzzle. *Am. Sociol. Rev.* **63**, 847–870 (1998).
3. H. E. Zuckerman, J. R. Cole, J. T. Bruer, *The Outer Circle: Women in the Scientific Community* (WW Norton & Co, 1991).
4. S. F. Way, D. B. Larremore, A. Clauset, Gender, productivity, and prestige in computer science faculty hiring networks, in *Proceedings of the 25th International Conference on World Wide Web* (2016), pp. 1169–1179.
5. A. Clauset, S. Arbesman, D. B. Larremore, Systematic inequality and hierarchy in faculty hiring networks. *Sci. Adv.* **1**, e1400005 (2015).
6. V. Valian, *Why So Slow?: The Advancement of Women* (MIT press, 1999).
7. C. M. Guarino, V. M. H. Borden, Faculty service loads and gender: Are women taking care of the academic family? *Res. High. Educ.* **58**, 672–694 (2017).
8. M. L. Bellas, Emotional labor in academia: The case of professors. *Ann. Am. Acad. Pol. Soc. Sci.* **561**, 96–110 (1999).
9. E. Leahey, Gender differences in productivity: Research specialization as a missing link. *Gen. Soc.* **20**, 754–780 (2006).
10. N. Robinson-Garcia, R. Costas, C. R. Sugimoto, V. Larivière, G. F. Nane, Task specialization and its effects on research careers. *eLife* **9**, e60586 (2020).
11. G. Sonnert, G. Holton, Career patterns of women and men in the sciences. *Am. Sci.* **84**, 63–71 (1996).
12. E. Hengel, *Publishing While Female. Are Women Held to Higher Standards? Evidence From Peer Review* (Cambridge Working Papers in Economics 1753, Faculty of Economics, University of Cambridge, December 2017).

13. J. Huang, A. J. Gates, R. Sinatra, A.-L. Barabási, Historical comparison of gender inequality in scientific careers across countries and disciplines. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 4609–4616 (2020).
14. S. Stack, Gender, children and research productivity. *Res. High. Educ.* **45**, 891–920 (2004).
15. L. A. Hunter, E. Leahey, Parenting and research productivity: New evidence and methods. *Soc. Stud. Sci.* **40**, 433–451 (2010).
16. M. Lutter, M. Schröder, Is there a motherhood penalty in academia? The gendered effect of children on academic publications in German sociology. *Eur. Sociol. Rev.* **36**, 442–459 (2019).
17. M. F. Fox, Gender, family characteristics, and publication productivity among scientists. *Soc. Stud. Sci.* **35**, 131–150 (2005).
18. J. R. Cole, H. Zuckerman, Marriage, motherhood and research performance in science. *Sci. Am.* **256**, 119–125 (1987).
19. M. Krapf, H. W. Ursprung, C. Zimmermann, Parenthood and productivity of highly skilled labor: Evidence from the groves of academe. *J. Econ. Behav. Organ.* **140**, 147–175 (2017).
20. P. Vincent-Lamarre, C. R. Sugimoto, V. Larivière, “The decline of women’s research production during the coronavirus pandemic” (Nature Index News, 2020).
21. K. R. Myers, W. Y. Tham, Y. Yin, N. Cohodes, J. G. Thursby, M. C. Thursby, P. Schiffer, J. T. Walsh, K. R. Lakhani, D. Wang, Unequal effects of the covid-19 pandemic on scientists. *Nat. Hum. Behav.* **4**, 880–883 (2020).
22. L. Schiebinger, S. K. Gilmartin, Housework is an academic issue. *Academe* **96**, 39–44 (2010).
23. M. A. Mason, M. Goulden, Do babies matter (part ii)? Closing the baby gap. *Academe* **90**, 10–15 (2004).
24. J. Misra, J. H. Lundquist, A. Templer, Gender, work time, and care responsibilities among faculty 1. *Sociological Forum* **27**, 300–323 (2012).
25. J. Joecks, K. Pull, U. Backes-Gellner, Childbearing and (female) research productivity: A personnel economics perspective on the leaky pipeline. *J. Bus. Econ.* **84**, 517–530 (2014).
26. K. Ward, L. Wolf-Wendel, Academic motherhood: Managing complex roles in research universities. *Rev. High. Educ.* **27**, 233–257 (2004).
27. B. K. Hawks, J. Z. Spade, Women and men engineering students: Anticipation of family and work roles. *J. Eng. Educ.* **87**, 249–256 (1998).
28. S. M. Van Anders, Why the academic pipeline leaks: Fewer men than women perceive barriers to becoming professors. *Sex Roles* **51**, 511–521 (2004).
29. H. Nicholas, M. A. Mason, M. Goulden, Problems in the pipeline: Gender, marriage, and fertility in the ivory tower. *J. High. Educ.* **79**, 388–405 (2008).
30. E. A. Cech, M. Blair-Loy, The changing career trajectories of new parents in STEM. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 4182–4187 (2019).
31. M. A. Mason, N. H. Wolfinger, M. Goulden, *Do Babies Matter?: Gender and Family in the Ivory Tower* (Rutgers Univ. Press, 2013).
32. S. F. Way, A. C. Morgan, A. Clauset, D. B. Larremore, The misleading narrative of the canonical faculty productivity trajectory. *Proc. Natl. Acad. Sci. U.S.A.* **114**, E9216–E9223 (2017).
33. J. R. Cole, S. Cole, *Social Stratification in Science* (University of Chicago Press, 1973).
34. S. F. Way, A. C. Morgan, D. B. Larremore, A. Clauset, Productivity, prominence, and the effects of academic environment. *Proc. Natl. Acad. Sci. U.S.A.* **116**, 10729–10733 (2019).
35. P. Larsen, M. Von Ins, The rate of growth in scientific publication and the decline in coverage provided by Science Citation Index. *Scientometrics* **84**, 575–603 (2010).
36. T. J. Matthews, B. E. Hamilton, Mean age of mothers is on the rise: United States, 2000–2014. *NCHS Data Brief*, 1–8 (2016).
37. Y. S. Khandwala, C. A. Zhang, Y. Lu, M. L. Eisenberg, The age of fathers in the usa is rising: An analysis of 168 867 480 births from 1972 to 2015. *Hum. Reprod.* **32**, 2110–2116 (2017).
38. T. J. Matthews, B. E. Hamilton, Delayed childbearing: More women are having their first child later in life. *NCHS Data Brief*, 1–8 (2009).
39. S. Lundberg, E. Rose, Parenthood and the earnings of married men and women. *Labour Economics* **7**, 689–710 (2000).
40. M. Gangl, A. Ziefle, Motherhood, labor force behavior, and women’s careers: An empirical assessment of the wage penalty for motherhood in Britain, Germany, and the United States. *Demography* **46**, 341–369 (2009).
41. H. Kleven, C. Landais, J. E. Sogaard, Children and gender inequality: Evidence from Denmark. *Am. Econ. J. Appl. Econ.* **11**, 181–209 (2019).
42. H. Antecol, K. Bedard, J. Stearns, Equal but inequitable: Who benefits from gender-neutral tenure clock stopping policies? *Am. Econ. Rev.* **108**, 2420–2441 (2018).
43. J. H. Lundquist, J. Misra, K. A. O’Meara, Parental leave usage by fathers and mothers at an american university. *Fathering* **10**, 337–363 (2012).
44. B. Kelly, K. McCann, Women faculty on the tenure track: The compounding role of being the breadwinner. *J. Professoriate* **10**, 73–109 (2019).
45. M. W. Sallee, The ideal worker or the ideal father: Organizational structures and culture in the gendered university. *Res. High. Educ.* **53**, 782–802 (2012).
46. K. Weisshaar, From opt out to blocked out: The challenges for labor market re-entry after family-related employment lapses. *Am. Sociol. Rev.* **83**, 34–60 (2018).
47. L. C. Sayer, S. M. Bianchi, J. P. Robinson, Are parents investing less in children? Trends in mothers’ and fathers’ time with children. *Am. J. Sociol.* **110**, 1–43 (2004).
48. V. Larivière, Y. Gingras, C. R. Sugimoto, A. Tsou, Team size matters: Collaboration and scientific impact since 1900. *J. Assoc. Inf. Technol.* **66**, 1323–1332 (2015).
49. American Association for University Professors (AAUP), Statement of Principles on Family Responsibilities and Academic Work (2001).
50. A. C. Morgan, S. F. Way, M. Galesic, D. B. Larremore, A. Clauset, Paid parental leave at US and Canadian universities (2018).
51. M. A. Mason, A. Stacy, M. Goulden, C. Hoffman, K. Frasch, *University of California Faculty Family Friendly Edge: An initiative for Tenure-Track Faculty at the University of California* (Berkeley: University of California Berkeley, 2005).
52. C. Olivetti, B. Petrongolo, The economic consequences of family policies: Lessons from a century of legislation in high-income countries. *J. Perspectives* **31**, 205–230 (2017).
53. L. Grant, I. Kennelly, K. B. Ward, Revisiting the gender, marriage, and parenthood puzzle in scientific careers. *Women’s Stud. Q.* **28**, 62–85 (2000).
54. L. L. Schiebinger, A. D. Henderson, S. K. Gilmartin, *Dual-career Academic Couples: What Universities need to know*, M. R. Clayman Institute for Gender Research (Stanford University, 2008).
55. M. Baker, The family life of academics: Gendered priorities and institutional constraints, in *Annual Conference of the Australian Institute of Family Studies* (2008), pp. 9–11.
56. M. Helmer, M. Schottdorf, A. Neef, D. Battaglia, Research: Gender bias in scholarly peer review. *eLife* **6**, e21718 (2017).
57. D. Murray, K. Siler, V. Larivière, W. M. Chan, A. M. Collings, J. Raymond, C. R. Sugimoto, Author-reviewer homophily in peer review. *bioRxiv*, 400515 (2019).
58. C. A. Moss-Racusin, J. F. Dovidio, V. L. Brescoll, M. J. Graham, J. Handelsman, Science faculty’s subtle gender biases favor male students. *Proc. Natl. Acad. Sci.* **109**, 16474–16479 (2012).
59. M. R. E. Symonds, N. J. Gemmell, T. L. Braisher, K. L. Gorringer, M. A. Elgar, Gender differences in publication output: Towards an unbiased metric of research performance. *PLOS ONE* **1**, e127 (2006).
60. C. Collins, L. C. Landivar, L. Ruppner, W. J. Scarborough, Covid-19 and the gender gap in work hours. *Gen. Work Organ.*, 1–12 (2020).
61. E. Gibney, Teaching load could put female scientists at career disadvantage. *Nature* 10.1038/nature.2017.21839 (2017).
62. D. A. Barbezat, J. W. Hughes, Salary structure effects and the gender pay gap in academia. *Res. High. Educ.* **46**, 621–640 (2005).
63. J. L. Malisch, B. N. Harris, S. M. Sherrer, K. A. Lewis, S. L. Shepherd, P. C. McCarthy, J. L. Spott, E. P. Karam, N. Moustaid-Moussa, J. M. Calarco, L. Ramalingam, A. E. Talley, J. E. Cañas-Carrell, K. Ardon-Dryer, D. A. Weiser, X. E. Bernal, J. Deitloff, Opinion: In the wake of covid-19, academia needs new solutions to ensure gender equity. *Proc. Natl. Acad. Sci. U.S.A.* **117**, 15378–15381 (2020).
64. E. H. Ecklund, A. E. Lincoln, Scientists want more children. *PLOS ONE* **6**, e22590 (2011).
65. M. A. Mason, M. Goulden, Marriage and baby blues: Redefining gender equity in the academy. *Ann. Am. Acad. Pol. Soc. Sci.* **596**, 86–103 (2004).
66. A. C. Morgan, S. F. Way, A. Clauset, Automatically assembling a full census of an academic field. *PLOS ONE* **13**, e0202223 (2018).
67. J. Dykema, J. Stevenson, L. Klein, Y. Kim, B. Day, Effects of e-mailed versus mailed invitations and incentives on response rates, data quality, and costs in a web survey of university faculty. *Soc. Sci. Comput. Rev.* **31**, 359–370 (2013).
68. M. M. Millar, D. A. Dillman, Improving response to web and mixed-mode surveys. *Public Opin. Q.* **75**, 249–269 (2011).
69. U.S. Department of Education, Characteristics of Postsecondary Faculty, in *The Condition of Education 2019 (NCES 2019–144)*, National Center for Education Statistics (2019).
70. F. Karimi, C. Wagner, F. Lemmerich, M. Jadidi, M. Strohmaier, Inferring gender from names on the web: A comparative evaluation of gender detection methods, in *Proceedings of the 25th International Conference Companion on World Wide Web* (2016), pp. 53–54.
71. F. Hamidi, M. K. Scheuerman, S. M. Branham, Gender recognition or gender reductionism? the social implications of embedded gender recognition systems, in *Proceedings of the 2018 chi conference on human factors in computing systems* (2018), pp. 1–13.
72. J. S. Fairweather, The mythologies of faculty productivity: Implications for institutional policy and decision making. *J. High. Educ.* **73**, 26–48 (2002).
73. C. S. White, K. James, L. A. Burke, R. S. Allen, What makes a “research star”? Factors influencing the research productivity of business faculty. *Int. J. Product. Perform. Manag.* **61**, 584–602 (2012).
74. M. R. Rosenzweig, K. I. Wolpin, Life-cycle labor supply and fertility: Causal inferences from household models. *J. Polit. Econ.* **88**, 328–348 (1980).

75. J. D. Angrist, W. N. Evans, Children and their parents' labor supply: Evidence from exogenous variation in family size. *Am. Econ. Rev.* **88**, 450–477 (1998).

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