Ph.D. parenthood dilemma in academia: The gender difference in trajectories of childbearing and Ph.D. pursuit among researchers

Keywords: life-course trajectories; Gender gap; Parenthood; Ph.D. recipients; academic career

Introduction

The past several decades have seen tremendous progress in increasing the participation of women in higher education, nearly achieving a gender balance at the doctoral level (48%) in 2018 [Llorens et al., 2021, for Research and Innovation, 2021a,b]. The gender shifts in doctoral education also occurred in the age of doctorate recipients. Not only is the median age of earned doctorates decreasing over time, but the gender gap in the median ages has also been steadily closing. In 1992, the median age peaked at 33.3 for men and 36.2 for women, while in 2022, women's median age (31.7 years) was only slightly higher than men's (31.2 years) [for Science and Engineering Statistics, 2023]. Accordingly, most of the women in graduate school for a Ph.D. degree are exactly during their peak childbearing time from the life course perspective [Marcus, 2007, Mary Ann Mason, 2013]. Inevitable physical, mental, and emotional changes brought by pregnancy make it hard to give birth and struggle to obtain a Ph.D. at the same time. Generally, mothers in graduate school are rare, and women generally finish their Ph.D. at an older age than men.

The "conventional wisdom" in academia advised women against having children during doctoral study and even to delay family formation until the point of achieving tenure [Kulp, 2016, Mason et al., 2013, Morrison et al., 2011, Wolfinger et al., 2008, 2009]. The additional five to seven years of racing the tenure clock put the females squarely at the end of the normal reproductive cycle [Mason, 2009]. The conflict between pregnancy, parenthood, and academic development exists throughout the career of academic women, and there is also no "golden rule" for women in academia to balance career and childbearing. Nevertheless, childless researchers are a minority. several surveys show a majority of researchers from different countries and across various disciplines have at least one child [Morgan et al., 2021, Zheng et al., 2022, Galván and Tenenbaum, 2023]. With more policy and institutional support, recent generations of academic women seek to be an "ideal academic" and a "good mother"simultaneously, and delayed childbearing is not desirable [Tower et al., 2014, Mirick and Wladkowski, 2018]. The career-childbearing patterns shaped by the time of gaining a doctorate degree and the time of giving birth vary substantially by the birth cohort, country of origin, and other indicators. However, few studies have been done to discern the different career-childbearing trajectories of researchers and explore the gender differences in the trajectories.

The parenthood penalty in academia in terms of academic performance, promotion opportunities, earning gaps, and long-term career paths has been well documented. Most attention has been paid to the motherhood penalty [Wolfinger et al., 2008, Wolf-Wendel and Ward, 2014, Tower and Latimer, 2016, Lutter and Schröder, 2019]. Several studies have explored the effect of parenthood during the doctoral study on the academic career [Mason, 2009, Mary Ann Mason, 2013, Kulp, 2016, Mirick and Wladkowski, 2018]. The results of the empirical studies show that Ph.D. mothers are more negatively affected by parenthood than men with children

and single women without children [Miller, 2009, Wolfinger et al., 2008, Mason et al., 2013]. By contrast, the recent cohorts of Ph.D. mothers are also found to have some advantages in attaining tenure-track jobs over men and women without children, as it is partly because they start to develop strategies for the existing and future potential conflict between career and family at an earlier time [Kulp, 2016]. Additionally, more institutional policies have been launched to help women with children stay in academia. These studies, however, neglect the intricate career-childbearing trajectories of researchers and usually take researchers with children as an integrated category or only focus on one group of parenting researchers. It is critical to understand how different career-childbearing trajectories are associated with researchers' academic careers and how the associations differ by gender.

A large body of research has emphasized the leaky pipeline in academia, where more females are moving out of academia at higher qualification levels, especially for females with children [Ward and Wolf-Wendel, 2004, van Anders, 2004, Mason et al., 2013, Kulp, 2016, Mirick and Wladkowski, 2018]. Given the fact of an even gender balance in the population with higher education, the underrepresentation of female researchers at higher qualification levels entails the question "What do these females do instead?". Non-ladder-rank positions, for example, adjunct faculty which is more available and flexible compared to tenure-tracked positions, are disproportionately likely to be women [Wolfinger et al., 2009]. In addition to the positions at universities and research institutes, there are plentiful research-intensive workplaces for scientists to pursue research and publishing. Most studies traditionally conceptualized the research career as a path that starts from graduate school and ends with a tenure-track position [Wolfinger et al., 2009], ignoring the researchers employed in a range of research roles across government departments and agencies. Considering other possible research careers can help us gain a better understanding of why the leaky pipeline occurs and where female researchers go instead by exploring to what extent the trajectories of doctoral education and childbearing determine their future careers.

To fill the gaps in discerning the patterns of doctoral education and childbearing events for researchers and their interactive association with gender on research performance and career, we make use of the largest sample survey of publishing parents worldwide. We aim to answer the following questions: 1) Is there a gender difference in having a child during a doctorate study in the early stages of an academic career, i.e., during a doctorate study and in the years immediately following a Ph.D.? 2) What are the common patterns of doctoral education and childbearing across the researchers' life course? Does the interactive association between gender and these life-course trajectories play a role in the researchers' academic performance and future employment sectors? Through addressing these questions, we aim to have a more comprehensive picture of how researchers harmonize parenthood and scientific careers, especially in the course of doctoral studies from a gender perspective.

Materials and methods

Data and sample

This study uses a global survey on the relationship between parenting engagement and academic performance conducted by Gemma E. Derrick et.al.[Derrick et al., 2022]. The survey is composed of 10,445 parent researchers, around 0.40% of the entire population of researchers indexed in Clarivate Analytics' Web of Science (*WoS*), who have at least one *WoS* paper during the period of 2007–2016 as first or last authors. There are some advantages of the dataset: 1) The geographical areas of respondents cover a wide variety of countries across different con-

tinents of North America, Europe, Asia, etc.; 2) The respondents come from different fields of research, including Social Sciences (31.2%), Arts & Humanities (6.8%), Health Sciences (29.1%) and Natural Sciences (32.9%). 3) The employment sectors of respondents are not only limited to those in academia, such as research-based academics and teaching-based academics but also cover the sectors in private institutes and governments; 4) The publication records can be linked to the survey to compare the respondents' research performance.

We excluded the respondents who lack the birth year of any of their children (25 individuals). We then excluded the respondents with suspicious childbearing ages younger than 16 or older than 50 (47 individuals) and those with suspicious Ph.D. ages younger than 20 (26 individuals). Since the survey was implemented in 2018, we also excluded the respondents who indicated they had a child born after 2018 (5 individuals), which we consider a mistake or typo in their answers. The sample size was reduced to 10,349 respondents. We aim to track the childbearing trajectories of respondent researchers from age 15 until age 40, so we also excluded the researchers born after 1978. The final sample analyzed contained 8,097 researchers, which represents 77.5% of the original sampled researchers. Among the parent researchers, 1,973 (24.37%) researchers have one child, 4,390 (54.09%) researchers have two children, and 1,744 (21.54%) researchers have three or more children.

Additionally, we code the researchers' birth years into five cohorts: before 1960 (the birth year earlier before 1960); cohort 1960 (birth year between 1960 and 1964); cohort 1965 (birth year between 1965 and 1969); cohort 1970 (birth year between 1970 and 1974); and cohort 1975 (birth year between 1975 and 1978). As the respondent researchers are from 119 countries in total, we further identify the geographical areas they come from at a more coarse scale, which includes the following 14 continental regions: Southern Europe, North America, South Asia, Northern Europe, Eastern Europe, Central Asia, Western Asia, South America, Sub-Saharan Africa, South-East Asia, Central America, and Northern Africa.

Cox proportional hazard models of gaining a doctoral degree

We employed the Cox proportional hazard model to estimate the hazard of obtaining a doctorate degree with different numbers of children and adjusted for other variables. The observation years for an individual is from 15 years old until 40 years old, but either the event occurred (obtaining a doctoral degree) or the observation period expired for those who had not yet obtained a doctoral degree, so-called right-censored data. The Cox model is expressed as follows:

$$H(t|X_0,...,X_k) = h_0(t)exp(\sum_{j=0}^{k} \alpha_j X_j(t)) \tag{1}$$

where the $H(t|X_0,...,X_k)$ means the hazard rate of obtaining a doctorate degree at age t for researchers with characteristics $|X_0,...,X_k|$, including the variables of interest, i.e., gender and the number of children, and other factors that are the researcher's birth cohort, geographical region of birth, and research field (Natural Sciences, Health Sciences, Social Sciences, and Arts and Humanities). $\alpha = |\alpha_i,...,\alpha_k|$ is the parameter vector we need to estimate.

Logistic model in the likelihood of childbearing in the early academic career

To address our first question, we use a logistic model to estimate the probability of childbearing behaviors during the early academic career. We define the period of doctoral study and the years immediately following a Ph.D. as the early stages of an academic career. In our data sample,

there are 441 researchers without a Ph.D. degree (5%), and we have no information about when they started their academic careers, so we excluded them in answering this question. The duration of doctoral study varies depending on the discipline and country and also differs by individual. A Ph.D. program typically takes four to six years; hence, we define the duration of doctoral education as five years. We also consider the five years following a Ph.D. as another period in the early academic career. We separately estimate the probability of childbearing in these two periods using the logistic model below.

$$\begin{aligned} logit(P(child_i = 1)|T) = \beta_0 + \beta_{gender} \times gender_i + \beta_{cov_k} \times cov_{k,i} \\ + \beta_{gender \times cov_k} \times gender_i \times cov_{k,i} + \sigma_i \end{aligned} \tag{2}$$

Here, $child_i$ is the logistic link function, which indicates the probabilities of having at least one child for researcher i during the period T ($T = 0$ represents the period during the doctoral study while $T = 1$ represents the period after a Ph.D.). In addition to the variable of interest, i.e., gender ($gender_i$), we also consider these control variables: the researcher's birth cohort, the field of research, the birth regions at continental level, the number of existing child(ern), and the researcher's age. We also included interactions between gender and other control variables in the model.

Multichannel sequence analysis and cluster analysis of childbearing-Ph.D. trajectories

Sequence analysis is an established method to study life courses in social science by efficiently grouping people with similar life course trajectories (i.e., sequences) and seeking patterns that show up across a number of trajectories. Since we simultaneously consider two separate life course domains of childbearing events and earning a doctorate degree, we employ an extended sequence analysis, that is, multichannel sequence analysis (*MSA*) [Gauthier et al., 2010, Gabadinho et al., 2011] followed by cluster analysis (*CA*) to identify common patterns of bidimensional (bichannel) life course trajectories.

The first step of *MSA* is to create bidimensional childbearing-Ph.D. sequences for researchers from age 15 to age 40, resulting in a sequence of 26 age-specific statuses for each channel. The two channels in the analysis are measured in the number of children and the Ph.D. states (No/Yes). The childbearing rates and the rates of earning a doctoral degree vary depending on the age, so we opt for the dynamic Hamming distance (*DHD*) with the advantage of strong timing sensitivity to construct the dissimilarity matrix between the sequences. Based on the dissimilarity matrix, we then apply Ward's hierarchical clustering method to group the similar sequences [Ward, 1963] and plot the results using a dendrogram to decide the number of clusters, that is the childbearing-Ph.D. trajectories in our analysis [MACINDOE and ABBOTT, 2004]. We used the average silhouette width (*ASW*), Hubert's C index (*HC*) and point-biserial correlation (*PBC*) to measure the cluster quality and evaluate the clustering results. Finally, we assign the cluster membership for each researcher and plot the clustering results. The sequence analysis and cluster solution can be conducted in R using the *TraMineR* package [Gabadinho et al., 2011].

Outcome of childbearing-Ph.D. trajectories

To investigate the outcome of different childbearing-Ph.D. trajectories by gender, we look at how the interaction of trajectories and gender impacts the career performance and development

of researchers. We take the mean normalized citation scores (*MNCS*) and the employment type to respectively represent the outcomes of research impact and career situation.

MNCS is the average impact of each paper compared to other papers published in the same speciality within the same year, to make the citations of publications more comparable across different research fields and publishing years. The employment status of the researchers consists of five different types: research-based academic positions, teaching-based academic positions, research-teaching-based academic positions, non-academic positions, which include positions in governments or private sectors and others, including unemployment. We estimate the *MNCS* using the linear regression model (Eq. (3)) and the probability of employment status using the multinomial logistic model (Eq. (4)).

$$\begin{aligned} MNCS_i = \gamma_0 + \gamma_{trajectory} \times trajectory_i + \gamma_{cov_k} \times cov_{k,i} \\ + \gamma_{trajectory \times cov_k} \times trajectory_i \times cov_{k,i} + \delta_i \end{aligned} \tag{3}$$

$$\begin{aligned} logit(P(emplo_i = m)) = \lambda_0 + \lambda_{trajectory} \times trajectory_i + \lambda_{cov_k} \times cov_{k,i} \\ + \lambda_{trajectory \times cov_k} \times trajectory_i \times cov_{k,i} + \mu_i \end{aligned} \tag{4}$$

The control variables in *cov* includes the researcher's gender, the researcher's birth cohort, the field of research and the birth regions.

Preliminary Results

Family-to-work conflict: The probabilities of gaining a doctoral degree after childbearing

Fig. 1 shows the instantaneous rate of obtaining a Ph.D. between the ages of 16 and 40, by the interaction of gender and the number of children for the researchers at different cohorts. Generally, researchers with two or more children have a lower probability of obtaining a doctoral degree later on. It suggests that the family-to-work conflict impacts the pursuit of a Ph.D. when raising more than one child. However, we did not observe the parenthood penalty for researchers with only one child as the researchers with single child are slightly more likely to earn a Ph.D. degree compared to those without children. This trend is found across cohorts.

From a gender perspective, male researchers are more likely to obtain a doctoral degree after having children relative to their female counterparts in the early cohorts (cohort before 1960, cohort 1960, and cohort 1965). However, such gender disparities decrease with cohort and females from the cohort 1970 even have slightly higher probabilities of earning a doctoral degree with a different number of children. It suggests that, more recently, female researchers are more likely to give birth before or during their Ph.D. study.

Work-to-family conflict: The probabilities of giving birth during the early academic career

Fig. 2 predicts the probabilities of giving birth during the early academic career, that is, the five years before and after obtaining a doctoral degree. It shows that gender disparity increases with cohort. Male researchers from recent cohorts are more likely to become fathers midway through their Ph.D., with the probability increasing from around 18% among the researchers from the cohort earlier than 1960 to 30% among those from the cohort after 1975. Only below 20% female researchers choose to be mothers when pursuing a doctoral degree across all cohorts.

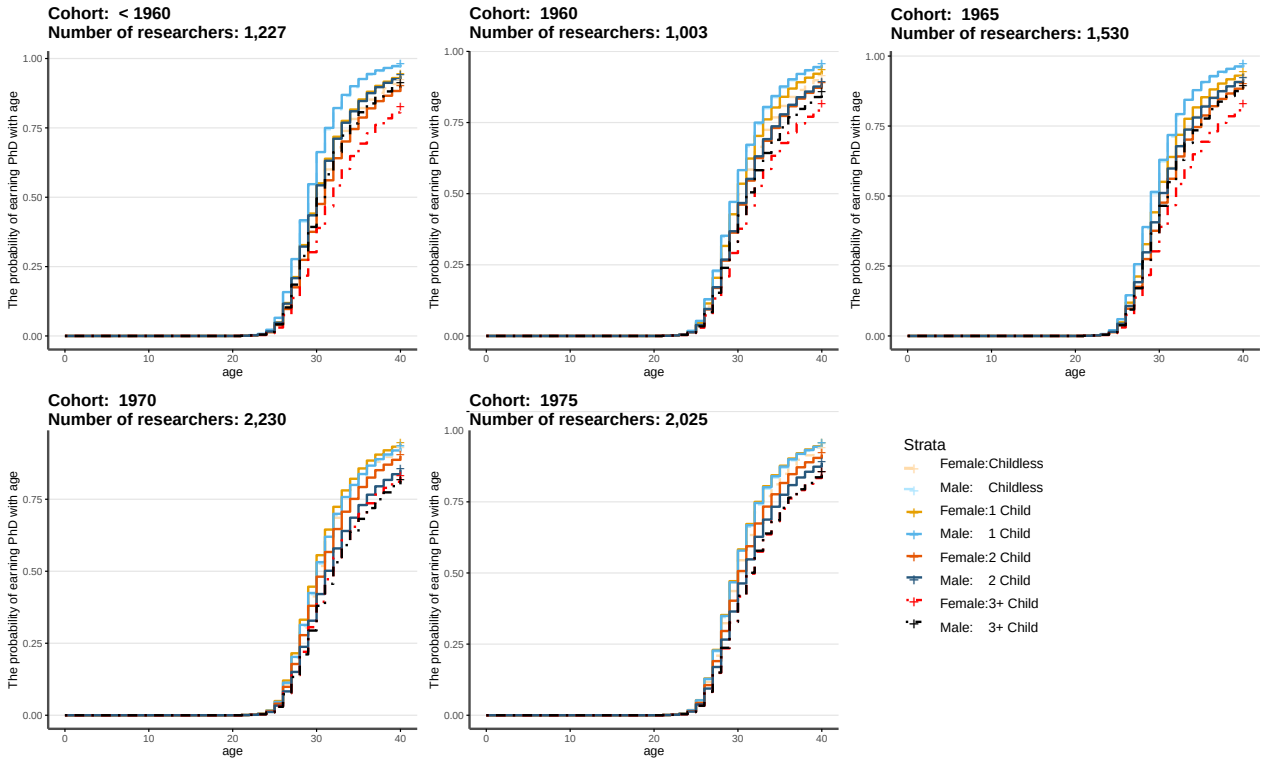

Figure 1: Survival analysis of time to obtain a Ph.D. for researchers who entered without or with Children by gender.

Similarly, the probability of having at least one child during the first five years since Ph.D. increases to around 70% among male researchers from the cohort after 1975. Among female researchers, the probabilities of giving birth after Ph.D. decrease with cohort, dropping from 60% (cohort earlier than 1960) to 50% (cohort earlier after 1975). The work-to-family conflict in the early academic career only occurs in female researchers.

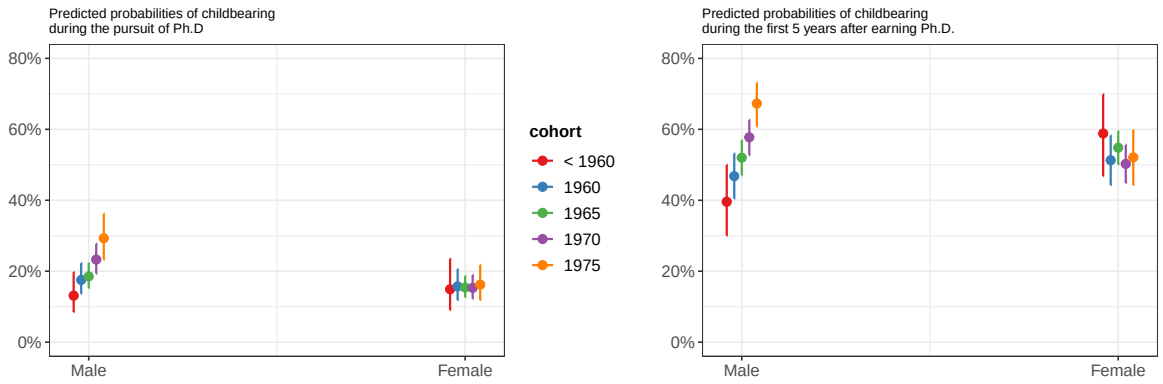

Figure 2: predicted probabilities of giving child during the pursuit of a Ph.D. (left) and during the first five years since Ph.D. (right).

Childbearing-Ph.D. trajectories of researchers

Using multichannel sequence and cluster analysis, we identify five Childbearing-Ph.D. trajectories (shown in Fig. 3 (a)). Among them, Trajectory 3 hosts the most researchers (2,217 (27.38%)), and the next are Trajectory 1 (1,922 (23.74%)), Trajectory 4 (1,802 (22.26%)), and Trajectory 2 (1,389 (17.15%)). Trajectory 5 has the fewest researchers (767 (9.47%)). That means most researchers are more likely to first pursue a doctoral degree and then have their first child. Later childbearing, to some extent, determines a smaller family with only one or two children. In addition, obtaining a Ph.D. degree and having children at an older age (Trajectory 1) is also a common career-family trajectory among researchers. Only a few researchers become parents while pursuing a Ph.D., and have more children across their academic career.

Fig. 3 (b) explores the gender stratification in the career-family trajectories of researchers. The largest gender gap shown in Trajectories 2 and 5 indicates females in academia are more likely to give birth earlier without a Ph.D. compared to their male counterparts, while male researchers tend to pursue a doctoral degree while having more children.

Outcome of Childbearing-Ph.D. trajectories of researchers by gender

Lastly, we discuss how different trajectories influence the academic impact (Fig. 4) and career Fig. 5 among female and male researchers. Overall, male researchers are more likely to get higher mean normalized citation scores (*MNCS*), in addition to Trajectory 2 where female researchers perform better in the group of researchers without Ph.D. degrees and generally receive lower citation scores. The largest gender gap is shown in trajectory 5, in which researchers usually have a larger family of more than two children. It suggests that female researchers are penalized by parenthood more, especially with the heavy childcare responsibilities of more children.

The academic position based on both teaching and research is the most common employment sector for both female and male researchers in all trajectories, and male researchers are much more likely to work in this sector. Female researchers tend to work in the research-based academic sector, especially when they have more children (the largest gender gap is shown in Trajectories 2, 4, and 5). The academic position with only research tasks is relatively more flexible than those with a fixed teaching schedule, which would help relax the conflict between work and family. This pattern suggests again that more childcare responsibilities are borne by female researchers.

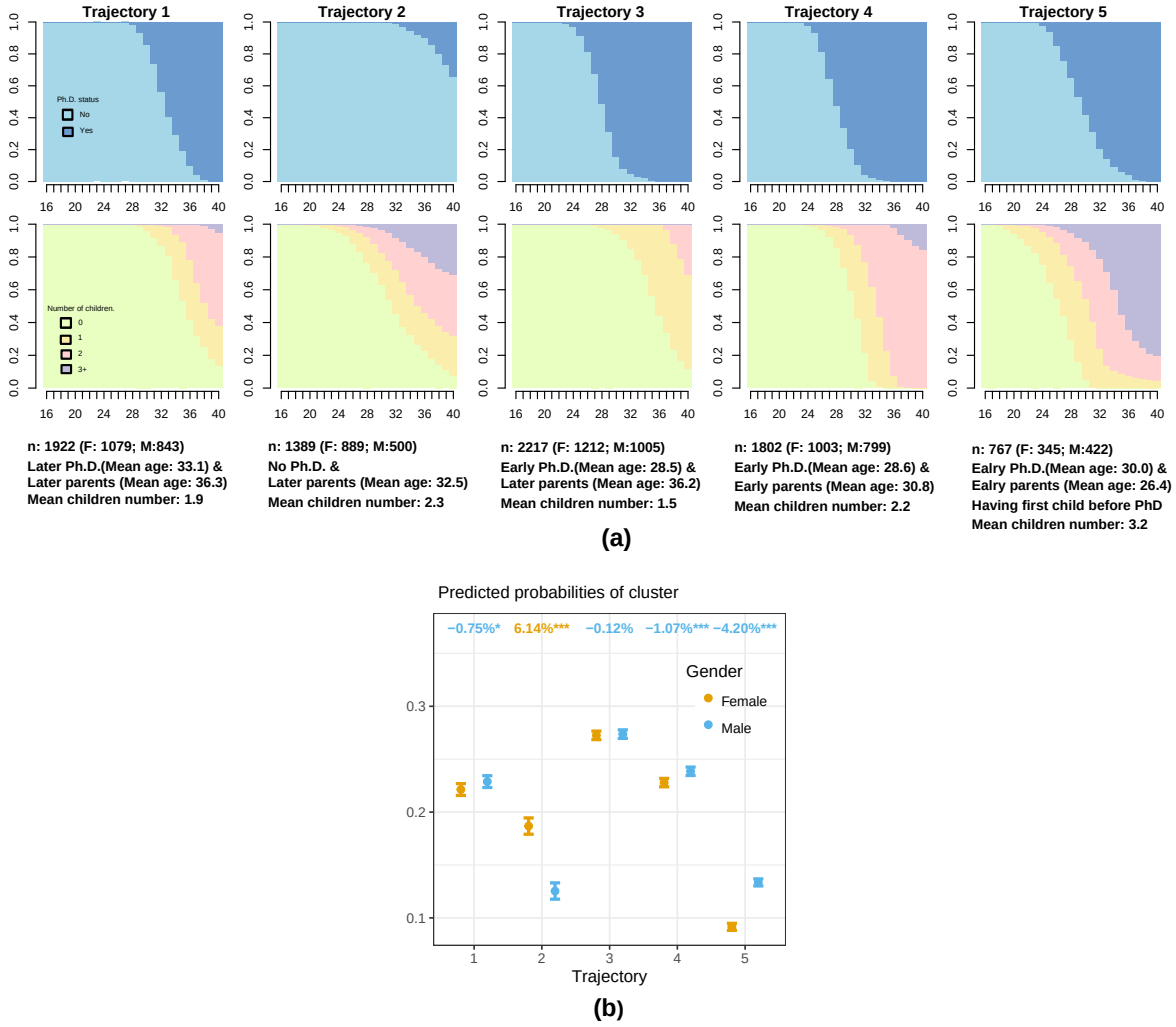

Figure 3: (a) State distribution plots of Ph.D. status (top) and the number of children (bottom) by trajectory. Age is shown on the horizontal axes, and the proportion of researchers belonging to each state at a given time between the ages of 16 and 40 is shown on the vertical axes. The description of each trajectory is shown below the plots. (b) Predicted probability of each trajectory by gender. The numbers on the top show the marginal effects of gender with statistical significance.

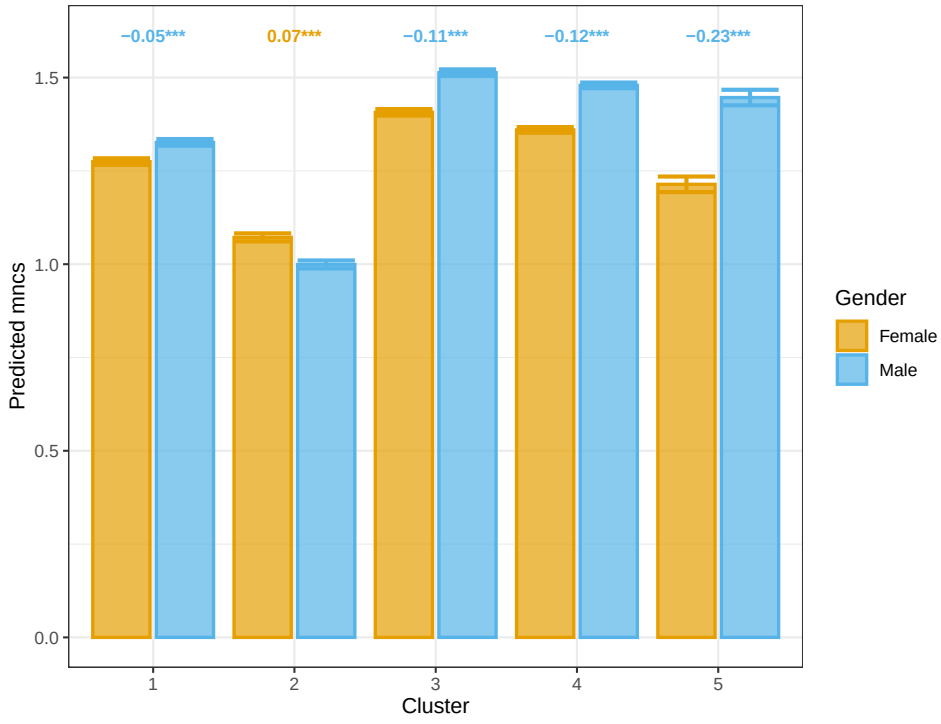

Figure 4: Predicted normalized field citation scores of female and male researchers by trajectory. The numbers on the top show the marginal effects of gender with statistical significance.

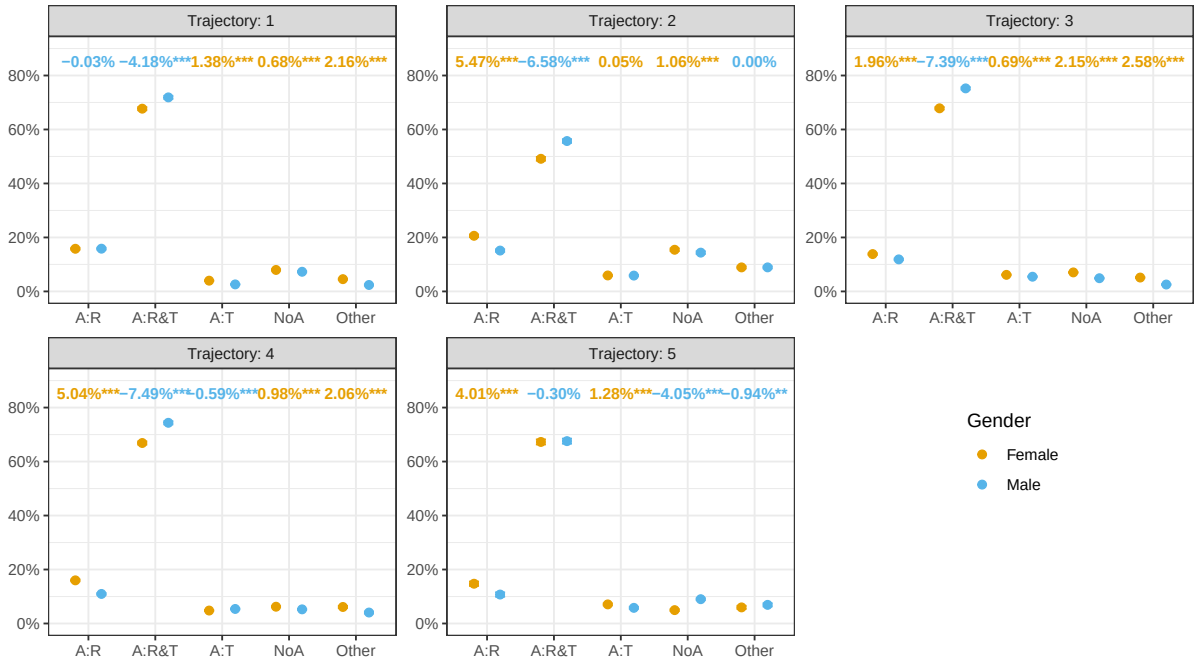

Figure 5: Predicted probabilities of occupation types (Jobs in academia including A:R (research-based position), A:T (teaching-based position), and A:R&T(research and teaching position), jobs out of academia: NoA (e.g., government staff, private company staff) and others including unemployment and retirement) of female and male researchers by trajectory. The numbers on the top show the marginal effects of gender with statistical significance.

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