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Investigating PhDs' early career occupational outcomes in Italy: individual motivations, role of supervisor and gender differences

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Abstract
The paper examines how individual motivations, the role of the supervisor and gender influence the early career path of doctorate holders. We investigate PhD graduates' occupational outcomes beyond academia in the framework of current literature on the oversupply of PhD holders and labor market constraints. Our analysis relies on two unique datasets. The first, at the national level, includes microdata from the Italian National Institute of Statistics regarding about 41,000 graduates who account for over 70% of the population of 6 cohorts surveyed for the period 2004–2014. The other dataset is from a single university, and resulted from an original survey of 760 PhD holders who earned their doctorates from the University of Turin in 2007–2017. We find that PhD holders' motivation towards science is associated with their subsequent employment in academia or in other research and non-research jobs. Sponsoring support in early career and the supervisor's propensity for basic research also play a role in the future academic career path. Gender differences in type of occupation, however, continue to persist even taking motivations and the supervisor's role into account.

Keywords PhD early career · PhD supervisor · Gender · Sponsoring · Academic labor market

Introduction

Obtaining a PhD is the first step in embarking on a career in science, both at university and in industry. After completing their doctorate, however, most scientists prefer to stay in academia (Delanty, 2002; Gemme & Gingras, 2012), but not all of them are able to

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obtain a tenure-track job because of stagnation or low growth in open positions (Walker & Yoon, 2017). As a result, they increasingly turn to better paid and more secure jobs outside academia. At the individual level, this outcome can also be seen as the consequence of increased competition, pressure to find research funds and prolonged job insecurity. For all these reasons, many academic researchers, government agencies and professional associations are increasingly dedicating attention to the employment outcomes of doctoral graduates (Jones, 2013), also in the light of the growing heterogeneity of students pursuing a PhD and the changing functions of doctoral education (Walker & Thomson, 2010). Gender is one of the most significant of the main sources of heterogeneity and garners considerable attention from scholars and policymakers because of women's underrepresentation in a number of STEM PhD programs and academic positions (European Commission 2021).

There are differences across countries in how important it is to hold a PhD for the follow-on career, both in and outside academia. In countries such as Germany, where the PhD has a long history, holding a doctorate has become a necessity for any type of research career. As the salary differential shows, it is also seen as an advantage in business careers (BuWiN, 2021). In Italy, doctoral programs were introduced in 1983, and were conceived as the gateway to an academic career (Ballarino & Colombo, 2010). Until the late Nineties enrolment rose very slowly, accelerating significantly in the period 1998–2008 when the number of students almost tripled to reach a maximum of about 14,000 admissions (Coda Zabetta & Geuna, 2020). The increase in the numbers of PhD holders and the Italian university system's limited capacity to absorb them has created a mismatch in their occupational outcomes (Ballarino & Colombo, 2010). In particular, starting in 2008, Italian universities put a strict hiring freeze in effect as a strategy for coping with budget constraints. The turnover replacement rate was reduced to 20%, climbing slowly back to 100% only in 2018; total academic staff thus decreased from about 63,000 in 2008 to 54,000 in 2017 (Coda Zabetta & Geuna, 2020).

The issue of PhDs' early career occupational outcomes is not only relevant for the Italian case. Similar challenges are faced by PhD graduates in other countries such as Germany and Poland, as well as non-European countries like the US, Japan, and China (Auriol et al., 2013; Cyranoski et al., 2011; Langin, 2019). However, the case of Italy is particularly challenging because of an unfavourable environment that makes it quite difficult for PhD graduates, especially women, to pursue a research career (Carriero & Naldini, 2022; Checchi & Cicero, 2022; Filandri & Pasqua, 2021; Gaiaschi & Musumeci, 2020; Goastellec & Vaira, 2017; Martucci, 2011).

The imbalance between supply and demand for PhDs and the resulting occupational consequences drew researchers' attention towards the factors that influence doctorate holders' post-degree job choices. In this article, we focus on individual motivations, the role of the dissertation supervisor and gender. While we can assume that people undertaking a PhD have a strong intrinsic motivation for science which naturally leads to academic research, we cannot overlook extrinsic motivations such as salary and job stability. Depending on which type of motivation prevails, a PhD can orient herself towards jobs in academia or elsewhere. Work outcomes depend also on external factors. The literature often emphasizes the role of the PhD supervisor (e.g., Gaule and Piacentini, 2018; Paglis et al., 2006), as the supervisor may "socialize" the candidate towards certain ways of doing research and thus affect work outcomes after the doctorate. Moreover, women may encounter more difficulties than men in entering certain science professions or may opt out of a science career for reasons relating to family responsibilities and prevailing gender norms.

Analyzing Italian micro-data from the Italian National Institute of Statistics (ISTAT) and a survey of the University of Turin's doctorate holders, we investigated PhD graduates' occupational outcomes and found that their observed research propensity during the PhD

program and stated motivations, particularly their "taste for science" and "taste for salary", are important predictors of their subsequent employment in academia or in other research and non-research jobs. A significant role is also played by the sponsoring activity of their dissertation supervisor and her involvement in basic vs. applied research. However, gender differences in occupational outcomes continue to persist even when motivations and the supervisor's role are considered.

Compared to previous studies on Italy (Ballarino & Colombo, 2010; Carriero & Naldini, 2022; Decataldo et al., 2019; Marini, 2022; Passaretta et al., 2019) we expand the research in several ways. We investigate more in-depth factors related to the doctorate path such as the role of supervisor in terms of research orientation and sponsoring activity, and individual motivations proxied by the decision of going to do a research visit abroad during the doctorate and taste for science and taste for salary. Second, our analysis is broader in scope as it (a) exploits all waves of the ISTAT survey; (b) encompasses all fields of study, rather than focusing solely on STEM or SSH disciplines; (c) takes different types of employment for PhDs into account, including research positions in both the private sector and academia. Finally, we look at gender differences systematically when analysing both individual outcomes and the supervisor's role.

Theoretical background & hypotheses

To explain the occupational outcomes of PhD graduates, various approaches can be followed that leverage young researchers' sociodemographic characteristics and motivations (Bloch et al., 2015; Roach & Sauermann, 2017), aspects of the university program they have followed (e.g., amount and quality of the preparation received), characteristics and relationship with their dissertation supervisor (Gopaul, 2011; Rudd & Nerad, 2015; Gaule & Piacentini, 2018), placement in professional networks (Blackford, 2018; Hadani et al., 2012; Germain-Alamartine et al., 2021) and macro-economic conditions and institutional reforms that affect job opportunities in and outside academia (Oyer, 2006; Passaretta et al., 2019; Parenti et al., 2020; Rehs & Fuchs, 2022). Here, we focus on individual motivations and the role of the PhD supervisor, paying special attention to gender differences in occupational outcomes.

Individual motivations

In the context of PhD careers, the literature in economics and sociology of science has defined individual taste for science as a person's passion and interest in pursuing scientific research and knowledge; and the taste for salary as a person's desire for financial rewards and benefits that come with their career choice (Merton, 1973; Stephan, 2012). It is the intrinsic motivation that drives a person to choose a career in science and to dedicate their time and efforts towards advancing their field. On the other hand, it is the extrinsic motivation that drives a person to choose a career based on the potential income and job security that it offers.

While both factors can influence a person's career decision, they may prioritize one over the other. Some individuals may have a stronger taste for science and be willing to accept lower salaries in exchange for the opportunity to pursue their research interests, while others may have a stronger taste for salary and prioritize financial stability over scientific interests. It is important to note that these two factors are not mutually exclusive (Agarwal

& Ohyama, 2013; Stern, 2004), and many PhD students and graduates aim to strike a balance between their passion for science and their desire for financial security.

We thus expect PhD holders with a stronger taste for science to be more likely to stay in academia, while those with a stronger taste for salary may prefer non-academic jobs (Arts & Veugelers, 2020; Janger & Nowotny, 2016; Roach & Sauermann, 2010). These motivations can be related to job characteristics, such as intellectual challenge, independence, and impact on society, as well as rewards such as salary, job security, and position. Researchers who value monetary rewards may opt for non-academic jobs, while those who prioritize intrinsic job characteristics may prefer to stay in academia. We thus formulate our expectations as follows:

H1a: PhD holders with a stronger taste for science are more likely to opt for academic jobs.
H1b: PhD holders with a stronger taste for salary are more likely to opt for non-academic jobs.

Role of the supervisor

Old and new sociological literature has explored the special role played by a PhD supervisor. The supervisor is a key element to explain success in academic careers, both in terms of socialization theory (Gopaul, 2011), and especially from a social capital perspective (Andersson et al., 2017; Gopaul, 2015; Maritz & Prinsloo, 2015; Rowlands, 2013). The supervisor acts both at the level of socialization and at the level of social capital, after, or rather in addition to, the primary levels: family and private ties. Undoubtedly, supervisors play a prominent role not only because of their "professional work" (Halse & Malfroy, 2010, p.83) with the candidate, which ranges from acclimatizing the doctoral student to the academic environment to assisting in research (e.g., Pearson and Brew, 2002). Above all, the supervisor provides access to networks that can be leveraged to access the labor market both in and outside academia.

Paglis et al. (2006) note that supervising is multidimensional. First, supervisors may act as mentors who provide advice on how to do research in academia, encourage younger scholars to pursue a specific path and sponsor projects or publications (Long & McGinnis, 1985; Paglis et al., 2006), and provide support with the fund-raising process. Young scholars who have the opportunity to work with important scientists are more likely to continue their academic careers (Reyes Gonzalez et al., 2018); PhDs can benefit concretely from their supervisor's position and status. Some studies distinguish between the concepts of mentoring and sponsoring, observing that the mentoring process refers more to emotional support for personal and professional development, while sponsoring is more a question of power. Supervisors can use their influence to further their PhD students' careers, recommending them for job opportunities and promotions. In observing these two processes and trying to explain the gender gap in academia, studies report that women are over-mentored but under-sponsored (de Vries & Binns, 2018; Ibarra et al., 2010; O'Connor et al., 2020).

H2a: PhD holders who were actively sponsored by their supervisor are more likely to remain in academia.

Furthermore, students' chances may depend on the general quality of the scientific environment in which they work. For these reasons, the principal supervisor can potentially

exert a significant influence on the development of young researchers' skills and orientation towards the academic sector (Buenstorf & Geissler, 2014; Gaule & Piacentini, 2018; Platow, 2012). For example, the kind of research (basic or applied) practiced by the supervisor may influence PhD students' choices of research topic and the latter in turn may orient them towards different job sectors (e.g., academia or business). In addition, considering whether the supervisor is engaged in applied or basic research means having an indication of the social capital (Gopaul, 2015; Maritz & Prinsloo, 2015; Pitman & Vidovich, 2013; Rowlands, 2013) to which she can provide candidates with access. If the supervisor is active in basic research, she is likely to provide her PhDs with valuable network connections in the academic sphere; conversely, if she is involved exclusively in applied research, she will most likely be able to provide access to "external" business networks.

H2b: PhD holders are more likely to opt for an academic job and less likely to choose a research job in business if their supervisor carries out basic research.

Gender differentiation

The explanatory factors considered above can be further articulated by taking the gender dimension into account.

Gender counts when we consider the role of individual motivations because an interest in science is not enough if it is not combined with a strong determination to remain in a very competitive environment such as academia. Some studies argue that women's underrepresentation in scientific research jobs is due to gender differences in certain individual traits such as risk appetite, self-confidence and competitiveness (Azmat & Petrongolo, 2014). Women, it is also suggested, may have stronger preferences for family responsibilities than men (Croson & Gneezy, 2009; Hyde, 2005; Passaretta et al., 2019; Pautasso, 2015).

Whether it is really a matter of preferences and not of constraints, the fact remains that for most women family-work conciliation is a major issue in science careers (Lawson et al., 2021; Tartari et al., 2022). Without robust welfare policies, the prevailing gender norms of the division of care, coupled with the uncertainties of an academic career (perhaps accentuated by certain overhauls of the university system), impose a greater cost on women. Other social norms concerning the "ideal worker" (Lund, 2015), and the gendered nature of some academic organizational cultures (Acker, 2006), can be particularly detrimental for women. For all these reasons, some women are more inclined to take other non-academic jobs, letting a taste for salary prevail which is also a taste for occupational stability (more certainty of employment and residence). Stated "preferences" are thus often rooted in expectations linked to gender roles and social norms.

H3a: Female PhD holders are more likely than males to opt for non-research jobs, both academic and non-academic.

If we incorporate the gender dimension in explanations that consider the role of the supervisor, we can hypothesize that gender counts because of homophily and role-modeling mechanisms. A supervisor of one's own gender can help, especially for women. As academia has long been and still is a male-dominated sector, especially in some fields, a woman can benefit from having a female advisor for her academic career. At the same time, in scientific fields where women are still a minority, especially in senior positions, there

are fewer opportunities for a woman to be mentored and sponsored by another woman. According to some scholars, gender similarity between PhD students and their advisors has a positive effect on scientific productivity and the chances of becoming a faculty member because of a better communication pattern, better understanding, and greater satisfaction (Gaule & Piacentini, 2018; Pezzoni et al., 2016; Schroeder & Mynatt, 1993). In particular, female PhD students may benefit from having a woman advisor and increase their chances of becoming part of the faculty themselves (Gaule & Piacentini, 2018). Other scholars, however, found a non-significant effect of gender similarity (Hilmer & Hilmer, 2007; Neumark & Gardecki, 1998; Smeby, 2000).

H3b: Female PhD holders who had a female supervisor are more likely to opt for academic jobs.

Data, variables and methods

Our analysis uses two different datasets, one at the national level created by ISTAT, the Italian National Institute of Statistics, and one from a single university, the University of Turin, which resulted from an original survey (UniTo survey). We employ the former dataset to provide a broad and representative picture. The latter will serve to dig deeper into the role of individual motivations and supervisor's influence.

National dataset

At the national level, we analyzed data on the occupational outcomes of PhD holders provided by ISTAT for the three survey waves 2010, 2014 and 2018 (graduation years 2004–2014). Each wave targeted all graduates of two cohorts, i.e., those who earned their PhD four or six years earlier. A strength of this dataset is the very large sample size obtained by merging the three waves (N = 41,193), which allows detailed descriptive analyses, and the very high response rate (> 70%) for each wave, which strengthens confidence in data representativeness.

The outcome variable is doctorate holders' type of occupation at interview time. We classified occupations in five categories: (1) research job at public institutions (e.g., assistant professors and post-docs at university or research at a public research organization); (2) business research job, defined by crossing-referencing information about employment sector and presence of some reported R&D activity in job content; (3) business job, again defined by employment sector but without R&D content; (4) government and non-profit jobs, defined by employment sector only;[1] (5) a residual category for those not in employment at interview.

ISTAT data do not contain information on preferences for pursuing different types of career after earning a PhD, or on the PhD student's supervisor—which we have at local level from the UniTo survey. To proxy the ex-ante PhD student's interest in a research career, we used a dummy variable for whether the respondent had a research visit abroad during her PhD program. The rationale is that people interested in a research career should

[1] It includes PhD holders who reported some R&D content in their job, but who do not hold official research positions. This group accounted for 57% of type 4 occupations (or 19% of the sample).

be motivated to carry out research abroad to increase their skills and to invest in their professional social network. They are willing to incur mobility costs to increase their research skills and to pursue an academic career. Spending a research period abroad is ultimately the student's decision, students should submit a specific and detailed application for the research visit and only 38% of our sample did so.[2]

As individual control variables, we included the following pre-PhD graduation factors that might be associated with occupational outcomes: gender, age at PhD, MA graduation grades, having Italian citizenship, teaching activity during the PhD program, having a scholarship during PhD, finishing PhD on time. Additionally, we controlled for overall satisfaction with the doctorate as proxy for the quality of the PhD program.

The descriptive statistics for the variables presented above are reported in Supplementary Table S1.

UniTo dataset

To obtain detailed data on individual preferences and the supervisor's characteristics, we carried out a survey of PhD graduates from the University of Turin in 2007–2017. We supplemented survey data with administrative data from MIUR and publications data from Scopus. After collecting and cleansing data, our final sample consisted of 760 doctorate holders.[3]

One question of the survey[4] presented respondents with a list of motivations for having chosen their current occupation and asked to rank them in order of importance on a Likert scale from 1 (not at all important) to 4 (very important). From this question, we isolate two items: "I wanted to continue research on the field of my PhD" (taste for science) and "Good salary available" (taste for salary). We did not calculate Likert scale means, but we built two dummy variables that take value 1 if an attribute scores 3 ("Important") or 4 ("Very important"). Another possible response to the question was: "It was the only acceptable employment I could find at the time". When developing the two variables of individual preferences, we included a condition that required respondents to answer "Not at all important" (coded as 1 on the Likert scale) to the aforementioned item[5].

The analysis included the supervisor's characteristics: gender (*SV_Female*), seniority (*SV_Full_prof*), and orientation towards basic research (*SV_Basic_science*). For the latter variable, we retrieved advisors' publications and used the CHI's classification of Science Citation Index into four levels of "basicness" (Carpenter et al., 1988; Narin et al., 1976). Each level contains journals reporting roughly the same type of research, from level 4 (basic research) to level 1 (applied research). We associated the CHI score with all advisors' publications and created a dummy variable if she has published at least two papers in

[2] See Appendix 2 of the Supplementary Material for admission requirement and further information collected at the University of Turin on research visits abroad.

[3] See Appendix 2 of the Supplementary Material for additional details on the UniTo survey design and coverage.

[4] The question reads as follows: "How important were the following reasons for taking your current job? Please rate their importance to you when making the decision."

[5] In a few cases, researchers did not provide an answer to this item. In these cases, we used multiple linear regression to input the missing data. We also report the results without this subset of respondents in Supplementary Table S9. These results are similar to those presented in "Multivariate analysis (UniTo sample)" section for the more comprehensive sample.

4-CHI journals, where two is the median. Finally, we created a dummy (*SV Sponsor*) which takes value 1 if the respondent states that the advisor has been very important in the transition between receiving the PhD and the first job.

The descriptive statistics for the variables presented above and all other control variables (with much the same definitions as in the national dataset) are reported in Supplementary Table S2.

Econometric strategy

To investigate job outcomes, we drew on a series of regression models. Job outcomes are hypothesized to be driven by individual preferences and individual characteristics in a unique job search process in which PhD holders engage after, or sometimes before, their graduation. Hence, when investigating our hypotheses on job outcomes, we observed one discrete outcome per respondent among the five available employment choices described above. Given the categorical nature of the outcome variable, multivariate analyses used multinomial logistic regression (Cameron & Trivedi, 2005) which takes the choice between job alternatives into account and allows the errors to be correlated across outcomes.

In the national sample, all models include fixed effects for survey year, time since graduation (6 or 4 years according to survey design), geographical area, and research field (see Supplementary Table S1 for the list).

In the UniTo sample, all models include fixed effects for PhD scientific field (except for architecture & engineering, not taught at UniTo) and cohort (2007-10, 2011-13 and 2014–2017).

Results

Descriptive analysis

Three main findings from descriptive analyses at the national level should be mentioned. First, there was a clear decrease in PhD holders employed at public research institutions (from 36.4 to 28.0%, see Supplementary Table S3) and a corresponding increase in government and non-profit jobs (from 29.9 to 36.0%). This is likely to be the result of the growing number of PhD holders and the concomitant reduction in jobs at public universities due to budget constraints. Business research jobs have increased somewhat (from 17.4 to 19.8%), but they did not compensate for losses in academia. Business jobs remained stable at around 10%. PhD graduates who are not in employment are also stable at about 7%.

For comparison with similar European economies, in 2009 the percentage of PhDs employed in public research institutions was around 29% in Denmark and the Netherlands, and around 43% in Spain. The percentage employed in the business sector (researchers and non-researchers) was around 35.5% in the two former countries, and 15% in the latter.[6]

Under the aggregate figures, however, we found substantial variation by field of study (see Supplementary Table S4). The drop in public research posts has affected doctorate holders in the humanities (-15 p.p., from 35.0 to 20.0%) and social sciences (-22.5 p.p., from 45.8 to 23.3%) to a much larger extent than those in natural and life sciences,

[6] Source: 2010 OECD/UIS/Eurostat data collection on careers of doctorate holders (CDH).

medicine and engineering. For example, PhDs in natural sciences who are employed in public research institutions decreased by only 4.7 p.p., going from 44.3 to 39.6%. If we take both public and business research positions into account, we find hardly any decrease in research job opportunities for PhDs in natural and life sciences, medicine and engineering.

The second finding worth mentioning regards PhDs' mobility and its relationship with occupational outcomes. Across survey years, the percentage of doctorate holders who did a research visit abroad during their PhD program rose from 29.3 to 42.5% (see Supplementary Table S5). On the one hand, this might signal young researchers' increasing awareness of the importance of broadening their experience and searching for better job opportunities abroad, given the shrinking national academic labor market. On the other hand, Italian PhD programs have progressively encouraged their students to go abroad during their training. In line with these figures, data also reveal that the percentage of PhD holders (considering only Italian citizens, or 97.5% of the sample) living abroad at interview has doubled from 5.9 to 13.0%. Gender differences are not particularly pronounced: women are less likely (about 5–7 p.p.) than men to go abroad, both during and after the PhD program. Focusing on PhD holders with a public research occupation, the percentage living abroad has tripled from about 8% in 2010 to 25% in 2018, with men at 28.5% and women at 21.2%.

The third finding concerns women's placement in types of occupation. Female PhD holders are less likely than men to be found in research jobs, both public and business, and more likely to be employed by government and non-profit organizations. The gap is 5–6% points in public research and about 8 p.p. in business research, without significant variations across survey years (see Supplementary Table S3). By contrast, there are considerable variations across fields of study (data not shown, available on request). The gender gap in public research is largest in natural sciences (10 p.p.), while in business research it is largest in engineering (11 p.p.). The smallest (and not significant) gender gap is found among doctors in medicine.

In the UniTo sample (see Supplementary Table S7), we find a significant difference among men and women in the outcome Private Research and Other Public (9 p.p. and −7 p.p., respectively). Male PhD holders are also more likely to have spent a period abroad (10 p.p.) and to be of foreign nationality (9 p.p.); they also express greater satisfaction with the PhD (8 p.p.) and are less likely to have a woman as advisor (–11 p.p.).

Multivariate analysis (national sample)

Through regression analysis, we estimated the partial association between *Research_visit_abroad*, as proxy for interest in a research career, and type of occupational outcome, as well as residual gender differences, net of several covariates. For ease of interpretation, we reported average marginal effects (AME) instead of logit coefficients for individual predictors and plotted a few of them in graphs.

Net of control variables, *Research_visit_abroad* during the PhD program is associated with public research (AME = + 0.078, Table 1), without appreciable differences between women and men (Fig. 1). The "boosting" effect of research mobility does not hold for a business research job, as the AME is tiny and not significant. Conversely, research mobility is negatively correlated with business jobs and especially with occupations in government and non-profit organizations (gender differences in the AMEs are negligible). These findings confirm that doing a research visit abroad during the PhD program is correlated to gaining a research position in public research institutions after graduation and, at the same time, reveal preferences for this kind of job as going abroad is expensive for PhD

Table 1 Multinomial regression analysis (AME)

	(1) Publ_Res	(2) Priv_Res	(3) Business	(4) Oth_Publ	(5) Unempl
Female	-0.037***	-0.048***	0.001	0.058***	0.026***
	(0.006)	(0.005)	(0.004)	(0.006)	(0.003)
Research_visit_abroad	0.078***	0.001	-0.022***	-0.047***	-0.010***
	(0.006)	(0.005)	(0.004)	(0.006)	(0.003)
Italian	-0.133***	0.029*	0.032***	0.106***	-0.034**
	(0.017)	(0.013)	(0.008)	(0.014)	(0.011)
High_satisfaction	0.083***	-0.007	-0.042***	-0.005	-0.029***
	(0.006)	(0.005)	(0.004)	(0.005)	(0.003)
Teaching	0.024***	-0.001	-0.005	-0.002	-0.016***
	(0.006)	(0.005)	(0.004)	(0.006)	(0.003)
Scholarship	-0.119***	0.026***	-0.002	0.115***	-0.020***
	(0.007)	(0.007)	(0.005)	(0.007)	(0.004)
Finished_on_time	0.067***	-0.022**	-0.002	-0.034***	-0.008
	(0.008)	(0.007)	(0.005)	(0.008)	(0.005)
Age_at_PhD_30–34	-0.043***	-0.014*	-0.006	0.055***	0.008*
	(0.007)	(0.006)	(0.005)	(0.006)	(0.004)
Age_at_PhD_35+	-0.094***	-0.047***	-0.041***	0.170***	0.011*
	(0.009)	(0.008)	(0.007)	(0.009)	(0.005)
MA_full_marks	0.037***	-0.008	-0.024***	0.017**	-0.022***
	(0.006)	(0.006)	(0.005)	(0.007)	(0.004)
Six_years_after_PhD	-0.002	-0.007	-0.005	0.027***	-0.012***
	(0.005)	(0.005)	(0.004)	(0.005)	(0.003)
Observations	41,168	41,168	41,168	41,168	41,168
Field FEs	Yes	Yes	Yes	Yes	Yes
Survey year FEs	Yes	Yes	Yes	Yes	Yes
Region FEs	Yes	Yes	Yes	Yes	Yes
LogLikelihood	-84269.7	-84269.7	-84269.7	-84269.7	-84269.7
Chi-squared	6523.2	6523.2	6523.2	6523.2	6523.2
Pseudo-R^2	0.084	0.084	0.084	0.084	0.084

Notes: standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

students. This is indirect support for H1a, which we further tested with UniTo survey data as described below.

Disaggregated analyses by field of study (not shown) highlight that the magnitude of the boosting effect of *Research_visit_abroad* varies across fields, but it is always positive and substantial for research jobs in public institutions. For business research jobs, the effect of research mobility experience is *negative* in the social sciences. It is small, but *positive* (i.e., boosting) in engineering and natural sciences, and not significant in the other fields. In all fields of study, the probabilities of getting business and government/non-profit jobs are negatively correlated to *Research_visit_abroad*, with varying intensity.

Regarding gender, as can be seen in Fig. 2, controlling for several covariates, significant differences remain in all outcomes except business jobs. Women are more likely than men to be out of employment or employed in government and non-profit jobs. Conversely,

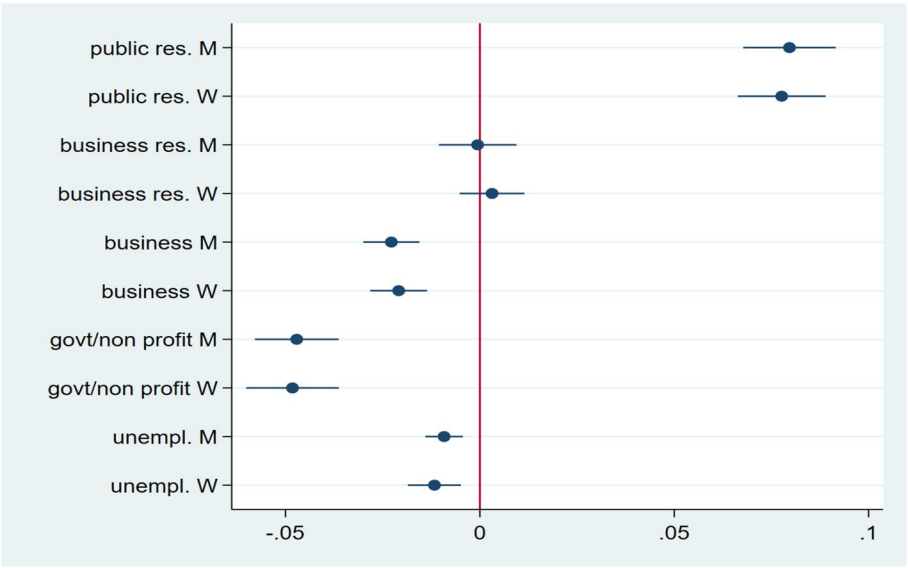

Fig. 1 AME of Research_visit_abroad on type of occupation, by gender

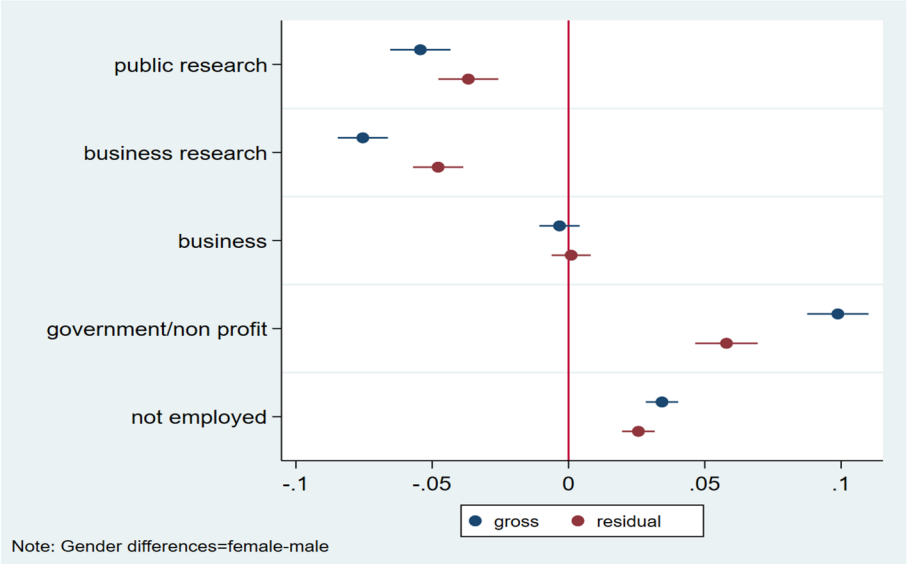

Fig. 2 AME of gender on type of occupation

women are underrepresented in both public and business research, thus confirming H3a. This finding takes the different distribution of women across fields of study into account.

The picture is more nuanced when we analyze each field of study separately (Fig. 3). Residual gender differences in public research are still considerable in natural sciences and to a lesser extent in life sciences; they are very small or not significant in all other fields. As

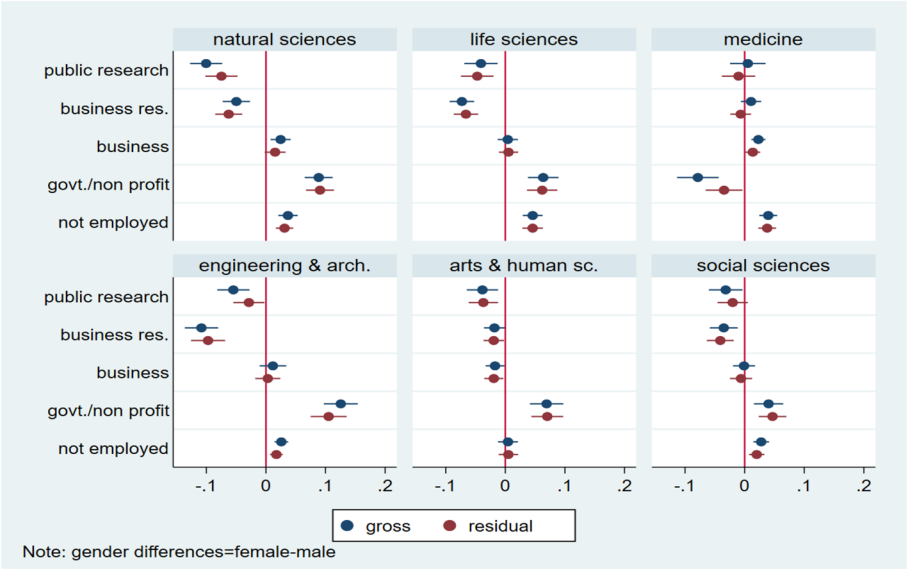

Fig. 3 AME of gender on type of occupation, by field of study

for business research, women are greatly underrepresented in engineering and to a lesser extent in natural, life, and social sciences, whereas in the other fields residual gender differences are small or not significant. Women from all fields but medicine are overrepresented in government and non-profit jobs, even controlling for covariates.

As a robustness check, we ran the multivariate analysis by dividing the sample into two periods, the first three cohorts 2004-2006-2008 (until the start of the decrease in PhD admissions and academic positions) and the second three cohorts 2010-2012-2014. For older cohorts *Research_visit_abroad* was clearly an individual choice, among the older cohorts only 33% of PhD students did a research visit abroad, while in the most recent cohorts the % rose up to 42%. We found consistent results in the older subsample, which is evidence that research visits abroad can be considered as a proxy of taste for science. We also ran the model including only the occupation after 6 years to consider the fact that a number of PhDs enter the labor market as academic postdocs and later move to a non-academic occupation. Finally, we estimated regressions (see Supplementary Table S6) excluding cases who kept the job they had before entering the PhD. Again, results are consistent with complete model estimations.

Multivariate analysis (UniTo sample)

We replicated the results obtained with the national sample for the UniTo sample. Unlike the national case, *Female* is positive but not significant for the probability of working in public research, while it is negatively correlated with a research career in business as in the national sample. The other variables are consistent with the results discussed for the national sample, except for *High_satisfaction* and *Scholarship* which are not significant (see Supplementary Table S8). In particular, the coefficient of the variable *Research_visit_abroad* confirms the finding that PhD holders who have spent a research period abroad

Table 2 Multinomial regression analysis (AME)

	(1) Publ_Res	(2) Priv_Res	(3) Business	(4) Oth_Publ	(5) Unempl
Female	0.057	-0.085***	-0.020	0.029	0.018
	(0.034)	(0.023)	(0.022)	(0.029)	(0.013)
Research_visit_abroad	0.132***	-0.002	-0.046	-0.098**	0.014
	(0.036)	(0.023)	(0.025)	(0.033)	(0.012)
Taste_for_science	0.305***	-0.098**	-0.087*	-0.087*	-0.034
	(0.046)	(0.030)	(0.035)	(0.042)	(0.027)
Taste_for_salary	-0.181***	0.098***	0.134***	-0.044	-0.007
	(0.054)	(0.027)	(0.032)	(0.050)	(0.027)
SV_Sponsor	0.196***	-0.031	-0.106***	-0.062*	0.003
	(0.033)	(0.021)	(0.028)	(0.031)	(0.012)
SV_Basic_science	0.121*	-0.034	-0.010	-0.041	-0.036
	(0.054)	(0.034)	(0.037)	(0.046)	(0.021)
SV_Female	0.002	-0.030	0.010	0.024	-0.007
	(0.037)	(0.026)	(0.025)	(0.031)	(0.014)
Observations	760	760	760	760	760
Control variables	Included	Included	Included	Included	Included
Field FEs	Yes	Yes	Yes	Yes	Yes
Cohort FEs	Yes	Yes	Yes	Yes	Yes
LogLikelihood	-752.922	-752.922	-752.922	-752.922	-752.922
Chi-squared	346.200	346.200	346.200	346.200	346.200
Pseudo-R^2	0.187	0.187	0.187	0.187	0.187

Notes: standard errors in parentheses; * $p<0.05$, ** $p<0.01$, *** $p<0.001$. *SV_Full_prof* included but not reported

during their PhD program are more likely to pursue an academic career and less likely to be employed in business or in the public sector.

Table 2 includes all controls reported in the national analysis and introduces new variables which allow a more detailed exploration of our hypothesis regarding individual motivations and the role of the supervisor in PhDs' career.

The two dummy variables reflecting candidates' motivations are consistent with H1a and H1b, respectively. *Taste_for_science* is positive and significant for a career in public research, while it correlates negatively with the choice of private research and non-research occupations in the public sectors. The opposite is true for *Taste_for_salary*. The two variables also have an opposite effect, negative for the former and positive for the latter, on the choice of working in the business sector.

SV_Female is not significantly correlated with any specific job outcome. We find that the sponsorship relationship between advisor and advisee (*SV_Sponsor*) is relevant in predicting PhD holders' choice of public research, and significantly decreases their probability

of choosing a career in the business sector (consistently with H2a)[7]. This effect might be explained by the fact that an advisor who wants to help her advisees at the beginning of their career arguably has more connections in academia than in the business sector. Furthermore, PhD holders who succeed in entering the university sector thanks to their advisor's sponsorship also have a higher probability of continuing an academic career afterwards.

We also find that advisors' research orientation towards more basic science (*SV_Basic_science*) is significantly associated with PhD holders' probability of choosing an academic career, thus supporting H2b. This effect might be explained by the fact that an advisor who has published in basic research journals transmits her orientation (and social capital) towards basic science to the advisee, who would in turn be more prone to choose basic science and thus an academic career.

Lastly, we tested whether the advisor's gender has an effect for gender homophile PhDs without finding a significant effect (results available on request).

Conclusions

Doctoral programs were established in Italy, as well as in other countries, as a gateway to an academic career. However, the surge in the number of doctorate holders, combined with shrinking job opportunities at universities, has meant that the most likely job outlets for a PhD are non-academic: since 2014, business employment in either research or management has been the most important occupational outcome. Our empirical analysis, based on data from a large national sample and a local survey, shows that three factors play an important part in orienting PhDs towards non-academic jobs. First, individual motivations matter, driving those who are more inclined to seek extrinsic satisfaction (taste for salary) and less motivated by a disinterested passion for science (taste for science) towards the business sector or non-research public jobs. Also, those who are willing to increase their knowledge of their chosen field (and bear the costs involved) with a research visit abroad during their PhD program tend to have a higher probability of staying in public research. It should be acknowledged, however, that in the UniTo sample individual motivations are measured ex-post, while research visit abroad is measured ex-ante in both samples.

Second, the academic supervisor's prevailing orientation towards basic rather than applied research is a factor that, combined with her sponsoring role, steers PhDs to take a job in academia. The data does not allow us to infer with certainty that the supervisor has a causal effect in this respect, as we cannot exclude self-selection in matching doctoral students and their supervisor. However, it is implausible to believe that the supervisor's role is completely spurious, as the effects of networking and socialization appear to be consistent with the literature investigating scientists' careers.

Third, the analyses showed that a tangible underrepresentation of women persists in public and business research in the STEM disciplines, while this is not true (or much less so) of medicine and SSH disciplines. This underrepresentation cannot be explained by differences in preferences, by propensity for mobility, or by the characteristics of the dissertation supervisor. We can interpret this result both as an effect of female self-exclusion from research jobs due to work instability and work intensity that are not compatible with family

[7] In an unreported result, we interacted *SV_Sponsor* with *SV_Female* to see whether the sponsoring effect of the supervisor was different for men and women, without finding significant differences (results available on request).

care expectations, and as an effect of discrimination mechanisms linked to gender bias, stereotypes and masculine cultures that are present to a greater extent in some STEM sectors (Moss-Racusin et al., 2012).

Overall, our findings can offer some suggestions for higher education and innovation policies. Regarding the recruitment of doctoral students, the role of individual preferences and motivations should be considered. If recruiters' aim is to train the new generation of university researchers, selection should focus more on identifying individuals who have not only the skills but also the right motivations for embarking on an academic career, thus avoiding failures and frustrations on both the individual and collective level. If the aim of the institutions that award doctorates is also to train people who bring advanced problem-solving skills or who transfer scientific knowledge to extra-academic fields, then it is important that training during the doctoral program be significantly and explicitly oriented in this direction. The supervisor's role is crucial in this connection. For various reasons, not all academic staff and not all universities and departments are well equipped for this purpose, with such as credentials as involvement in applied research or a solid history of working with companies and non-research public institutions. It would thus seem appropriate to differentiate the supply of doctoral programs by taking the specific skills and the most probable job opportunities into account. It is unrealistic to think that the same department is able to develop equally valid programs for academic and extra-academic career tracks.

Lastly, the issue of gender as a discriminating factor for a scientific career remains an extremely important issue that must be addressed at several levels. Given its deep roots, universities can have a limited impact on horizontal gender segregation, which leads women to be less attracted by certain STEM disciplines. By contrast, creating environments that are more women-friendly (or friendly in general) and implementing integrated policies for equality (such as gender equality plans) may well be within the power of university institutions.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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