Simone Bartsch*, Guido Buenstorf**, Anne Otto***, and Maria Theissen****

Are Employment Trajectories of STEM Doctoral Degree Holders Gender-Specific?

Evidence from a Large German Technical University*****

Abstract: Gender balance across different employment sectors is beneficial in order for society to make the best use of its talent pool. However, particularly in the STEM (science, technology, engineering and mathematics) fields, women are underrepresented as researchers and professors in universities and non-university research organizations in Germany. To better understand the career trajectories of doctoral degree holders, we investigate the critical phase of transition into the post-graduation employment context. Based on rich process-generated data for a large German technical university, we explore the relationship of employment sector and employment volume during and after doctoral training. Results of a sequence analysis indicate that the employment trajectories of men and women follow similar patterns, but that the prevalence of individual sequences differs substantially by gender. Our findings suggest substantial path dependence in employment biographies. Regression results show no overall gender-specific difference regarding the post-graduation employment sector when controlling for previous sector-specific work experience and STEM subfields. However, when distinguishing between men, women without children and women with children (mothers), we observe that mothers are more likely to remain in the university sector compared to men. In the years following doctorate completion, both women without children, and women with children are significantly less often full-time employed than are men.

Keywords: Doctoral degree holders; employment biographies; sector mobility; gender differences; motherhood.

* Simone Bartsch, Technical University of Berlin (TUB), Germany, Center for Junior Scholars, Fraunhofer Str. 33-36, Room 503a, 10587 Berlin, E-Mail: simone.bartsch@tu-berlin.de. https://orcid.org/0000-0002-4560-484X; corresponding author.

** Guido Buenstorf, International Center for Higher Education Research (INCHER), University of Kassel, Germany https://orcid.org/0000-0002-2957-5532.

*** Anne Otto, Institute for Employment Research (IAB), Germany https://orcid.org/0000-0003-3563-3206.

**** Maria Theissen, International Center for Higher Education Research (INCHER), University of Kassel, Germany https://orcid.org/0000-0003-4178-8917; Funding from Deutsche Forschungsgemeinschaft, Grant Number BU 2454/8-1 (FOR 5234), is gratefully acknowledged.

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Sind die Erwerbsverläufe von Promovierten aus den MINT-Fächern geschlechtsspezifisch?

Empirische Analyse am Beispiel einer großen deutschen technischen Universität

Zusammenfassung: Um den vorhandenen Talentpool optimal zu nutzen, profitiert die Gesellschaft von einem ausgewogenen Geschlechterverhältnis in den verschiedenen Beschäftigungssektoren. Allerdings sind in Deutschland insbesondere in den MINT-Bereichen (Mathematik, Informatik, Naturwissenschaften, Technik) Frauen als Forscherinnen und Professorinnen an Universitäten sowie außeruniversitären Forschungseinrichtungen unterrepräsentiert. Um die Karrierewege von Promovierten besser zu verstehen, untersuchen wir die kritische Übergangsphase nach der Promotion. Auf der Grundlage umfangreicher prozessgenerierter Daten für eine große deutsche technische Universität untersuchen wir den Zusammenhang zwischen Beschäftigungssektor und Beschäftigungsvolumen während und nach der Promotion. Die Ergebnisse einer Sequenzanalyse deuten darauf hin, dass die Beschäftigungsverläufe von Männern und Frauen ähnlichen Mustern folgen, sich die Prävalenz einzelner Sequenzmuster allerdings deutlich nach Geschlecht unterscheidet. Unsere Ergebnisse deuten auf eine erhebliche Pfadabhängigkeit in den Erwerbsbiografien hin. Die Regressionsergebnisse zeigen keine geschlechtsspezifischen Unterschiede in Bezug auf die Sektorenwahl nach der Promotion, wenn man sektorspezifische Berufserfahrung und Fächerunterschiede berücksichtigt. Wenn wir jedoch zwischen Männern, Frauen ohne Kinder und Frauen mit Kindern (Müttern) unterscheiden, stellen wir fest, dass Frauen mit Kindern im Vergleich zu Männern eher im Hochschulsektor bleiben. Sowohl Frauen ohne Kinder als auch Frauen mit Kindern sind in den Jahren nach Abschluss der Promotion deutlich seltener vollzeitbeschäftigt als Männer.

Stichworte: Promovierte; Erwerbsbiografien; Sektorenmobilität; Geschlechtsunterschiede; Mutterschaft

1. Introduction

In order to make the best use of an economy's pool of talent, and to achieve gender equity as well as to secure innovative solutions for diverse societal problems (see e.g., Tannenbaum et al. 2019, Schiebinger et al. 2011–2021), gender balance in employment across different sectors is beneficial for society. However, STEM (science, technology, engineering, and mathematics) disciplines are often characterized by substantial gender imbalances, e.g., regarding the professorate at German universities (BuWiN 2021). To devise effective policies, it is vital to understand what mechanisms and circumstances can lead to gender-specific differences in observable labor market outcomes such as employment sector and employment volume.

One of the most critical junctures in the careers of doctoral degree holders (DDHs for short) is the phase of transition, after doctoral training, into post-graduation employment. On the one hand, doctoral training may be the initial step of pursuing an academic career. On the other hand, doctoral training can be put to a variety of uses in the labor market. In particular Germany has a long tradition of DDHs being employed in private-sector research and development (R&D), as well as in high-level managerial and administrative positions. Compared to education in the humanities and the social sciences, which primarily provide generic skills, education in STEM fields prepares graduates for entering occupation-specific segments of the labor market (e.g., van Klein 2011).

We use rich data for TU Berlin to explore potential gender-specific patterns in the career trajectories of more than 1,800 STEM DDHs covering a 10-year period starting five years before doctorate completion and running up to five years afterwards. Our dataset was built by refining record linkage techniques developed by Heinisch et al. (2020) while linking administrative information provided by TU Berlin with the Integrated Employment Biographies (IEB) dataset of the Institute for Employment Research (IAB). It covers more than 80 % of the respective TU Berlin graduation cohorts for whom we have detailed data on employment sectors —university, non-university research or other sectors—and also employment volume for the whole period. To control for potential effects of motherhood driving gender differences, we build on Müller/Strauch (2017) to trace women with children in the IEB. Our single-university setting allows us to avoid confounding heterogeneity stemming from variation in university and regional characteristics (as Lee et al. 2010; Jiang 2021).

In our empirical analysis we first employ sequence analyses (Abbott/Tsay 2000) separately for female and male DDHs to detect different clusters of career trajectories, and second we use multivariate regression analyses focusing on the relevance of employment sector (Bornmann/Enders 2004; Bloch et al. 2015) and employment volume during doctoral training for post-graduation employment, given sector-specific acquired work experience. We expect that the employment context during doctoral training shapes job-relevant knowledge acquisition, access to networks, and researcher identity formation processes, that are plausibly connected to career decisions. To investigate potential gender effects, we control for field-specific differences (Cheryan et al. 2017; Eren 2021; Schwerter/Ilg 2021)[1] and motherhood (e.g., van Anders 2004; Schubert/Engelage 2010; Koenig et al. 2021).

1 On the national level, in 2018 women accounted for 42 % of all doctoral students in science and mathematics, compared to 21 % in engineering (BuWiN 2021).

Results of the sequence analysis indicate that employment trajectories can be grouped in quite similar clusters for male and female DDHs. However, the prevalence of these clusters differs substantially by gender, in part reflecting an uneven representation of men and women in STEM subfields. Our findings are moreover suggestive of path dependence in employment biographies, as employment contexts during doctoral training predict post-graduation careers. Regression results indicate that both female DDHs with and without children are significantly less often full-time employed than men. Still, with more than 34 percentage points four years after graduation, the reduction in the full-time employment share of women with children is about four times as sizeable as the one estimated for women without children. Women with children, but not those without, are significantly more likely to remain in the university sector.

Our contribution to the literature is threefold. First, we trace similarities and differences between men and women in the evolution of employment sectors and employment volume over a 10-year period centered around the phase of doctorate completion, a critical juncture for (research) careers (Shauman 2017; Cañibano et al. 2019). To the best of our knowledge, we provide the first gender-specific sequence analyses for DDHs in the STEM fields. Second, we show how employment context during doctoral training relates to post-graduation employment outcomes. This apparent path dependence suggests that addressing gender differences might require balancing employment conditions as early as at the doctoral training stage. Third, we show that process-generated data can be employed to trace the employment trajectories of more than 80 % of the respective DDHs population. This corresponds to an improvement of about 30 percentage points over prior work using a similar approach (Heinisch et al. 2020), which is made feasible by access to university records.

2. Related literature

The transition phase from doctoral training into subsequent employment is decisive for DDHs' career pathways. In Germany, the majority of DDHs leave the university system directly after graduation or in the following few years (Koenig et al. 2021). Especially STEM DDHs have attractive career options in industry (Goldan et al. 2022), but opportunities vary between STEM subfields. While DDHs in engineering traditionally have favorable job prospects in manufacturing, in chemistry a doctorate is required as prerequisite for obtaining any adequate position at all—irrespective of the sector.

What factors shape the transition phase, i.e., continuation or changes in employment sector and/or employment volume after doctorate completion? An extensive body of literature shows that individual preferences (e.g., a "taste for science"; cf. Roach/Sauermann 2010; Noppeney et al. 2021), guidance from doctoral advisors and other mentors (e.g., Cidlinská 2019; Olson et al. 2021) and (perceived) career opportunities under current labor market conditions (e.g., Kinoshita et al. 2020) influence these individual career decisions. There is also some evidence that acquiring work experience in different sectoral employment contexts during doctoral training is associated with these transition patterns (e.g., Denton et al. 2019). Working experience allows DDHs to gain access to career-relevant knowledge and establish social contacts in the workplace (Weiss et al. 2014), and employment contexts during doctoral training also shape researcher identity formation processes.

In our study, we aim to examine the relationship between the employment context during doctoral training and post-graduation employment in STEM DDHs' careers. We focus on the roles of gender and motherhood for this transition phase. To frame our analysis and to conjecture upon potential underlying mechanisms at work, we point out related theories and elicit evidence from prior research, although we do not have detailed data on all potentially relevant factors in the empirical part of this paper. We highlight factors related to the employment context for DDHs' career decisions and illustrate the relevance of employers' hiring decisions to elicit both sides of the labor market. Furthermore, we consider the embeddedness of the overall labor market in the broader structural and cultural context of Germany with respect to parenthood among DDHs.

DDHs' decisions

Regarding employment sector, the university sector is the most common sector of employment during doctoral training, while significantly fewer doctoral students at this stage hold a position in non-university research organizations or in other sectors. Doctoral students obtain work experience, which enables them to acquire job-relevant knowledge, build social contacts and create networks opening new career opportunities. Employers and colleagues likewise may provide useful information on job vacancies for job search (Granovetter 1973; Lent et al. 1994; 2000; Weiss et al. 2014). Goldan et al. (2022) propose that doctoral students may benefit from sector-specific information and networks for their careers while employed at university, thereby enhancing the likelihood for subsequent employment in the same sector. The authors stress that doctoral students working in research organizations and other sectors may have similar advantages in their sectors. In addition, vicarious learning from role models, based on personal interactions with mentors, peers, and colleagues, as pointed out by social-cognitive theory (Bandura 1986), contributes to the emergence of vocational interests, goals, and career decisions. As these personal interactions are embedded in a sectoral context during the doctorate, they may reinforce sectoral persistence in post-graduation employment. Prior research confirms that integration into the respective scientific community via social contacts and network access is important for increasing DDHs' propensity for remaining employed in either the university or the non-university research sector following graduation (Jungbauer-Gans/Gross 2016; Jaksztat et al. 2017; Langfeldt/Mischau 2018).

Employment volume[2] differences within the same sector and discipline[3] may also impact knowledge acquisition and network access. Weiss/Klein (2011) and Robert/Saar (2012) highlight that the type of job might be important for the quality of acquired knowledge and contacts while working. If employment volume differences translate into different tasks e.g., within the academic sectors, or differences in teaching activities or embeddedness in administrative processes in the respective institution, this entails factual differences in the type of accumulated work experience. Despite substantial variation in idiosyncratic arrangements with advisors, prior evidence nonetheless indicates that tasks performed during doctoral training are shaped by employment volume. For Germany, full-time employed doctoral candidates within the National Academic Panel Study (Nacaps 2020) report having less time to work on their dissertation projects compared to their part-time employed peers.[4] Additional teaching tasks imply less time for research and may delay completion of the doctorate (Maher et al. 2004). At the same time, being employed full-time at the university is shown to be related to a stronger sense of belonging (Ryan et al. 2019) to the respective community, thus indicating more reliable contacts which may motivate DDHs to remain in the same sector.

Sense of belonging is a key factor in developing a solid self-conception as being a researcher (Caza et al. 2018; Eren 2021)—a researcher identity. Being a 'proper' STEM scientist is often associated with publications in prestigious journals, a strong h-index, international experience, high success rate in grant competitions (Cidlinská 2019), and accordingly requires extreme personal commitment. An individual's identity, as argued by identity theory, depends on the external roles the individual holds and on related expectations (Caza et al. 2018). Identities are internal, comprising internalized meanings, perceptions and expectations associated with the roles held by the individual (Gaunt/Scott 2017). In line with numerous studies proposing that identity is socially constructed (Castelló et al. 2021), we consider identity formation during doctoral training (Bentley et al. 2019) as an ongoing process embedded in organizational structures and shaped by personal experiences and social interactions with mentors, peers, and others. Regarding female DDHs, researcher identity formation processes can be hampered by masculine culture in the workplace and by gender stereotyping, as well as by role conflicts (most prominently related to parenthood; later in this section) (e.g., Cheryan et al. 2017; Master/Meltzoff 2020; Cidlinská et al. 2022).

2 In our sample for the analysis (see section 3), the percentage of female DDHs with a full-time (part-time) position one year before graduation is 31.5 (37.9) and remarkably lower compared to the corresponding share for their male peers with 55.1 (24.7).

3 Moreover, the recommendations of the *Deutsche Forschungsgemeinschaft* (DFG) regarding adequate payment of doctoral candidates varies among STEM subfields (https://www.dfg.de/formulare/55_02/55_02_de.pdf; last access 13 Oct 2022).

4 Own calculations based on the SUF (doi: 10.21249/DZHW:nac2018:1.0.0).

Employer decisions

Employers' preferences for job candidates of a certain gender might contribute to an increased likelihood that female and male STEM DDHs are concentrated in distinct labor market segments (employment sectors and types) following the achievement. The dominant economic approaches of taste-based discrimination (Becker 1957) and statistical discrimination (Arrow 1973; Phelps 1972) explain gender bias in recruiting with, respectively, subjective (dis)likings or the formation of expectations based on objective (e.g., sex, age, education, work-experience, parenthood) and subjective elements, to mitigate imperfect information about the relative productivity of the candidate. Employers' expectations regarding average gender differences thus translate into tendencies to discriminate. But according to critics of these approaches, this occurs regardless of time and social context (Keuschnigg/Wolbring 2016). Yet, recent literature stresses the role of the specific organizational context in which such discrimination evolves (e.g., Reskin 2003). Bertogg et al. (2020) show that discrimination is highly contextual on different levels (e.g., recruiter, firm, country) and depends on occupational characteristics, especially varying degrees of gender stereotyping associated with specific STEM occupations (Yavorsky 2019). In line with this, Kübler et al. (2018) find that discrimination against women is most pronounced in male-dominated STEM occupations.

From a sociological perspective, Ridgeway's (1997, 2011) theoretical work suggests that the assessment of an applicant's productivity is based on (implicit) gender status beliefs which often ascribe a higher social status to men such that they are believed to perform better and to deserve higher rewards (e.g., Rashotte/Webster 2005). Despite modern norms of gender equity, these beliefs have proven to be quite persistent. Unintentional recruiting bias, with men being perceived to have stronger competences, is corroborated by studies for STEM both in the private sector (e.g., Hill et al. 2010) and in the academic sector (e.g., Moss-Racusin et al. 2013). Recruiting practices of STEM faculty members were found to be implicitly biased when looking for new lab managers (Moss-Racusin et al. 2012), and scientific papers were shown to be evaluated as having higher quality when attributed to a male author (Knobloch-Westerwick et al. 2013).

Gender-specific parental roles in Germany

Overall, the individual career decisions of DDHs as well as employers' hiring practices are embedded in larger structural and cultural contexts (Nielsen 2017; Cañibano et al. 2019; McAlpine et al. 2021). External limiting factors such as insufficient childcare infrastructure, inflexible working hours and gender-specific parental roles (Schubert/Engelage 2011; Jaksztat et al. 2012) among others can contribute to gender-specific labor market outcomes among parents, especially regarding employment volume. Regarding sector choice, female DDHs with children, who seek part-time positions, may end up in different types of jobs than their male peers, as not all jobs are available for reduced employment volumes (Shauman 2017).

Not every woman has children before or directly after doctorate completion (Buenstorf et al. forthcoming), and both, mothers and fathers, need family-friendly environments. However, compared to their male peers, female DDHs are typically more challenged to integrate their roles of being both a researcher and a mother or being both a researcher and a woman in childbearing age with or without childbearing preferences (Schubert/Engelage 2010; Bentley et al. 2019; Cidlinská et al. 2022). Universities do not address parenthood in a gender-neutral way, but primarily consider supporting mothers via childcare provision (Bomert/Leinfellner 2017). This does not affect the academic working culture and/or induce any change to re-define the existing working culture in general (e.g., Nielsen 2017; Miner et al. 2018). An academic career is a prime example of a job with a culture of long hours, which also entails traveling and mobility requirements, putting stress on dual-career couples in general and even more so on parents (Grönlund 2020; Czerney et al. 2020). Even within STEM fields in academia, mothers are more likely to interrupt their employment and/or reduce working hours than are fathers (Langfeldt/Mischau 2018).

The considerations above guide our empirical analysis and help us form expectations regarding empirical patterns. We first expect a substantial degree of sectoral path dependence in DDHs' post-graduation choice of employment sectors due to prior access to sector-specific knowledge and networks as well as employers' attempts to reduce uncertainty regarding the fit of the potential new employee. Second, we expect that female researchers are less likely to remain in the academic sector if they were exposed to a male-dominated environment during doctoral training, hampering the development of a solid researcher identity. As female shares vary substantially across STEM subfields, e.g., electrical engineering versus bio-/food technology, we control for these discipline-specific effects. Third, we expect that female DDHs with children are more likely to be part-time employed. Role conflict is present regardless of the employment sector but given the highly competitive post-doctoral phase in pursuing an academic career, we would expect a shift towards the other sectors for many mothers in line with the 'leaky pipeline' phenomenon (e.g., Nielsen 2017). Those women remaining successfully in academia despite motherhood are more positively selected compared to their male peers (Kim/Moser 2022). We therefore differentiate between women with and without children (mothers). Neither fathers nor childless women who intend to become pregnant soon can be identified in our data.

3. Data and analytical strategy

3.1 Data and construction of the sample

For our analysis of STEM DDHs career trajectories, we employ the TU Berlin Panel of PhD graduates (TUBPP). TUBPP is an original dataset that links process-based information on doctoral holders from TU Berlin with the Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB). The linked dataset allows us to trace the entire employment biography of the respective individuals, including all spells available in German social security records before, during and after doctoral training. In this regard, TUBPP is similar to IIPED (IAB INCHER Panel of Earned Doctorates) which covers DDHs from all German universities (Heinisch et al. 2020). IIPED links the IEB with information about dissertations and their authors from the online catalog of the German National Library (Deutsche Nationalbibliothek). As it is based on richer administrative data, TUBPP is superior to IIPED in terms of the share of DDHs that could be matched to IEB entries.

With about 35,000 students in winter term 2020/21 (Destatis 2021) and about 400 PhD graduates in 2020 (Bartsch 2022), TU Berlin is one of the largest of Germany's technical universities, which traditionally have focused on STEM subjects and tend to be more open to university-industry collaboration than other research universities. TU Berlin is a member of TU9, a network of the nine leading technical universities in Germany. Presumably, potential doctoral students in STEM fields compare TU Berlin primarily with these other leading technical universities when choosing an adequate university. Since all TU9 are located in thick urban labor markets, STEM DDHs face rather similar conditions for their subsequent careers after completing their doctoral degrees. Hence, selection of doctoral students among TU Berlin and the other universities within the agglomeration of Berlin appears to be of less concern. However, from the perspective of our study, TU Berlin provides a particularly interesting empirical context as Berlin has the highest female share in STEM-related occupations of all German states (*Länder)*: 21.3 % compared to 15.7 % in Bavaria or 13.5 % in North Rhine-Westphalia, where comparable universities such as TU Munich, RWTH Aachen and TU Dortmund are located (Anger et al. 2021).

We obtained administrative data covering all 9,094 DDHs who obtained their doctoral degree from TU Berlin in the years 2000 to 2020. The data encompasses individual information (e.g., date of birth, gender, nationality) as well as information on doctoral training such as subject, date of certification, final grade, and duration of doctoral training.[5] We linked this dataset to the Integrated Employment Biographies (IEB) of the Institute for Employment Research (IAB), which is based

5 As information on the duration of the doctorate is only available for approx. 73 % of the DDHs of the TUB, we do not use this information in the analyses.

on employers' social insurance reports and process-generated data from the Federal Employment Agency.

The IEB data goes back to 1975 (1993 for Eastern Germany). They contain detailed information on the employment histories of all employed individuals subject to social insurance, as well as on the marginally employed (i.e., people with temporary and occasional part-time jobs with a limited number of working hours, which are subject to specific regulations in terms of taxation and social insurance payments), benefit recipients, jobseekers, unemployed individuals, and participants in active labor market policy programs. In the IEB, daily information is available on the start and end dates of the 'spells in employment' histories (e.g., employment/unemployment phases, participation in measures). The IEB data additionally comprise a set of individual characteristics (e.g., gender, nationality) for every worker, as well as job characteristics (e.g., type of employment, occupation, industry affiliation, region of workplace) (Antoni et al. 2019). The IEB cover about 80 % of the labor force in Germany (employment abroad is not captured). Self-employed individuals, civil servants, and doctoral students exclusively financed by scholarships (without compulsory social insurance) are not contained in the data. Self-employment is widespread among graduates in medicine, law, and business disciplines. In our STEM data, self-employment is of lesser relevance, except for smaller STEM subfields such as construction and planning. Note also that founders of research-oriented university spin-offs often remain in the social security system, in this case they are included in the IEB. One might be concerned regarding the exclusion of civil servants because most university professors in Germany are civil servants. However, as only a small share of DDHs holds (junior) professorships within the timeframe of our analysis (up to five years after completion of doctoral training) (GWK 2020), this data limitation appears of minor relevance for our study. The same applies to lectureships (*Akademische Räte*), which are (mostly permanent) positions with civil servant status. Moreover, no new positions of this type have been established at TU Berlin since 2000.

To combine the TU Berlin data with the IEB, we performed a systematic record linkage using a set of individual identifiers (e.g., first- and lastname, date of birth, sex, nationality).[6] These identifiers are available in both underlying datasets. Out of the 9,094 DDHs included in the TU Berlin data, 84.5 % could be successfully matched to the IEB. For graduates with multiple corresponding entries in the IEB, we additionally checked for university employment spells in Berlin prior to doctorate completion. While matching quotas of male and female DDHs are rather similar (85.4 % and 82.6 % respectively), the considerably lower percentage for DDHs

6 The Data and Information Management Department of the IAB conducted the record linkage ensuring social data protection. This department only keeps the confidential data used (e.g., name) for this linkage method. Researchers do not have any access. The TUBPP comprises an anonymized system-independent individual identifier for each DDH, which is only accessible on secured data machines at IAB.

with a foreign citizenship (68.5 %) probably indicates their greater propensity to exit the German labor market (due to return migration).

For our empirical analysis, we use data on STEM graduates who obtained their doctoral degrees from 2004 to 2013. The cohorts 2000–2003 are excluded due to missing birthdate information for a significant proportion of DDHs implying considerably lower matching quotas.[7] To achieve a more homogeneous sample, we imposed the following criteria: Inclusion of individuals older than 20 and younger than 40 years at graduation. Most DDHs who complete their doctoral training within this age range go on to subsequent early career stages (BuWiN 2021). Moreover, we exclude DDHs with fewer than two recorded spells in the IEB. The final sample includes 2,513 individuals, of whom 607 (24.2 %) are female and the remaining 1,906 (75.8 %) are male. More than two-thirds (69.8 %) of the included DDHs graduated in engineering (including computer sciences); DDHs from the sciences (including mathematics) account for 30.2 % of the sample. The share of female graduates varies noticeably across the individual engineering fields: from 9.5 % in electrical engineering to 48.8 % in bio- and food technology. For computer sciences, the female share is 14.6 %. The overall share of women in the sciences is 28.9 %, with food chemistry having the highest share (66 %) and physics the lowest share (17.5 %) of female DDHs. Overall, the shares of women are very similar to the shares for Germany in the same period (DZHW 2022; Table A-1).

3.2 Analytical strategy[8]

In the first part of our empirical analysis, we employ sequence analyses to detect typical career paths during and after doctoral training separately for male and female DDHs. A sequence analysis first performs a distance analysis across all sequences and then a cluster analysis of these distances. Technically, distance measurement employs an optimal matching procedure of the different sequences (Abbott/Tsay 2000; Lesnard 2014). The subsequent cluster analysis of these distance measures is based on Ward's algorithm minimizing the within-cluster variance (Ward 1963). Since there are no established reference values for clustering, the number of clusters in this study is determined by sufficient case numbers and the analytical power of the identified groups (Brzinsky-Fay 2007). We define ten possible employment states a DDH may have. In doing so, we differentiate between three sectors of employment: 'university' refers to jobs at regular universities and universities of applied sciences, 'research' encompasses employment in non-univer-

7 For earlier cohorts, the matching quota ranges from 68.6 % (2003) to 74.5 % (2001) while on average this share amounts to 85.6 % for the cohorts 2004 to 2013. These matching quotas refer to all DDHs at the TU Berlin.

8 The Stata do-file used for our analyses is available via the DZHW Research Data Centre: https://doi.org/10.21249/DZHW:bartsch2023:1.0.0

sity public and private research organizations[9], whereas ‘other sectors’ include the private sector[10] and the non-academic public sector. The first six states correspond to full- and part-time employment in one of these three sectors respectively. Three additional states are ‘marginal’ employment, vocational training, and unemployment/job search. Finally, an individual may not have been listed in the IEB at a given point in time, or no further spell information may be available for them. This indicates that the respective person is neither unemployed nor employed, thus being not subject to social insurance.

In the second part of our study, we apply regression analysis to investigate the effects of work experience obtained within a specific employment context during doctoral training on post-graduation employment patterns as well as potential gender-specific effects controlling for STEM subfields and motherhood. Here, we concentrate on DDHs’ labor market outcomes two (t+2) and four (t+4) years after obtaining the doctorate. While we rely on the entire sample (N=2,513) in the sequence analysis, including missing information, we excluded DDHs with missing information regarding their employment states for the regression analysis. The IEB data do not comprise information on marital status and household composition. Müller/Strauch (2017) developed a workaround to deduce birth information for children based on social security notifications if women interrupt their employment for maternity leave. We follow their approach adjusting this procedure slightly to our specific dataset to calculate the expected date of birth if a woman (aged up to 37 years) leaves the labor market for at least 14 weeks (duration of German maternity protection period, Mutterschutzgesetz) before re-entering. We impose a one-year period between two births. Overall, the number of children is slightly underestimated as multiple births are counted as only one child and as births can only be detected during employment subject to social security contributions. To date it is not possible to reliably deduce fatherhood information based on the IEB data, as by far not all fathers take parental leave in Germany.

Using this procedure, we identify those female DDHs who have not had children by the fifth year after doctorate completion, which constitutes the end of our observation period. Likewise, we differentiate female DDHs who become mothers within two, and respectively four years of graduation (women with children in t+2; women with children in t+4). Of all 422 female DDHs in the sample used for the regression analysis on full-time employment, 22.0 % are women with children in (t+2) and 34.7 % are women with children in (t+4) indicating many birth events

9 We subsume in the employment sector ‘research’ all employers assigned to research activities in the NACE (Rev.2)-Classification of Economic Activities (codes 72.110, 72.190, 72.200). Non-university public research organizations comprise, for instance, research institutes of the Helmholtz Association and Max Planck Society, which conduct research activities including basic and applied research as well as support for industrial development. Private research organizations mainly provide research infrastructure and support to industrial development.

10 However, we cannot identify in-house research activities of private sector firms.

happening in the very first years after doctorate completion.[11] As our main contextual explanatory variables for employment context during doctoral training we include both prior work experience in the employment sectors 'university', 'research' and 'other sectors' as well as acquired work experience in full-/part-time or marginal employment positions. Work experience is operationalized by adding up the days of all respective employment episodes. While differentiating employment sectors, we cumulate all spells in full-/part-time or marginal employment in the respective sector. For work experience in full-time, part-time, and marginal employment positions we vice versa cumulate days in jobs with the respective employment volume across sectors. Furthermore, an indicator variable denotes all DDHs who completed vocational training before having completed their doctoral degree as this may be relevant for later employers, signaling earlier work experiences in a specific industry. In addition to these main explanatory variables, we incorporate age (at graduation date) which employers might use for anticipation-building regarding potential child-related employment interruptions or reductions, foreign citizenship as proxy for potential language issues if a DDH obtained the doctorate within a solely English-speaking work environment, and data-matching quality (an indicator variable denoting whether the IEB contained more than one potential entry to which the DDHs could have been merged) as further control variables (see Table A-4 for variable definitions).

4. Typical career patterns of female and male STEM DDHs

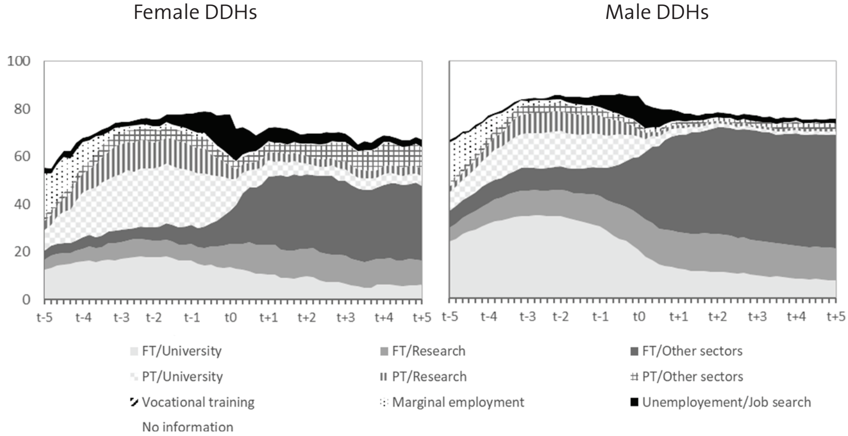
We use a sequence analysis (Abbott/Tsay 2000) to identify typical career trajectories of female and male STEM DDHs in the five-year periods during/after doctoral training. These five-year periods were mainly chosen due to an administrative regulation that TU Berlin adopted in 1992.[12] It states that doctoral and postdoctoral researchers paid from the university's own budget may only be employed full-time and for a period of five years. In 2008, the provision was adjusted to allow part-time and shorter contracts under certain conditions. As this regulation does not apply to third-party funded positions, we nonetheless observe part-time employment in our sample. We center the sequence analysis on the date of graduation, t0, and map employment states bimonthly. We identified eight typical career patterns (clusters) separately for male and female DDHs.

Figure 1 shows the overall distribution of female and male DDHs across the possible states in the five-year period before and after the date of graduation (observation point t0), and Figure 2 shows this by gender for the respective clusters. The average duration (in months) in one of the states is reported in Table A-2

11 The corresponding shares of mothers among female DDHs for the regression analyses on employment sector are 22.0 % in (t+2) and 35.3 % in (t+4).

12 Our choice of five-year periods before and after completing the doctorate implies that observed career trajectories are not directly affected by the time limits defined by the *Wissenschaftszeitvertragsgesetz*.

Figure 1: Overall distribution of STEM DDHs across ten potential labor market states, in percent



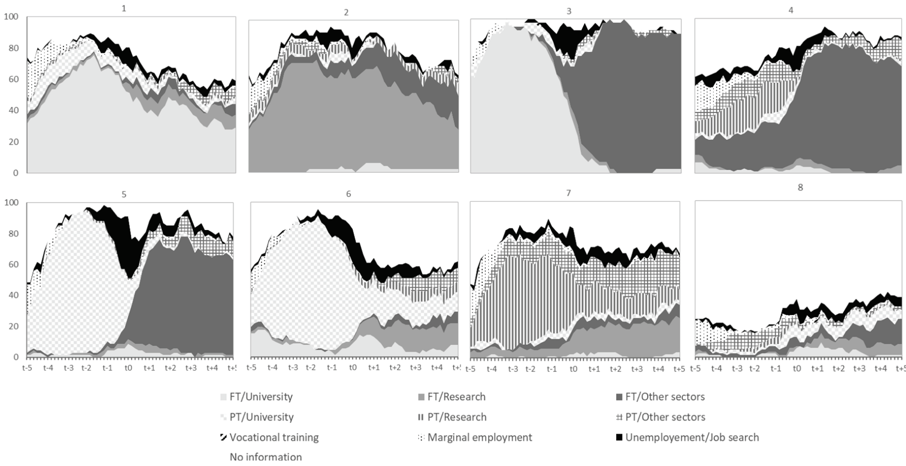
Note: FT denotes full-time employment; PT denotes part-time employment. t0: date of graduation. t-1/t+1: point of observation one year before/after graduation.
Source: TUBPP.

and the characteristics of the clusters in Table A-3. In line with extant evidence (Bloch et al. 2015; BuWiN 2021), unemployment is of minor importance for DDHs in our dataset. During the five years before (after) graduation, they are on average unemployed for 1.9 (2.1) months. Yet, the greatest average length with 16.0 months is full-time university employment during doctoral training, which can be explained by the aforementioned administrative regulation that TU Berlin adopted in 1992.

Before and after graduation, female DDHs are full-time-employed for less time than their male peers. This difference in employment volume is statistically significant for other sectors and also for university. During doctoral training, women work on average 9.5 months in full-time jobs at university, but men work considerably longer with 18.3 months. Conversely, female DDHs work significantly longer part-time at university than do men in this period (12.0 versus 7.5 months). This discrepancy is also true for the other two sectors before doctorate completion. Regarding employment sector, we do not find substantial differences between male and female DDHs, but a difference between pre- and post-graduation with a greater relevance of longer employment episodes in other (non-academic) sectors after graduation. For unemployment and marginal employment, we only observe a significant difference for the latter employment status after doctoral training.

Employing the sequence analysis separately for men and women allows us to identify both similarities and disparities in the career trajectories of men and women. The first four sequence patterns in Figure 2 are very similar for women and men. Cluster 1 depicts typical university careers with a high share of full-time employment at university before and after doctoral training. Cluster 2 mainly shows full-time careers in non-university research organizations. Cluster 3 includes career pathways that start from full-time university employment during doctoral training, followed by post-graduation employment in other sectors. Cluster 4 also illustrates similar career paths for both female and male DDHs. It shows predominant full-time employment outside university and research after graduation, but mixed employment patterns and a higher share of part-time employment during doctoral training. In this cluster, we find a particularly high share of graduates from bio- and food technology, the subject with the highest share of women in the sample (Table A-3).

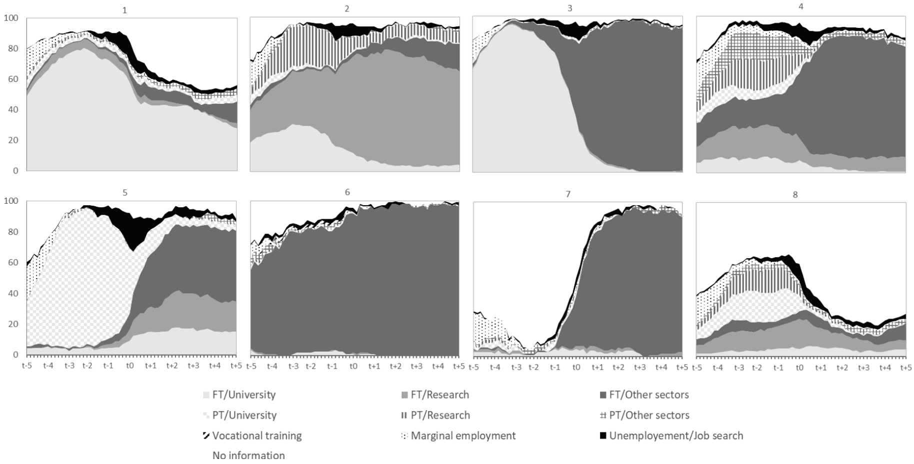
Figure 2: Typical career patterns of female STEM DDHs, distribution of all persons in the cluster across the possible states, in percent



Note: FT denotes full-time employment; PT denotes part-time employment. t0: date of graduation. t-1/t+1: point of observation one year before/after graduation.
Source: TUBPP.

Between them, Clusters 1–4 cover 46 % of the women and 61 % of the men in the sample. Cluster 3, with a change from university to other sectors after the doctorate is by far the 'biggest' cluster for men (and the 'smallest' for women). Cluster 4, which includes part-time and rather mixed employment during doctoral training as compared to the other three clusters, is the biggest cluster for female DDHs. In Clusters 1–3, full-time employment is predominant before and after graduation. Regarding subjects, we find average to high shares of engineers in all three clusters, with the highest share of them in Cluster 3 and especially high shares of computer scientists (Clusters 1 and 3), electrical engineering (Cluster 2), and mechanical

Figure 3: Typical career patterns of male STEM DDHs, distribution of all persons in the cluster across the possible states, in percent



Note: FT denotes full-time employment; PT denotes part-time employment. t0: date of graduation. t-1/t+1: point of observation one year before/after graduation.
Source: TUBPP.

engineering (Cluster 3). Considering that women are underrepresented in these subjects, it comes as no surprise that although these three clusters mark careers of both male and female DDHs, only 29 % of all women are concentrated within these three clusters, compared to 49 % of all men. Women in these male-dominated subjects appear to follow career patterns similar to those of their male colleagues.

In Cluster 5 most female and male DDHs originate from sciences and mathematics and work part-time at university during doctoral training. After graduation, the pattern looks different for men and women: While in the female cluster, full-time employment in other sectors is predominant, a substantial proportion of men remain at universities and in non-university research organizations. Cluster 5 is also the cluster with the lowest share of childless women and the highest share of women with children (t+4).

For women, Clusters 6–8 are characterized by mixed patterns regarding employment sector, part-/full-time employment and lacking information following doctorate completion. Cluster 6 is marked by a high share of science and mathematics DDHs as well as a high share of part-time university employment during doctoral training. In this cluster, we find the highest share of women with children at the time of doctorate completion. In Cluster 7, which is characterized by a high share of biotechnologists, most women are part-time employed at non-university research organizations during doctoral training. Cluster 8 encompasses many episodes for which information is lacking. Since the share of DDHs with foreign citizenship is highest in this cluster, the lack of information might be due to the funding of doctoral training through scholarships and subsequent employment abroad.

For men, Clusters 6–8 also show quite different patterns: Cluster 6 comprises mainly typical industrial DDHs whose careers take place outside university and public research, having already begun during their doctoral training. In Cluster 7, no information is available on employment status during doctoral training, making it likely that many scholarship-holders are concentrated in this cluster who later enter employment outside university and research institutions. Cluster 8, similar to those for female DDHs, comprises great swathes of sequences with no information indicating that many DDHs might be employed abroad, are self-employed or civil servants. The share of DDHs with foreign citizenship is also highest here.

Taken together, these patterns suggest a path-dependence regarding post-graduation employment at universities and research institutes (Clusters 1 and 2) in line with our conjecture that sector-specific work experiences during doctoral training influence post-graduation employment choices. This seems to be especially true for the academic sector, as there are no clusters that combine non-academic employment before graduation with subsequent employment at universities or public research institutes. As noted above, fewer women than men pursue academic careers after completing their doctorate. This may reflect subject choices but might also hint at a possible effect of women already having lower shares of employment at universities and research institutes during doctoral training. Our sequence analysis moreover finds that women with children concentrate on particular – relatively unstable – career paths, whereas women without children follow more diverse career trajectories that are more like those of men. These differences between women with and without children are plausibly related to role conflicts that mothers face.

5. Labor market outcomes of female and male STEM DDHs

In this section, we investigate potential gender differences in DDHs' labor market outcomes in the second and fourth year following doctorate completion. To isolate differences related to motherhood, we differentiate between three groups of DDHs: male DDHs, female DDHs with children below the age of 18 years (at the point in time when the labor market indicator is measured) and women without children (women for whom no children below the age of 18 are observed by the fifth year after graduation). We focus on the employment sector that DDHs enter after graduation and whether they take up a full-time position.[13] We first provide descriptive evidence on post-graduation employment sector and volume for male and female

13 We consider as other employment states here also 'No information', but only if there is still an entry for a given point in time in the IEB. In the sequence analysis, we also report no information for a given point in time when there is no entry in the IEB (see Section 3). Note that the sample for sector employment comprises DDHs with a part-/full-time employment spell two or four years after graduation.

DDHs (with and without children). Second, we employ regression analyses to identify which factors help explain gender-specific differences in labor market outcomes. Note that the sample for investigating employment sectors comprises only DDHs with part-/full-time employment spells after graduation, whereas the sample used to analyze employment volume includes all employment states reported in the TUBPP.

5.1 Descriptive analysis

Table 1 shows shares of male DDHs, female DDHs without children and female DDHs with children by employment sector and volume two (t+2) and four years (t+4) after graduation. Holding a position in the university sector after graduating is observed more often for childless female DDHs, 19.5 % in (t+2) and 16.2 % in (t+4), compared to male DDHs with 17.0 % in (t+2) and 13.0 % in (t+4). Notably, these shares are even higher among women with children. A comparable pattern is found for the non-university research sector; here men appear slightly more frequently than women without children, but again women with children show higher shares than both men and women without children. Accordingly, women with children are less often employed in other (non-academic) sectors (54.6 % in (t+4); compared to 65.5 % for women without children and 66.9 % for men).

Full-time post-graduation employment exhibits remarkably large gender differences. Whereas nine out of ten male DDHs hold a full-time position two and four years after graduating, the same holds true for only eight out of ten women without children. As expected, full-time employment is least often observed among women with children (51.4 % in t+4).

Table 1: Employment shares of DDHs in sectors two (t+2) and four (t+4) years after doctoral training, in percent

	Employment Sector	Men	All Women	Women without children	Women with children
t+2	Other Sectors	60.4	55.4	59.3	43.7
	University	17.0	21.5	19.5	29.9
	Research	22.7	23.0	21.2	26.4
t+4	Other Sectors	66.9	61.2	65.5	54.6
	University	13.0	17.0	16.2	20.6
	Research	20.1	21.8	18.3	24.8
t+2	Full-time employment	91.1	75.8	78.5	58.1
t+4	Full-time employment	90.6	69.4	78.6	51.4

Note: Employment: part-/full-time employment.
Source: TUBPP.

5.2 Regression analyses

Results of multinomial logit regressions regarding the likelihood of being employed in the university sector, at non-university research organizations or in other sectors (our reference group) are reported in Table 2. Table 3 summarizes the results of binary logit regressions on having a full-time position compared to all other employment volumes. Both tables include two models, where we differentiate between female and male DDHs in Models (1), and further differentiate the female DDHs into women with and without children in Models (2). We report average marginal effects in both tables. We found that results are very similar between the two points in time (t+2) and (t+4). Therefore, we concentrate our discussion on results for (t+4); results for (t+2) are found in Table A-5 und Table A-6 in the appendix.[14]

Employment sectors

Four years after graduation we find, compared to their male peers, no significantly higher likelihood for female DDHs to be employed at a university (Model (1) in Table 2). Estimation results for Model (2) show that the gender difference remains insignificant for female DDHs without children. In contrast, women with children are on average 7.3 percentage points (significant at the 5 % level) more likely to work at a university than men. For post-graduation employment in non-university research organizations, neither model yields significant gender differences.

We also find pronounced relationships between STEM subfields and subsequent employment sectors. DDHs in mechanical engineering are most likely to be employed outside academia. In electrical engineering and mechanics/flow research/transportation, DDHs are less likely to work in the university sector compared to other sectors.[15] In addition, our results indicate that the employment context during doctoral training is systematically related to subsequent employment sectors. Specifically, each additional 100 days of work experience in the university sector increases the probability of remaining in this sector (versus other sectors) by 0.4 percentage points (significant at the 5 % level). Work experience acquired in non-university research organizations during doctoral training is even more strongly associated with the likelihood of remaining in that sector (1.4 percentage points for each 100 days; significant at the 1 % level), whereas work experience in other sectors reduces the likelihood of post-graduation university employment by 1.0 percentage point for each 100 days (significant at the 1 % level). These patterns are in line with the career trajectories illustrated by the sequence analysis in section 4 and

14 Regressions for (t+1), (t+3) and (t+5) yielded very similar results. Results are available upon request.

15 If we add interaction terms between STEM subfields and the female dummy in Model (1), only one of them is significantly different from zero, and point estimates are not suggestive of a systematic relationship between female shares in STEM subfields (which might proxy for gender stereotyping) and individual career choices.

our expectations based on related research. They suggest that DDHs' careers are path-dependent in the sense that sector-specific work experience during doctoral training increases the likelihood of post-graduation employment in the same sector. Sector-specific work experiences acquired prior to doctoral training do not show significant effects. In an additional analysis[16], we integrated interaction-terms between gender and sector-specific work-experience to detect whether the employment context during doctoral training has different effects for men, women with and without children. Yet, the regression results are in most cases insignificant and therefore do not confirm this expectation.

Employment volume

Table 3 summarizes estimation results on factors associated with the likelihood of full-time employment four years after graduation. In Model (1) we find that female DDHs are 13.9 percentage points (significant at the 1 % level) less likely to hold a full-time position than their male peers. This gender difference in employment volume is even more pronounced when we differentiate between female DDHs with and without children in Model (2). Women with children are 34.4 percentage points (significant at the 1 % level) less likely than male DDHs to be full-time employed. With 8.4 percentage points (again significant at the 1 % level), this difference is considerably smaller but still appreciable for female DDHs without children. Associations between STEM subfields and employment volume after doctoral training are less pronounced than those obtained for employment sectors. A doctoral degree in mechanical engineering is associated with a higher probability of full-time employment relative to a degree in science, whereas fewer DDHs in civil engineering/geotechnology hold full-time positions after graduation.

Similar to post-graduation employment sectors, we moreover find some indication of path dependence with respect to employment volume during and after doctoral training. Extending full-time employment during doctoral training by 100 days increases the likelihood of holding a full-time position four years after graduation by 0.5 percentage points (significant at the 1 % level). In addition, Model (1) suggests that part-time work experience before doctoral training may be associated with a lower probability of subsequent full-time employment. The respective estimate is only marginally significant, however, and not robust to the differentiation between women with and without children in Model (2). We also ran additional analyses[17] with interaction-terms between gender and work experience in jobs with different employment volumes to detect whether effects vary among men, women with and without children. This was not the case.

Taken together, in line with our expectations from related research, we observe that employment contexts during doctoral training, with respect to employment

16 Results are available from the authors upon request.

17 Results are available from the authors upon request.

sector and employment volume, are related to post-graduation employment patterns. Contrary to our expectations, female DDHs with children are more likely to remain in the university sector compared to male DDHs, and female DDHs without children are also less likely to be full-time employed compared to their male peers.

Table 2: Multinominial logit regressions of sector employment four years after doctoral training (t+4), average marginal effects

	Model 1		Model 2	
Variables	t+4		t+4	
ref.: Other sectors	Uni	Research	Uni	Research
Gender (ref.: Men)				
Women	0.030	0.008		
	(0.019)	(0.023)		
Motherhood (ref.: Men)				
Women with children			0.073**	0.043
			(0.035)	(0.037)
Women without children			0.016	-0.025
			(0.025)	(0.027)
Nationality (ref.: German)				
Foreign	0.057***	-0.011	0.061***	-0.008
	(0.022)	(0.026)	(0.022)	(0.027)
Age, date of certification	0.009***	0.007*	0.009***	0.006*
	(0.003)	(0.004)	(0.003)	(0.004)
Data matching quality (ref.: No)				
Yes	0.034	-0.018	0.037	-0.017
	(0.041)	(0.056)	(0.041)	(0.055)
Subjects (ref.: Science)				
Energy/Process/Environ. engineering, Materials Sc.	-0.073**	0.026	-0.074**	0.022
	(0.029)	(0.030)	(0.029)	(0.030)
Bio-/Food technology	-0.067*	0.034	-0.069*	0.025
	(0.036)	(0.033)	(0.037)	(0.034)
Electrical engineering	-0.090***	-0.019	-0.093***	-0.021
	(0.034)	(0.035)	(0.034)	(0.035)
Computer Sc.	0.020	-0.096**	0.016	-0.096**
	(0.025)	(0.039)	(0.026)	(0.038)
Mechanics, Flow research, Transportation	-0.112***	0.007	-0.114***	0.005
	(0.032)	(0.033)	(0.032)	(0.033)

	Model 1		Model 2	
Variables	t+4		t+4	
Mechanical engineering	-0.135***	-0.112***	-0.137***	-0.113***
	(0.039)	(0.041)	(0.039)	(0.041)
Civil engineering, Geotech.	-0.001	-0.046	-0.006	-0.050
	(0.026)	(0.032)	(0.026)	(0.033)
Vocational training (ref.: No)				
Yes	-0.044	-0.000	-0.042	0.001
	(0.035)	(0.037)	(0.035)	(0.037)
Before doctoral training				
WE Uni in 100 days	0.002	-0.003	0.002	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)
WE Research in 100 days	0.000	-0.001	0.000	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)
WE Other Sectors in 100 days	-0.000	-0.002	-0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
During doctoral training				
WE Uni in 100 days	0.004**	0.000	0.004**	0.000
	(0.002)	(0.002)	(0.002)	(0.002)
WE Research in 100 days	-0.002	0.014***	-0.002	0.014***
	(0.002)	(0.002)	(0.002)	(0.002)
WE Other Sectors in 100 days	-0.010***	-0.004	-0.010***	-0.004
	(0.003)	(0.003)	(0.003)	(0.003)
Years of graduation	YES	YES	YES	YES
Observations	1,819	1,819	1,794	1,794
Pseudo R^2	0.101	0.101	0.102	0.102

Note: Ref.= reference category. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. WE: Work experience in part-/full-time/marginal employment.
Source: TUBPP.

Table 3: Logit regressions of full-time employment four years after doctoral training (t+4), average marginal effects

Variables	Model 1 t+4	Model 2 t+4
Gender (ref.: Men)		
Women	-0.139***	
	(0.016)	
Motherhood (ref.: Men)		
Women with children		-0.344***
		(0.043)
Women without children		-0.084***
		(0.025)
Nationality (ref.: German)		
Foreign	0.024	0.007
	(0.023)	(0.022)
Age, date of certification	-0.010***	-0.012***
	(0.003)	(0.003)
Data matching quality (ref.: No)		
Yes	0.123*	0.111*
	(0.066)	(0.061)
Subjects (ref.: Science)		
Energy/Process/Environ. engineering, Materials Sc.	-0.013	-0.005
	(0.026)	(0.027)
Bio-/Food technology	-0.012	-0.009
	(0.025)	(0.024)
Electrical engineering	-0.016	-0.012
	(0.033)	(0.032)
Computer Sc.	0.019	0.015
	(0.036)	(0.034)
Mechanics, Flow research, Transportation	-0.028	-0.025
	(0.031)	(0.030)
Mechanical engineering	0.124***	0.124***
	(0.045)	(0.045)
Civil engineering, Geotech.	-0.074***	-0.065***
	(0.024)	(0.024)

Variables	Model 1 t+4	Model 2 t+4
Vocational training (ref.: No)		
Yes	0.045	0.038
	(0.034)	(0.034)
Before doctoral training		
Full-time WE in 100days	0.000	0.001
	(0.002)	(0.002)
Part-time WE in 100days	-0.004*	-0.003
	(0.002)	(0.002)
Marg. Empl. WE in 100days	0.001	0.001
	(0.001)	(0.001)
During doctoral training		
Full-time WE in 100days	0.005***	0.005***
	(0.002)	(0.002)
Part-time WE in 100days	0.001	0.001
	(0.002)	(0.002)
Marg. Emp. WE in 100days	-0.001	-0.003
	(0.005)	(0.004)
Years of graduation	YES	YES
Observations	1,887	1,861
Pseudo R^2	0.125	0.148

Note: Ref.= reference category. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. WE: Work experience in part-/full-time/marginal employment.
Source: TUBPP.

6. Discussion and conclusions

This study aimed to explore career trajectories of STEM DDHs and potential gender-specific differences focusing on the critical transition phase after doctorate completion investigating the impact of previous work experiences in specific employment contexts during doctoral training on post-graduation employment patterns. Based on related research from different disciplines, we expect that employment sector and employment volume during doctoral training shape knowledge acquisition, network access and researcher identity formation processes. We empirically analyzed career paths of a large sample of STEM DDHs from a leading German technical university, therefore a homogenous group in terms of city and university of graduation, based on a new, original dataset.

Results from our sequence analysis reveal typical career trajectory patterns, among others a cluster of ‘full-time university careers’ or a cluster of ‘full-time university to other sectors careers’ for both male and female DDHs. However, the share of male DDHs in the sample who have a continuous career pattern like this is higher compared to their female peers. We furthermore observe that female DDHs without children follow career trajectories comparable to their male peers, whereas female DDHs with children concentrate in more unstable career paths regarding employment sector and employment volume. The composition of STEM subfields varies across the respective clusters. For instance, we find many electrical engineers within the cluster ‘full-time research organization careers’, whereas DDHs from bio- and food technology are prominent within the cluster ‘diverse employment patterns during doctoral training to full-time in other sectors’. These differences also relate to gender differences, as female shares in STEM subfields vary in our sample (e.g., 9.5 % in electrical engineering versus 48.1 % in bio- and food technology).

In a multivariate regression analysis, we thus controlled for STEM subfields. Again, our results suggest a substantial degree of path dependence between sector-specific work experience during doctoral training and post-graduation employment sectors. DDHs employed outside the academic sector during doctoral training rarely migrate to employment in academia after completing their doctorate, and a corresponding tendency to remain in the same employment sector is found for those employed both at universities and non-university research organizations during doctoral training. These findings confirm at least partly our expectations that sectoral employment context during the doctoral training appears to be associated with sector-specific access to career-relevant information and networks for subsequent employment. This stronger sectoral persistence in the academic sector is in line with previous evidence on DDHs’ sectoral employment paths (e.g., Goldan et al. 2022; Langfeldt/Mischau 2018). This could reflect a biased focus on the part of supervisors who prepare their doctoral students primarily for academic careers (Roach/Sauermann 2010). In addition, our results point to the importance of addressing gender imbalances in academic careers (Findeisen 2011; Beaufaÿs/Engels 2012; Auspurg et al. 2017) early, during the doctoral training.

However, we also would like to emphasize that within all sectors of employment differentiated above, there may be relevant within-sector heterogeneity in the extent to which STEM-specific knowledge acquired during doctoral training is required either for day-to-day business, as a quality signal for gaining employment, for effective supervision of subordinates, or not at all. A further limitation of our study is that we cannot directly investigate whether gender stereotyping experienced during doctoral training affects later choices of employment sector. As women employed in strongly male-dominated fields tend to experience stronger explicit stereotypes (Smyth/Nosek 2015), we therefore used the variation of female shares in STEM subfields as proxy variable (e.g., 9.5 % in electrical engineering to 48.8 % in bio-/food technology for the DDHs in our sample). This variation is interwoven with employment opportunities outside academia also varying by STEM subfields, which might help to explain why we did not obtain strong evidence of associations between gender and post-graduation employment sectors.

Controlling for motherhood within our regressions, we observe a higher likelihood of part-time post-graduation employment for women with children. In addition, women with children are more likely to remain in the university sector after doctorate completion. A plausible interpretation is that universities may be more flexible than other employers regarding part-time employment and flexible work arrangements (work schedule, hours, and locations) for highly educated individuals such as DDHs. In addition, university employment is not necessarily employment in research. In the past decades, universities have expanded their numbers of managerial and administrative staff, which provided new employment opportunities for DDHs. At present, our data do not allow us to differentiate between employment in university research and other university employment. This is a relevant limitation. In future work, we plan to add publication information to the TUBPP to see how long individual DDHs remain active researchers after graduating. We will also extend the observation period, since after four years it is not yet possible to say whether the respective DDHs will remain in the university sector also in the long run (e.g., beyond the period of the *Wissenschaftszeitsvertragsgesetz*). Here, the fact that the transition from doctoral training coincides with the transition to motherhood could have an effect. Some women may prefer to stay in the familiar context of their universities, even if limited in time, and forego chances to establish career networks in industry or elsewhere.

More surprising than the result for female DDHs with children is, however, our finding that women without children also have a lower probability of working full-time compared to men. Consistent with our expectations based on related research and previous evidence, this finding might at least in part reflect gender bias in recruiting for positions in the academic sector and beyond, given that particularly implicit gender beliefs are quite persistent. Yet, the relevance of this factor might be questioned in light of strong shortages of skilled STEM workers in the German labor market. This raises the question of whether this outcome also reflects deliberate choices due to various reasons such as limited project funding in the academic sector, long commuting distances etc.

Prior research on German DDHs being parents does not differentiate between mothers and fathers (e.g., Koenig et al. 2021), neglecting gender-specific parental roles. We do not differentiate between male DDHs with and without children purely for data-driven reasons, as the IEB do not comprise detailed information on household composition, and we are to date not able to apply a workaround to also identify men with children in a reliable way (as not all fathers take parental leave which would be visible in the social security records). Given this, we cannot investigate whether men with children might behave differently to men without children, women with and without children, e.g., leaving the university sector more often to secure higher earnings for the family by being employed within the private sector.

We conclude by noting that while our use of a single-university dataset reduces problems that might emerge from heterogeneity in actual or perceived degree quality as well as regional labor market conditions, it should be acknowledged that the TU Berlin and its DDHs might be special and differ from other DDHs in other regions of Germany. This might particularly apply to those DDHs in our sample who deliberately stay after graduation in Berlin due to a capital-effect, the preference to remain in this attractive metropole. Compared to immobile DDHs from TU Munich, another member of the TU9 network, there are fewer local job opportunities in big industries available for immobile DDHs from TU Berlin, but a high number of universities and research institutions, which might lead to an 'academia'-bias in our sample.

Most research on employment outcomes of (doctoral) graduates is survey-based. In contrast, our analysis was based on process-generated administrative data. In labor market research, the use of process-generated data such as the IEB is well-established. However, they are not very informative regarding individual educational attainments. Our TUBPP dataset shows that information on education can be fruitfully linked to the IEB, and that a matching rate above 80 % can be attained with access to administrative records. We consider the use of process-generated data to study career paths of DDHs and other graduates from higher education as complementary to large-scale surveys. Many questions for which survey data have traditionally been used can be answered equally well or even better using process-generated data. At the same time, process-generated data do not include information about individual motives, attitudes etc. In our view, this type of information should be the focus of future surveys, whereas as little information as possible should be collected that can be readily obtained from process-generated data. Ideally, ways of systematically linking process-generated and survey data should be devised that minimize costs while safeguarding subjects' privacy.

Our analysis is nevertheless limited to career trajectories within the German social security system, and we have identified for both female and male DDHs one cluster of careers for which hardly any information on employment status is available in our data. We cannot trace likewise academic career paths which rely on long stays abroad or a transition into self-employment or a position as civil servant. In this respect, a linkage of process-generated and survey data in future research might provide valuable insights on career paths beyond the German social security system.

Another interesting avenue for future research is to link patent data to our TUBPP dataset. Like the underrepresentation of women in top positions in the academic sector, gender imbalances in innovation activities are as striking as they are persistent. Based on long-term trends in female inventor shares in U.S. patent data, it has been estimated that another 118 years will be required until 50 % of all inventors are women (Bell et al., 2019). Several studies find that female scientists and engineers are less likely to become innovators than their male counterparts (Murray/ Graham 2007; Sugimoto et al. 2015; Jensen et al. 2018). Investigating the relationship between employment context during doctoral training and later innovative activities may help to accelerate expedient interventions to increase gender balance in this respect.

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Appendix

Table A-1: Share of female DDHs at TU Berlin by subject in % (graduation years 2004–2013)

Subject	%
Mathematics, Natural sciences	29.5
Energy/Process/Environmental Engineering, Materials Science	28.0
Bio-/Food Technology	48.1
Electrical engineering	9.5
Computer Science	14.6
Mechanics/Flow research	13.4
Transportation	11.1
Mechanical Engineering	15.4
Civil Engineering/Geotech.	34.2

Source: TUBPP.

Table A-2: Average duration of 10 labor market states in months

		Total	Men	Women	Significance-level	t-value	Degrees of freedom
Status: Average number of months/n=		2,513	1,906	607			
Five year-period before date of doctoral certificate	FT/University	16.0	18.3	9.5	***	3.340	1,043
	FT/Research	5.8	6.4	3.9		1.914	438
	FT/Other sectors	5.7	6.4	3.7	**	1.986	1,807
	PT/University	8.5	7.5	12.0	***	3.961	2,738
	PT/Research	4.2	3.8	5.6	***	2.433	513
	PT/Other sectors	1.9	1.8	2.5	***	6.887	8,058
	Vocational training	0.0	0.0	0.0	***	2.447	3,004
	Marginal employment	2.7	2.7	3.1		0.008	836
	Unemployment/Job search	1.9	1.7	2.7		1.592	1,281
	No information	13.3	11.5	16.9		-0.963	425
Five year-period after date of doctoral certificate	FT/University	6.1	6.5	5.0	**	2.943	2,258
	FT/Research	8.3	8.9	6.8	***	3.961	2,738
	FT/Other sectors	23.7	25.9	17.5	***	6.712	2,299
	PT/University	1.7	1.3	3.3	***	6.886	8,058
	PT/Research	1.1	0.8	2.0		-0.963	425
	PT/Other sectors	1.6	1.0	3.7		0.051	659
	Vocational training	0.0	0.0	0.0			
	Marginal employment	0.2	0.2	0.2	**	2.862	114
	Unemployment/Job search	2.1	1.9	3.0		0.787	1,740
	No information	15.1	13.5	18.4		0.023	195

Note: t-test, *** p<0.01, ** p<0.05, *p<0.1.
Source: TUBPP.

Table A-3: Descriptive characteristics of the clusters

Female DDHs	**Cluster**								
	Total	1	2	3	4	5	6	7	8
Percentages n=	607	86	50	42	101	68	92	82	86
Subjects									
Science	33.3	31.4	26.0	16.7	26.7	60.3	47.8	20.7	30.2
Engineering	66.7	68.6	74.0	83.3	73.3	39.7	52.2	79.3	69.8
Energy/Process/Environmental Engineering, Materials Science	13.0	11.6	10.0	21.4	13.9	14.7	13.0	11.0	11.6
Bio-/Food Technology	18.6	7.0	22.0	11.9	29.7	10.3	14.1	30.5	18.6
Mechanical engineering	4.3	3.5	4.0	16.7	5.0	0.0	4.3	3.7	2.3
Electrical engineering	3.0	3.5	10.0	2.4	1.0	1.5	1.1	3.7	3.5
Mechanics/Flow res.	1.8	4.7	4.0	0.0	1.0	0.0	1.1	2.4	1.2
Computer Science	5.8	14.0	10.0	16.7	5.0	0.0	3.3	0.0	3.5
Transportation	2.6	4.7	0.0	7.1	2.0	4.4	4.3	0.0	0.0
Civil engineering/ Geotechnology	17.6	19.8	14.0	7.1	15.8	8.8	10.9	28.0	29.1
Age at submission (mean)	32.8	32.8	32.3	32.3	32.0	31.2	32.6	32.4	32.1
Foreign	23.4	18.6	20.0	7.1	24.8	14.7	15.2	23.2	52.3
Women with children, t+2	24.4	23.3	24.0	19.0	20.8	25.0	35.9	29.3	15.1
Women with children, t+4	33.9	32.6	34.0	28.6	29.7	44.1	43.5	39.0	19.8
Women without children, t-5/t+5	62.1	65.1	58.0	64.3	65.3	52.9	54.3	58.5	75.6

Male DDHs	**Cluster**								
	Total	1	2	3	4	5	6	7	8
Percentages n=	1,906	305	259	325	265	217	113	102	320
Subjects									
Science	29.2	25.2	24.7	9.5	24.9	70.0	11.5	34.3	36.9
Engineering	70.8	74.8	75.3	90.5	75.1	30.0	88.5	65.7	63.1
Energy/Process/Environmental Engineering, Materials Science	11.4	10.8	13.1	12.3	12.5	5.1	14.2	9.8	12.5
Bio-/Food Technology	6.6	3.3	8.5	0.3	12.1	5.5	8.8	9.8	9.1
Mechanical engineering	10.3	6.6	5.8	23.7	13.2	2.8	15.0	8.8	5.3
Electrical engineering	10.4	10.8	16.2	13.5	10.9	2.3	5.3	11.8	8.4
Mechanics/Flow res.	3.6	3.9	4.6	6.2	3.4	2.3	5.3	2.9	0.3
Computer Science	11.4	23.0	10.8	14.2	8.3	0.9	7.1	7.8	10.6
Transportation	6.9	6.9	6.6	13.5	4.2	4.1	16.8	3.9	1.9
Civil engineering/ Geotechnology	10.3	9.5	9.7	6.8	10.6	6.9	15.9	10.8	15.0
Age at submission (mean)	32.8	33.4	33.3	33.4	33.3	32.3	33.8	31.3	32.9
Foreign	17.5	16.1	12.0	12.3	14.7	9.7	9.7	25.5	36.3

Source: TUBPP.

Table A-4: Definition of explanatory variables

Personal characteristics	
Female	1 if female, 0 if male
Women with children	1 if Women with children, 2 if Women without children, 0 if Men
Age	Age at time of graduation
Age²	Age (at time of graduation) squared
Foreign	1 if foreign graduate, 0 if German graduate
Data matching quality	1 if number of prs_ids in IEB data > 1, if number of prs_ids in IEB =1
Doctoral degree	
Year of graduation	Year of achieving the doctoral degree
STEM field	■ Science (including Mathematics) ■ Engineering ■ Energy/Process/Environmental Engineering, Materials Science ■ Bio-/Food Technology ■ Mechanical engineering ■ Electrical engineering ■ Mechanics/Flow research ■ Computer Science ■ Transportation ■ Civil engineering/Geotechnology
Work experience	
Vocational training	1 if graduate completed a vocational training before completion of doctoral training, 0 otherwise
Experience (in 100 days)	■ Marginal, part- and full-time employment work experience in employment sectors before doctoral training ■ Marginal, part- and full-time employment work experience in employment sectors during doctoral training ■ Marginal*/part-time*/full-time employment work experience before doctoral training ■ Marginal*/part-time*/full-time employment work experience during doctoral training

Table A-5: Multinominial logit regressions of sector employment two years after doctoral training (t+2), average marginal effects

	Model 1		Model 2	
Variables	t+2		t+2	
ref.: Other sectors	Uni	Research	Uni	Research
Gender (ref.: Men)				
Women	0.026	-0.014		
	(0.021)	(0.023)		
Motherhood (ref.: Men)				
Women with children			0.123**	0.027
			(0.048)	(0.040)
Women without children			0.003	-0.030
			(0.026)	(0.026)
Nationality (ref.: German)				
Foreign	0.075***	-0.009	0.094***	-0.009
	(0.023)	(0.026)	(0.023)	(0.027)
Age, date of certification	0.007*	0.007*	0.006*	0.008**
	(0.004)	(0.004)	(0.004)	(0.004)
Data matching quality (ref.: No)				
Yes	0.013	-0.033	0.021	-0.029
	(0.047)	(0.058)	(0.046)	(0.058)
Subjects (ref.: Science)				
Energy/Process/Environ. engineering, Materials Sc.	-0.064**	0.026	-0.068**	0.027
	(0.029)	(0.029)	(0.030)	(0.030)
Bio-/Food technology	-0.082**	0.026	-0.101**	0.034
	(0.039)	(0.035)	(0.042)	(0.036)
Electrical engineering	-0.119***	-0.009	-0.129***	-0.012
	(0.037)	(0.034)	(0.037)	(0.034)
Computer Sc.	0.017	-0.106***	0.009	-0.112***
	(0.029)	(0.039)	(0.030)	(0.040)
Mechanics, Flow research, Transportation	-0.116***	0.018	-0.123***	0.012
	(0.033)	(0.033)	(0.033)	(0.034)
Mechanical engineering	-0.138***	-0.117***	-0.153***	-0.116***
	(0.037)	(0.040)	(0.038)	(0.040)
Civil engineering, Geotech.	0.002	-0.029	-0.014	-0.033
	(0.029)	(0.032)	(0.030)	(0.033)

	Model 1		Model 2	
Variables	t+2		t+2	
Vocational training (ref.: No)				
Yes	-0.026	-0.019	-0.026	-0.021
	(0.037)	(0.038)	(0.039)	(0.039)
Before doctoral training				
WE Uni in 100 days	0.003	-0.003	0.003	-0.004*
	(0.002)	(0.002)	(0.002)	(0.002)
WE Research in 100 days	0.000	-0.003	-0.000	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)
WE Other Sectors in 100 days	-0.001	-0.002	-0.000	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)
During doctoral training				
WE Uni in 100 days	0.002	-0.001	0.003	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
WE Research in 100 days	-0.005**	0.017***	-0.004	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)
WE Other Sectors in 100 days	-0.017***	-0.007**	-0.016***	-0.006*
	(0.004)	(0.003)	(0.004)	(0.003)
Years of graduation	YES	YES	YES	YES
Observations	1,846	1,846	1,770	1,770
Pseudo R^2	0.129	0.129	0.136	0.136

Note: Ref.= reference category. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. WE: Work experience in part-/full-time/marginal employment.
Source: TUBPP.

Table A-6: Logit regressions of full-time employment two years after doctoral training (t+2), average marginal effects

Variables	Model 1 t+2	Model 2 t+2
Gender (ref.: Men)		
Women	-0.099***	
	(0.015)	
Motherhood (ref.: Men)		
Women with children		-0.260***
		(0.049)
Women without children		-0.090***
		(0.024)
Nationality (ref.: German)		
Foreign	0.021	0.017
	(0.021)	(0.021)
Age, date of certification	-0.014***	-0.013***
	(0.003)	(0.003)
Data matching quality (ref.: No)		
Yes	0.067	0.059
	(0.050)	(0.048)
Subjects (ref.: Science)		
Energy/Process/Environ. Engineering, Materials Sc.	0.024	0.028
	(0.026)	(0.026)
Bio-/Food technology	-0.003	-0.002
	(0.025)	(0.025)
Electrical engineering	-0.030	-0.017
	(0.030)	(0.031)
Computer Sc.	-0.023	-0.022
	(0.033)	(0.032)
Mechanics, Flow research, Transportation	-0.032	-0.025
	(0.030)	(0.029)
Mechanical engineering	0.015	0.035
	(0.030)	(0.031)
Civil engineering, Geotech.	-0.047**	-0.035
	(0.024)	(0.025)
Vocational training (ref.: No)		

Variables	Model 1 t+2	Model 2 t+2
Yes	0.063*	0.056
	(0.037)	(0.037)
Before doctoral training		
Full-time WE in 100days	-0.000	0.000
	(0.002)	(0.002)
Part-time WE in 100days	-0.002	-0.001
	(0.002)	(0.002)
Marg. Empl. WE in 100days	-0.001	-0.001
	(0.001)	(0.001)
During doctoral training		
Full-time WE in 100days	0.009***	0.009***
	(0.002)	(0.002)
Part-time WE in 100days	0.000	0.000
	(0.002)	(0.002)
Marg. Emp. WE in 100days	0.004	0.004
	(0.004)	(0.004)
Years of graduation	YES	YES
Observations	1,932	1,855
Pseudo R^2	0.128	0.1411

Note: Ref.= reference category. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. WE: Work experience in part-/full-time/marginal employment.
Source: TUBPP.