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Inequality at the top. The gender earnings gap among the Italian educational elite

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ABSTRACT

Does a gender earnings gap exist at the top of the educational distribution? Based on population data on two recent cohorts of PhD graduates in Italy, we find that women's monthly earnings are on average 16 % lower than men's after 5–6 years in the labor market. The gender earnings gap is even wider at the bottom and top of the earnings distribution, reaching approximately 22 % and 19 %, respectively. Educational pathways before and during PhD studies, occupational characteristics, and family situation explain almost half of women's average penalty and working hours alone one-fifth of it. The wider penalties at the bottom and top of the earnings distribution remain largely unexplained.

1. Introduction

The gender earnings gap (GEG) is a ubiquitous phenomenon: despite the promotion of equal-pay and opportunities legislation, the labor earnings of women are lower than those of men in virtually all Western societies (Blau & Kahn, 2017). The existence of a GEG challenges the view of a fair and efficient job-allocation process in Western economies. In terms of equity, modern economies are believed to rely on meritocratic principles and to reward workers according to productivity rather than ascriptive characteristics such as gender or race (Treiman, 1970). In terms of efficiency, the existence of the GEG represents a disincentive for women's productivity and for future generations of women to invest in education and human capital.

Scholars have long been interested in the drivers of the GEG and analyzed its variations across countries, time, and subgroups of the population (Arulampalam et al., 2007; Bertrand et al., 2010; Boll et al., 2017). A crucial attempt in the existing literature has consisted in identifying the component of the raw gender gap that is purely due to statistical or taste discrimination against women (Buchmann & Di Prete, 2006). Recent research has shown that the raw gap has decreased in the last decades (Iceland & Redstone, 2020), although it has remained substantial in recent times (Blau & Kahn, 2006, 2017). Studies also found significant gender gaps among tertiary graduates in both the US (Joy, 2003) and Europe (García-Aracil, 2007; Triventi, 2013). Finally, some studies in the US have already begun to investigate the GEG among the educational elite, that is, PhD degree holders, and showed that even in this selected subgroup of the population, women tend to earn less than men (Torche, 2018).

This article focuses on recent cohorts of doctoral-degree holders in Italy and contributes to the literature on the GEG in contemporary societies by providing a better understanding of the sources of the disadvantages faced by highly educated women in the labor market. Although PhD holders are a relatively small group, attention to their labor market outcomes is crucial for several reasons. First, at the macro level, doctoral graduates play a key role in fostering economic development and promoting innovation (Diamond et al., 2014; Garcia-Quevedo et al., 2012). PhDs represent an "elite" that is likely to enter the most prestigious and remunerative occupations in the labor market and contribute to growing economic inequality (Posselt & Grodsky, 2017). Any gender inequality in PhDs' economic rewards may disincentivize talented women from applying to doctoral programs, thereby limiting women's access to leadership positions and yielding negative macroeconomic effects.

Second, at the micro level, it is important to understand whether unequal pay persists even among the individuals with the highest level of human capital and for whom competence should be the fundamental criterion in recruitment and promotion (Hout, 1988). This is especially relevant nowadays as women have surpassed men in university graduation rates and academic performance (Buchmann & Di Prete, 2006). Lastly, it is interesting to comprehend whether a GEG still exists in a selected segment of the population with allegedly strong preferences

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towards employment (Hakim, 1997).

This study has two main objectives. First, it aims to assess the existence and the extent of the GEG among recent cohorts of PhD graduates in Italy. Second, it seeks to determine the extent to which individual characteristics including educational pathways, occupational careers, and family situation may explain the GEG. A key contribution of the article is to move beyond the focus on average differences between men and women. We rely on recently developed techniques that integrate recentered influence functions and the Kitagawa-Oaxaca-Blinder decomposition (Rios-Avila, 2020) to explore whether the gender gap differs along the earnings distribution and examine drivers of the gender gaps in the lower and upper tails of the distribution.

We use population data including information on the educational careers and the labor income (earnings) of two recent cohorts of PhD graduates interviewed 5–6 years after the obtention of their doctoral degree. The few existing contributions in the literature relied on local samples of PhD graduates and addressed the issue of gender disparities only tangentially (e.g., Ballarino & Colombo, 2010; Campostrini, 2011; D'Agostino & Ghellini, 2011; Lee et al., 2010). We improve on those contributions by examining specifically women's penalties based on high-quality population data.

We show that women have lower monthly earnings than men even at the top of the educational distribution in Italy. The raw gap is 16 % on average and even higher at the bottom and top of the earnings distribution. The wider gender gaps in the tails remain largely unexplained by individual characteristics commonly addressed by mainstream narratives on the roots of gender inequality in contemporary society.

2. Theoretical framework

2.1. Selectivity and the gender earnings gap in Italy

The literature on gender inequalities in the labor market distinguishes between demand- and supply-side explanations for females' penalties. Supply-side explanations stress the role of preferences for education, occupation, family arrangements, and structural and cultural constraints related to gender norms (Ginn et al., 1996; Gash, 2008; Hakim, 1997). Demand-side explanations emphasize the influence of employers' prejudices and statistical discrimination when recruiting prospective employees, negotiating their wages, and assigning tasks and promotions (Kunze, 2018).

The concept of selection is key when focusing on the subgroup of the population at the top of the educational distribution. The selectivity of the PhDs matters for both demand- and supply-side explanations. On the supply side, PhD graduates represent only a small portion of their birth cohort and have successfully survived educational transitions of increasing difficulty (Mare, 1981). This is especially relevant in Italy where the proportion of PhD holders among the population aged 25–44 years is comparatively low at approximately 0.5 % (OECD, 2019). Hence, PhDs are likely to differ from the average individual in terms of cognitive skills, non-cognitive skills, attitudes, and preferences towards employment (Mullen et al., 2003; Posselt & Grodsky, 2017). This positive selection may even be stronger among women, who may have encountered higher cultural barriers than men throughout their educational careers (Hakim, 1997, 2006a, 2006b). Thus, female PhDs are likely to value their occupational career over family responsibilities.

Selection is also important in demand-side explanations. Some authors have argued that employers screen potential candidates for high-skilled positions mostly based on educational qualifications and ability rather than ascriptive characteristics such as gender or social background (Breen, 2004; Breen & Jonsson, 2005; Hout, 1988). These arguments would lead us to expect a reduced or even no GEG among PhD graduates. Yet, the few existing studies portray a different story. In the UK, female PhDs earn 11 % less than men after 3 years and a half in the labor market (Schulze, 2015). This figure amounts to 16 % in Sweden (Amilon & Persson, 2013) and 17 % in recent US cohorts (Rathnasekara, 2022). Several studies in Germany found a GEG ranging from 16 % (Goldan, 2021) to as high as 46 % (Bornmann & Enders, 2004) depending on the specific cohort and point in the life course considered. In the early 2000s, a study conducted on a convenience sample of PhD holders in Northern Italy reported a GEG of around 200 euros per month (Ballarino & Colombo, 2010).

It is also important to consider the broader cultural, economic, and institutional context in which our PhD cohorts made the transition to the labor market. Some of the cohorts examined in this work entered employment during a period of economic instability and stagnation (Passaretta et al., 2019). Competition among job seekers is fierce in times of economic downturns, and employers may be less inclined to hire new personnel on a permanent contract (Kahn, 2010). In this situation, discrimination against vulnerable categories, such as women, may even increase. Moreover, Italy is a country where traditional gender norms survived modernization and may still impair women's attachment to the labor market (Lomazzi, 2017). Hence, even if equally productive compared to men, female doctoral graduates in Italy may still discount labor-market attachment due to personal preferences or the anticipation of employers' discrimination.

All in all, the findings in other countries and the considerations on the institutional, cultural, and broader economic context in Italy lead us to expect a GEG even among the strongly selected population of doctoral graduates.

2.2. Distributional dynamics

Previous studies on the general population suggest wider raw gaps at tails of the wage or earnings distribution (e.g., Arulampalam et al., 2007). There is also evidence that variations depend on the educational level. In Spain, for example, the gender wage gap grows along the distribution for the tertiary educated but shrinks for the lowest educated (De la Rica et al., 2008).

The economic literature has paid particular attention to the distributional dynamics of the component of women's disadvantage that cannot be traced back to observed individual characteristics. This unexplained component was often assumed to measure discrimination against women and was found to be stronger at the top and partly at the bottom of the distribution, phenomena usually referred to as the "glass ceiling" and "sticky floor," respectively (Booth et al., 2003; Bjerk, 2008; Christofides et al., 2013; Cohen & Huffman, 2007). The "glass ceiling" is a hidden barrier that prevents women from being hired and promoted to top positions. In contrast, the "sticky floor" describes a situation where women have fewer chances to climb up the ladder and are trapped for longer in low-paid entry-level positions despite having endowments similar to those of men (Booth et al., 2003).

The interpretation of variations in the unexplained gender gap along the distribution as a "glass ceiling" or a "sticky floor" rests on the assumption that this unexplained gap reflects discriminatory behavior only. This assumption is violated if the unexplained gap also captures non-perfect accounts of all potentially relevant individual characteristics impacting wages and earnings. Therefore, we will interpret with caution any variations in the unexplained GEG along the earnings distribution.

But do the wider gaps at the tails remain when focusing on individuals at the very top of the educational distribution? Many mechanisms responsible for gender inequalities in the overall population may still affect doctoral graduates. There is no a priori strong reason to expect a different distributional pattern among PhDs. On the one hand, male PhDs may still have a greater attachment to the labor market than their female counterparts, although all PhDs are generally highly career oriented. Hence, the strong selectivity of doctoral graduates may result in an overall reduction of the gender gap but the same distributional pattern as in the general population. On the other hand, the selectivity of doctoral graduates restricts the set of occupations in which they are likely to be employed and possibly narrows the range of corresponding

earnings. Following this argument, we could expect smaller variations in the GEG along the distribution among PhDs than in the general population.

2.3. Factors explaining the gender earnings gap

The GEG is the result of multifaceted processes involving individuals' endowments (supply side) and employers' discriminatory practices (demand side). Supply-side drivers are usually classified into four main groups: human capital factors, occupational factors, working time, and family situation (e.g., Triventi, 2013). Differences in the distribution of endowments among women and men can contribute to the GEG if such endowments boost economic returns. This section discusses whether and how these sets of endowments can contribute to the GEG among PhD holders. At the end, we also underline the importance of demand-side factors including employers' discriminatory behavior.[1]

We present general arguments as they have been elaborated in the literature, which has mostly focused on factors explaining the gap on average and not along the wage/earnings distribution. Because it is not easy to predict how the role of endowments may vary along the distribution, we will refer to this aspect only when theoretical arguments can be extended clearly to distributional dynamics. Thus, the assessment of the contribution of specific endowments along the earnings distribution remains an explorative feature of our empirical analyses.

2.3.1. Human capital factors

PhD holders have achieved the highest level of education possible and are a country's educational elite. Notwithstanding, they differ in a variety of characteristics that may represent additional qualifying elements for the labor market, in terms of both productivity-enhancing skills and indirect signals of productivity and trainability. These may include characteristics of pre-doctoral educational careers (e.g., grades, track attended in high school), characteristics of the PhD program (e.g., access to grants, region, field of study), and experiences accumulated during the doctoral studies (e.g., teaching, visiting periods abroad). While all these factors plausibly relate to earnings in and outside academia, strong gender disproportions in their endowment are rather unlikely. Gender inequalities in higher education have been declining and even reversing in recent times (Jacobs, 1996). Some of the human capital factors we mentioned, such as high school track or graduation grade (see Supplementary table B2), are even likely to be to women's advantage as they usually perform better in school (Buchmann et al., 2008).

The field of study is perhaps the most important of the human capital factors. Men are disproportionally represented in engineering, mathematics, and computer science at the tertiary level. Women, instead, are disproportionally represented in education, the humanities, and social sciences. These patterns are found in Italy (Triventi, 2010) and elsewhere (Barone, 2011; Charles & Bradley, 2002). It is also well known that technical and scientific fields offer occupations with higher remuneration than humanistic degrees and social sciences in many countries (Ballarino & Bratti, 2009; Reimer et al., 2008). Based on these arguments, the previous research identifies the field of study as an important driver of the GEG among tertiary graduates (Gerber & Cheung, 2008), even if its contribution appears to be reduced when controlling for individuals' general skills and more detailed individual characteristics (Triventi, 2013).

[1] It is important to recognize that access to a given endowment, such as educational credentials or the sector of employment, is the result of individual preferences but also depends on the broader set of opportunities and constraints faced by individuals in their life course (e.g., Ginn et al., 1996; Gash, 2008). Access to a particular endowment may even reflect the anticipation of future employers' discriminatory behaviour.

2.3.2. Occupational factors

The second set of factors includes occupation-related characteristics, such as the type, place, and sector of employment. The existing literature highlights the role of occupations and occupational sectors among the labor-market factors (Charles & Grusky, 2004; Mandel & Semyonov, 2006; Mandel, 2012; Olivetti & Petrongolo, 2008; Smyth & Steinmetz, 2008). Studies focused on the whole population showed that women concentrate in occupations and sectors characterized by lower pay (Leicht, 2008), lesser career mobility, and limited working autonomy and authority (Chang, 2000; Reskin, 1993). This also partly applies to high skilled doctoral graduates. One may think that female PhDs regularly apply for professional occupations with high pay, strong opportunity for career mobility, and high job autonomy and authority. However, even female doctorates might have lower likelihood of applying to top-level jobs and sectors compared with equally qualified men because of a lack of confidence (Sterling et al., 2020). Field studies accord to this view by demonstrating that women are more averse to competition than men, not least because of men's overconfidence and attitudes (Niederle & Vesterlund, 2011).

Also processes of 'allocative' and 'valuative' discrimination by employers may cause earnings differences through occupational segregation (Petersen & Morgan, 1995). 'Allocative' discrimination refers to a situation where employers discriminate women in hiring decisions because of prejudices (Reskin & Roos, 1990), the expected risk of losing workers after childbirth (England, 2005), statistical discrimination (Bielby & Baron, 1986), the desire to preserve the "status" of a job by keeping women out (Goldin, 2002), or incongruence in terms of leadership stereotypes (Johnson et al., 2008) 'Valuative' discrimination may occur because female-dominated occupations are considered less important to societies (*devaluation thesis*; England, 1992) and characterized by less occupation-specific training (Tam, 1997) as well as over-supply (*crowding thesis*; Bergmann, 1974). 'Allocative' discrimination may be more important than 'valuative' discrimination among PhDs. In fact, training is less important for highly specialized doctoral graduates and the typical female-dominated occupation among doctorates, such as the medical professions, are generally considered important for society.

The workplace (country of work) is also crucial because there is clear evidence that Italian PhDs working abroad benefit from a wage premium (Di Cintio & Grassi, 2017). This seems important as female PhDs in Italy are less likely to work in a foreign country after graduation (Passaretta et al., 2019), a pattern that is possibly linked to family or caring commitments and other work–life balance issues (Ackers & Gill, 2008; Børing et al., 2015).

2.3.3. Working hours and the family situation

Working hours deserve particular attention among the supply-side factors. Many of the existing studies focused on gender disparity in the hourly wage, thus factoring out a fundamental part of the processes that generate women's disadvantage in economic resources. Moreover, the wage rate is a less appropriate metric when returns on working hours are non-linear, as in the case of professionals (Morgan & Arthur, 2005). Studies that concentrated on the general population found that women are more likely to be employed in part-time jobs, which, in turn, affects their monthly earnings (Kunze, 2018). Working time is influenced by external constraints that limit the opportunities available to women (Ginn et al., 1996), including family and care responsibilities, a central additional explanatory factor for the GEG (Blossfeld et al., 2015). Differences in working time are not only rooted in labor-market processes but might also stem from individual preferences produced by gendered processes of socialization, experiences in the education system, informal peer pressure, family duties, and the anticipation of employer discrimination (Hakim, 1997; Fagan, 2001).

Three aspects must be considered when thinking about the importance of working hours for the GEG among the selected population of doctoral graduates. First, the selectivity of PhDs in terms of cognitive

achievement, motivation, or attitude toward employment suggests that working hours are more balanced between men and women with a doctoral degree than in the general population. For example, although women still do most of the household work and are usually responsible for childcare (Crompton & Lyonette, 2006), gender differences in attitudes towards employment and family are likely comparatively limited among PhD holders. Third, men are more likely than women to work in occupations where additional working hours are disproportionately rewarded, a situation to which Goldin (2014) refers as a non-linear wage-hours schedule in highly skilled occupations. If this is the case, then working hours should be particularly important in explaining the GEG at the top of the earnings distribution.

2.3.4. Discrimination within the same occupation

Employers' decisions might be driven not only by considerations of profit maximization but also by "taste discrimination" (Becker, 2017) or "statistical discrimination" (Phelps, 1972). Employers' (or their customers') decisions can be guided by prejudices against women or stereotyped information about the productivity characteristics of women as a group and their 'fit' to top-level positions. Such discrimination not only contributes to the allocation of women to lower paid occupations but creates situations where men and women with analogous endowments, employed in the same occupation, and working the same number of hours receive a different salary from the same employer.

We expect this form of discrimination to be particularly relevant in top-level occupations and, consequently, to drive the gender gap in the upper part of the earnings distribution of PhDs. The existing research points towards gender biases in the evaluation of the characteristics required for leadership positions (Eagly & Karau, 2002). Gender stereotypes associate brilliance with men, and women with exceptional cognitive abilities face backlash for not conforming with this stereotype (Quadlin, 2018). These mechanisms can reduce women's chances of being promoted to leadership positions, thus widening the gender gap, especially at the top of the earnings distribution of PhDs.

3. Analytical strategy

3.1. Data

We use unique and high-quality population data from two rounds of the Italian National Institute of Statistics' survey on PhD Graduates conducted in 2009 and 2014. The data includes information on two cohorts of PhDs who graduated in 2004 and 2008 and were interviewed 5–6 years after graduation (in 2009 and 2014, respectively). All graduated PhDs without exception were invited for an interview. Data were collected via Computer-Assisted Telephone Interview in 2009 and via Computer-Assisted Web Interview in 2014. The response rates were above 70 % in both rounds, which is far beyond that of other commonly used data. Regardless of the high response rate, we used adjustment factors provided in the surveys to ensure that our analyses are representative of the PhD cohorts. Details on the adjustment weights provided by the surveys are available in the Supplementary material (Section A). The sample includes 13,577 individuals overall, 98 % of which were non-missing in our analytical covariates (see Table 1). Among the latter sample, 95 % were employed at the time of the interview, and 85 % of the employed (10,682 individuals) reported monthly earnings. This final analytical sample includes 5158 PhDs who graduated in 2004 and 5524 in 2008 across the whole spectrum of academic disciplines.

Table 1
Definition of the analytical sample.

	N
Overall	13,557
Non-missing in covariates	13,324
Employed	12,621
Non-missing in earnings (analytical sample)	10,682
Ph.D. cohort 2004 (survey 2009)	5158
Ph.D. cohort 2008 (survey 2014)	5524

3.2. Monthly earnings

We use monthly earnings from the main job (after taxes) to evaluate individuals' position in the stratification of economic resources. Alternative measures, such as hourly wages, are closer measures of individuals' productivity and earning potential but may not reflect the actual availability of economic resources. Women's working schedules are often subject to constraints that go beyond individual preferences, and, therefore, the time devoted to paid labor is an important driver and a crucial theoretical dimension of gender disparities.

Information on monthly earnings was self-reported and missing in approximately 15 % of the cases in our analytical sample (see Table 1). This data was equally likely to be missing for men and for women in both rounds. Regardless of the balance between men and women, we adopted a weighting strategy to account for selective missingness in the outcome based on gender, PhD cohort, place of work, social origin, field of study, and region of PhD attainment separately in the two surveys. Adjustment factors were computed using inverse probability weighting and trimmed via response propensity–score stratification (Chen et al., 2012; Vandecasteele & Debels, 2007). In short, our procedure assigned heavier weights to individuals with a higher probability of not having reported their earnings and, at the same time, avoided biases due to extreme adjustment factors resulting from imperfect weighting models. Technical details on the weighting procedure are provided in the Supplementary material (section A).

Information on earnings was released for scientific use after the truncation of the tails. Earnings were truncated in approximately 4 % of the cases in our analytical sample. Therefore, we can rely on exact information for almost all individuals.[2] The proportion of truncated earnings is similar among men and women. The proportion of subjects in the upper truncated tail is higher among men than among women (1.9 % vs 0.9 %), while the opposite is true for the truncated lower tail (1.9 % of men and 3.4 % of women). Such slight differences suggest that, if anything, our analyses provide a conservative estimate of the GEG at the mean. Under the assumption that men's exact earnings are more likely to be in the upper values of the truncated tails, the gender gap at the top and bottom of the earnings distribution is also likely an underestimation of the true gap. Additional information on truncation can be found in Supplementary table B1.

Monthly earnings are weighted by the purchasing power of the country of work (PhDs may work outside Italy) and the reference year (2009 or 2014) and then logged to obtain an approximately normal distribution. The log transformation preserves the variance and allows us to interpret the GEG as a *percentage difference* between the earnings of women and men. Before the log transformation, the average monthly earnings in our analytical sample are 1529 euros; the 10th and 90th percentiles correspond to 888 euros and 2336 euros, respectively.

3.3. Control variables and endowments

Table 2 lists the covariates used in the analyses. Missingness in those covariates was minor (under 2 %) in the data (see Table 1). The first set of variables controls for the potential composition of our sample in terms of graduation cohort, social origin, and citizenship.

The second set groups the remaining endowments, which are the

[2] Truncation mostly occurred in the lower tail of the distribution, where the variance in true wages is mechanically limited by 0. Hence, truncation likely has a minor impact on the estimated mean GEG. Furthermore, truncated wages are out of the quantile range examined; thus, they do not affect the estimates of the distributional analysis.

Table 2
Overview of covariates used in the analyses.

Controls[a]	Endowments				
	Pre-PhD[b]	PhD studies[c]	Occupation[d]	Working hours	Family situation[e]
Parental education	High school track	Field of study	Detailed sector	Weekly hours	Civil status
Citizenship	Graduation grade	Age at completion	Professional job		Children
PhD cohort	Graduation abroad	Delay	Contract type		
		Teaching experience	Job start		
		Grant	Work abroad		
		Visiting abroad			
		Macro-region			

Notes:
[a] Parental education: Both primary or less, one lower secondary, one upper secondary, both upper secondary, one tertiary, both tertiary. Citizenship: Italian/other. PhD cohort: 2004 vs 2008.
[b] High school track: *Liceo classico*, *liceo scientifico*, *liceo linguistico*, *liceo sociopsicopedagogico*, *liceo artistico*, *istituto tecnico*, *istituto professionale*, foreign institution. Graduation grade: 107 or less/108 or more. Graduation abroad: Yes/no.
[c] Field of study: All fourteen fields of study available at the PhD level. Age at completion: 29 or less/35 or more. Delay: Yes/no. Teaching experience: Never, occasionally, regularly. Grant: Standard, 'assegno di ricerca', teaching grant, none. Visiting abroad: Yes/no. Macro-region: North-east, nort-west, centre, south.
[d] Detailed sector: Agriculture, mineral extraction, energy, water and waste management, chemical and pharmaceutical products, machinery and mechanical equipment, electrical, elettronic and optical equipment, transportation equipment, other industries, academia: professors, academia: tenured researchers, academia: non-tenured researchers, academia: administration and technicians, academia: other, non-academic instruction, research: public, research: private, public administration and defence, professional, scientific and technical activities, health and care, finance and insurance, information and communication, commerce, accomodation, and restoration, international organizations, transport services, other services, human resources. Professional job: Yes/no. Contract type: Standard, non-standard, self-employment. Job start: Before/after PhD. Work abroad: Yes/no
[e] Civil status: Single, married/cohabitating, widowed/divorced. Children: Yes/no.

supply-side drivers of the GEG, into five categories. First, we distinguish between two groups of human capital factors: *pre-PhD* characteristics, including information on previous educational histories, such as high school track and graduation grades, and *PhD-studies characteristics*, encompassing a vast array of features of the PhD attained, such as the 14 detailed fields of study at the doctoral level, the timing of completion, and teaching experience.

The third group of endowments includes *occupational* features such as contract type and whether the job is framed within a formal profession or carried out abroad. Unfortunately, detailed occupational codes were not available in the data. However, we were able to include a detailed variable distinguishing 25 sectors of the economy. Such a variable also differentiates between research jobs in and outside academia as well as detailed positions in academia, which is by far the largest sector of employment for PhDs in Italy (around 37 % in our sample).

Working hours are considered in a left-alone category because, as we discussed earlier, they may be particularly important in explaining the GEG in Italy. The last group of factors includes some variables related to the *family situation*, such as the civil status and the presence of children.

3.4. Methods

The analyses revolve around two main objectives: to establish the existence of a GEG and to explain the gender gap by PhDs' characteristics. The raw, unconditional gender gaps at the mean and along the earnings distribution are virtually identical to the conditional gaps once the controls listed in Table 2 are considered in the anayses (see Supplementary figures C1 and C2) . Hence, for the sake of simplicity and parsimony, we focus on the estimation of the unconditional gap and its decomposition.

In the first part of the analyses, we use OLS and quantile regression to estimate the raw GEG at the mean and along deciles of the unconditional distribution of the (log) earnings. Unlike in other studies focused on the general population (e.g., Kunze, 2018), selectivity into employment is a minor issue in our context. Table 1 shows that 95 % of our PhDs were employed at the time of the interview; therefore, our estimates are representative of the vast majority of the population under scrutiny. As a sensitivity check, we also account for selection bias in the estimation of the average gender gap via Heckman selection models and find similar results (see Supplementary figure C1).[3]

In a second step, we apply Kitagawa-Oaxaca-Blinder (KOB) decomposition methods (Blinder, 1973; Kitagawa, 1955; Oaxaca, 1973) to assess the overall percentage of the GEG explained by PhDs' characteristics and the specific role of the latter in accounting for the gender gap at the mean. We apply a "twofold" decomposition, which separates sex-based differences in the outcome into a part that can be explained by differences in group characteristics (the "endowments effect") and a part that cannot (Jann, 2008).[4] The unexplained component is often attributed to discrimination because it captures gender differences in the coefficients associated with the characteristics included in the model; however, this component also reflects the effects of all potential differences between the two groups that remain unobserved.

While the decomposition of the average gender gap requires standard analytical tools, the decomposition along the earnings distribution is more challenging (Rios-Avila, 2020). The KOB method implies the identification of the unexplained (residual) part of the gender–earnings association when feeding covariates into the model (the endowments, in our specific case). The problem arises from the fact that, unlike in bivariate quantile regression, coefficients for the residual gender gap cannot be interpreted as the average differences between men and women at different quantiles of the unconditional distribution of earnings. Indeed, individuals at the high end of the distribution conditional on covariates are not necessarily those who are at the high end of the unconditional distribution (Wenz, 2019). A standard solution to approximate the interpretation of coefficients from conditional quantile regressions to the bivariate scenario is unconditional quantile regression (UQR; Firpo et al., 2009). UQR consists in regressing transformations of the outcome—the *recentered influence functions* (RIFs)—rather than

[3] We use the number of children and civil status as exclusionary restrictions in the two-step estimation.
[4] The two components are computed as follows: $DX = (X_F – X_M) \times B_M$ and $D_B = X_F \times (B_F – B_M)$, where DX is the share of the gender gap attributable to the observed endowments and DB is the unexplained part; X_F and X_M are the vectors of values related to the characteristics observed in women and men, respectively; $B_F – B_M$ are the coefficients related to the characteristics observed in women and men, respectively.

unconditional quantiles themselves on the covariates of interest. A similar use of RIFs also extends to decomposition methods (Firpo et al., 2018). This approach allows us to apply KOB decomposition to distributional statistics and decompose the gender gap at different deciles of the unconditional distribution of earnings. We estimate the contribution of both the broad categories of endowments (pre-PhD characteristics, PhD characteristics, occupational features, working hours, and family situation) and all detailed variables therein in accounting for the raw gender gap. To estimate this model, we rely on the *oaxaca_rif* routine in the Stata statistical software (Rios-Avila, 2020).

It is important to bear in mind that the decomposition analysis, both in the classical KOB method and in the RIFs approach, assesses the contribution of each endowment to the GEG based on a shift-share analysis that simulates how the GEG (at the mean or specific quantiles) would look like if a given characteristic (e.g., field of study) was distributed similarly among men and women. While this approach does not allow for a "micro-individual" interpretation of the effect of the endowments, it is relevant from a policy perspective as it identifies the factors with the highest potential to reduce the GEG that policy interventions can target.

4. Empirical results

4.1. A gender earnings gap among PhDs?

Fig. 1 plots the raw GEG expressed in percentage differences between women's and men's earnings at the mean (orange line) and along the unconditional earnings distribution (black connected dots). On average, women's monthly earnings are around 16 % lower than men's. This figure is remarkable if we are looking at an educational elite, which is likely a more homogeneous group in terms of occupational aspirations and ability than the general population. As anticipated, the average gender gap remains unchanged when adjusting for potential differences in the composition of doctoral graduates in terms of socio-demographic characteristics and accounting for sample selection bias (see Supplementary figure C1). The existence of an average gap between male and female PhD holders is consistent with our general expectation and previous findings in other national contexts (Amilon & Persson, 2013; Goldan, 2021; Rathnasekara, 2022; Schulze, 2015; Torche, 2018).

The average gender gap masks important dynamics along the wage distribution as women's penalty is more pronounced in the tails. In the bottom decile of the distribution, women's earnings are 22 % lower than men's. The gender penalty between the 20th and 70th percentiles (11–14 %) is slightly lower than the GEG found at the mean, while it grows to 19 % among earners above the 80th percentile. The difference between the 90th and 10th percentiles is not statistically significant at the conventional 95 % level of confidence but only at the 90 % level ($p = 0.096$). Conversely, the differences between the median (50th percentile) and both the 10th and 90th percentiles are statistically significant ($p < 0.000$).

Overall, the population data for the two cohorts of PhD graduates reveal a U-shaped pattern featuring stronger gender inequality at the top and bottom of the earnings distribution. This pattern is reminiscent of some of the previous international research that found wider gaps in the tails when looking at the general population (Arulampalam et al., 2007) or tertiary graduates (De la Rica et al., 2008).

4.2. Explaining the gender earnings gap

Fig. 2 shows the overall contribution of the five groups of endowments (pre-PhD and PhD characteristics, occupational characteristics, working hours, and family situation) to the explanation of the GEG. Panel A presents the percentages of the total GEG explained at the mean (orange line) and along the distribution (black connected dots) computed as ratios between the explained components and the raw gaps estimated via KOB decomposition. Panel B lays out the raw GEG on the log scale and the relative explained and unexplained components along the distribution. Altogether, our endowments explain approximately 43 % of the average difference in the earnings of men and women (see panel A). However, this figure changes strikingly when we examine different points of the earnings distribution. The explanatory power of the observed endowments is highest between the 20th and the 40th percentiles, where they account for between half and 70 % of women's penalty. Conversely, endowments explain only approximately 27–30 % of women's penalties in the high portion of the distribution (from the 80th to the 90th percentile) and at the very bottom (10th percentile).

Panel B visualizes the portion of the raw GEG (in log points) that remains unexplained by endowments. The figure clearly shows that the unexplained component is markedly stronger in the tails (where the raw gap is the widest). Hence, it seems that the classical individual characteristics used to explain women's penalties on average are inadequate when trying to account for the stronger penalties observed in the tails.

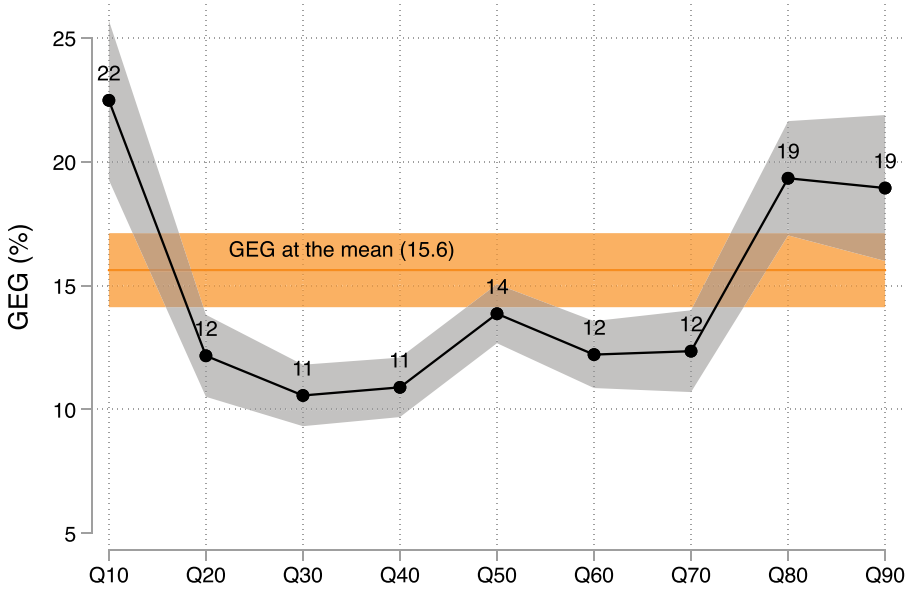

Fig. 1. Raw gender earnings gap (% change) at the mean (orange line) and along quantiles (black connected dots) of the unconditional distribution. Note: women's penalty is computed as a percentage difference between the earnings of women and men.

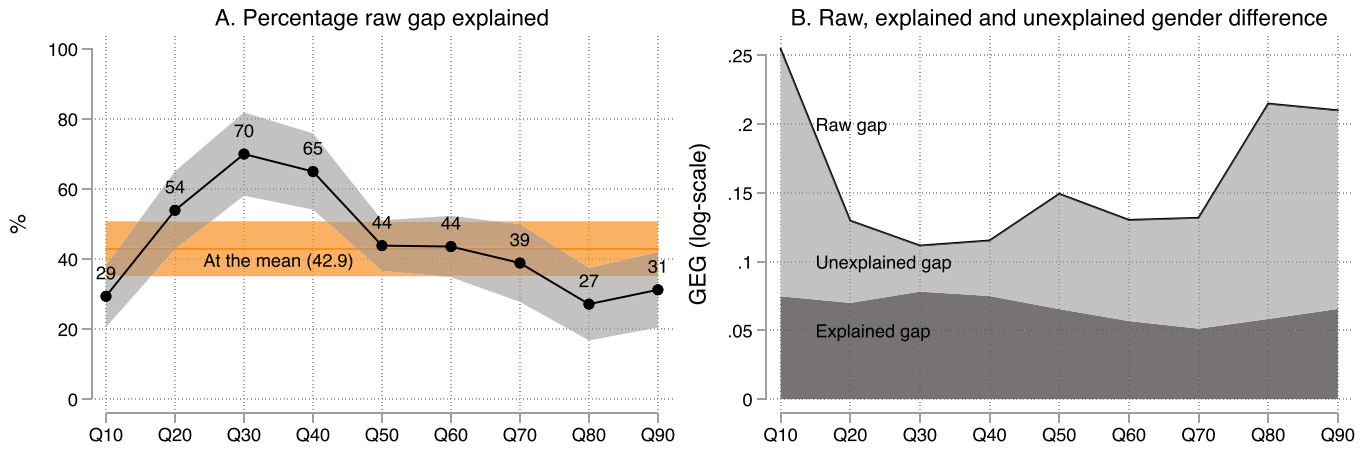

Fig. 2. Panel A: Overall percentage of the raw gender gap explained at the mean (orange line) and along quantiles (black connected dots) of the unconditional earnings distribution (95 % confidence intervals calculated using the Delta method). Panel B: Raw, explained and unexplained difference between men's and women's earnings along quantiles of the distribution.

This result is in line with some of the previous studies that found evidence of either "sticky floors" or "glass ceilings" in different countries and subgroups of the population. Our results on PhDs graduates in Italy are consistent with both dynamics, although the lack of statistical control for all possible endowments may artificially inflate the unexplained component. This is a limitation we share with all the previous studies.

But which are the most important factors when it comes to the explanation of women's disadvantage? We start by reporting the results of the decomposition of the average GEG (Fig. 3). Panel A shows the contribution of pre-PhD and PhD characteristics, occupational characteristics, working hours, and family situation to the average gender gap. Panel B details the specific contribution of each of the factors included in the five categories of endowments. Altogether, the contribution of the five broad categories adds up to 43 %. Notably, the contributions of the detailed categories within a broad category sum to the overall contribution of the broad category.

The figure clearly indicates that the lion's share of the average difference in men's and women's earnings is explained by the characteristics of the occupation obtained after doctoral graduation and working hours, in line with our expectations. Around 20 % of the average gender gap is rooted in occupational differentiation in terms of contract type, place of work, detailed sector of employment, the timing of the job entry, and the professional orientation of the job (see Panel A). This figure implies that men took advantage of occupational differentiation. If women had the same distribution of occupational characteristics as men, the GEG would be reduced by approximately 20 %. Among the occupational characteristics, contract type and, especially, working abroad are the most important factors and explain around 6 % and 10 % of women's penalty, respectively (see Panel B). Men are much more likely to have a permanent contract (8 % points) and work abroad (4 % points) than women, and these two occupational characteristics come with large earnings premiums (see Supplementary table B2). In contrast, the detailed sector of employment does not explain a large share of women's penalty: although there are strong differences in average earnings by sector, female PhDs do not systematically self-segregate in the occupational sectors with the lowest economic returns (see Supplementary table B2). Finally, according to our theoretical speculations, working hours are of particular importance and explain 22 % of the average gap alone.

Contrary to our expectations, characteristics of the doctoral studies seem to play a minor role and altogether account for approximately 9 % of women's penalty. This is almost entirely due to differentiation in terms of the field of study at the PhD level, which explains 8 % of the GEG. While the role of the field of study is non-trivial, it is lower than we

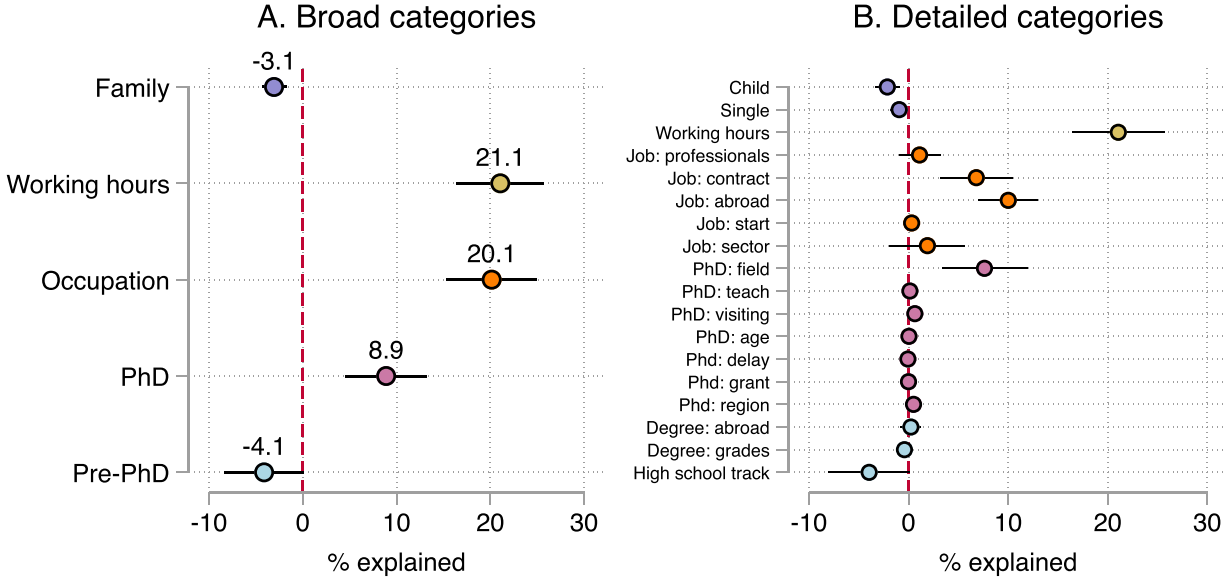

Fig. 3. Percentage of the raw gender gap at the mean explained by endowments: broad and detailed categories.

expected based on the notion that men traditionally graduate from more remunerative fields at the tertiary level. In our PhD cohorts, men were more likely to graduate from hard sciences characterized by larger monetary returns, such as industrial engineering, mathematics, and physics (see Supplementary table B2). However, the share of women who graduated from other remunerative fields, such as law and economics, is similar to that of men and even one-third higher in the most remunerative field, medicine (see Supplementary table B2).

It is also striking that both characteristics of the educational career before PhD enrolment and, especially, family arrangements explain a minor portion of the average gender gap. The negative value of - 3.1 implies that the average gap would be 3.1 % higher if women had family arrangements similar to men's (see Panel A). This result run contrary to the common sensa idea that men benefit from lower family burdens. However, we should bear in mind that our study has limitations in the assessment of the role of family arrangements. In the absence of rich information on the family, the role of the family situation may have been picked up by the number of hours worked monthly in our decomposition analyses. It is likely that the extraordinary role played by working hours in our analyses also reflects the gender imbalance in care obligations and the division of labor at home, at least to some extent.

Finally, it is interesting to examine whether the characteristics of the educational and occupational careers and the family situation are of different importance in explaining the gender gap at various points of the earnings distribution. We have already shown that our five groups of endowments are better suited to explain women's penalty in the middle-low portion of the distribution and less useful for explaining why men have higher earnings at both the top and the bottom. Are some specific groups of mediators more important than others when it comes to explaining gender inequality in the tails? Fig. 4 provides a generally negative answer to this question. The most important characteristics, which are those related to the occupation, are better able to explain the gap between the 20th and 40th percentile, as are the characteristics of the doctoral studies. Working hours, instead, seem equally important to the explanation of women's penalty throughout. Finally, the decomposition of the gender gap along the earnings distribution confirms the residual importance of family arrangements and the characteristics of the educational career before doctoral enrolment. Additional analyses (not shown) indicate that the role of the detailed categories used to explain the average gap does not vary dramatically when we shift the focus to the earnings distribution.

5. Conclusions

The gender pay gap is a highly debated phenomenon in advanced economies. Most of the current research focuses on gender differences looking at the whole population or tertiary graduates. Only a few studies have investigated gender inequalities in labor-market outcomes among individuals with the highest educational attainment, namely, doctoral graduates. By drawing a portrait of an elite in the Italian labor force, this article offered new insights into processes of labor-market inequality for a population that is widely believed to have meritocratic opportunities. In particular, we examined whether women obtain lower monthly earnings than men 5–6 years after PhD graduation, both on average and along the earnings distribution. In addition, we examined the extent to which the GEG traces back to gender imbalances in the distribution of human capital factors, occupational characteristics, working time, and family responsibilities.

A substantial GEG exists even among recent cohorts of PhD graduates in Italy despite the high level of selectivity of the population under scrutiny. Women earn on average 16 % less than men, a result very much in line with recent findings from the US (Rathnasekara, 2022), Germany (Goldan, 2021) and Sweden (Amilon & Persson, 2013). In Italy, this translates into an estimated gap of approximately 260 euros per month or 3129 euros annually. Although this may not seem excessively large, three points should be borne in mind. First, earnings are lower in Italy than in many other Western countries, and 260 euros per month represents a substantial amount. Second, the GEG refers to men and women who are equally highly qualified and specialized. Third, we focused on labor earnings 5 years after PhD graduation, but there is evidence of increasing penalties for women throughout their occupational career (Weichselbaumer & Winter-Ebmer, 2005).

The average GEG we found among PhDs is consistent with those reported by previous studies on the whole Italian population (Cutillo & Centra, 2017) and tertiary graduates (Cantalini, 2015; Triventi, 2013). However, the GEG we observed at the bottom of the distribution (10th

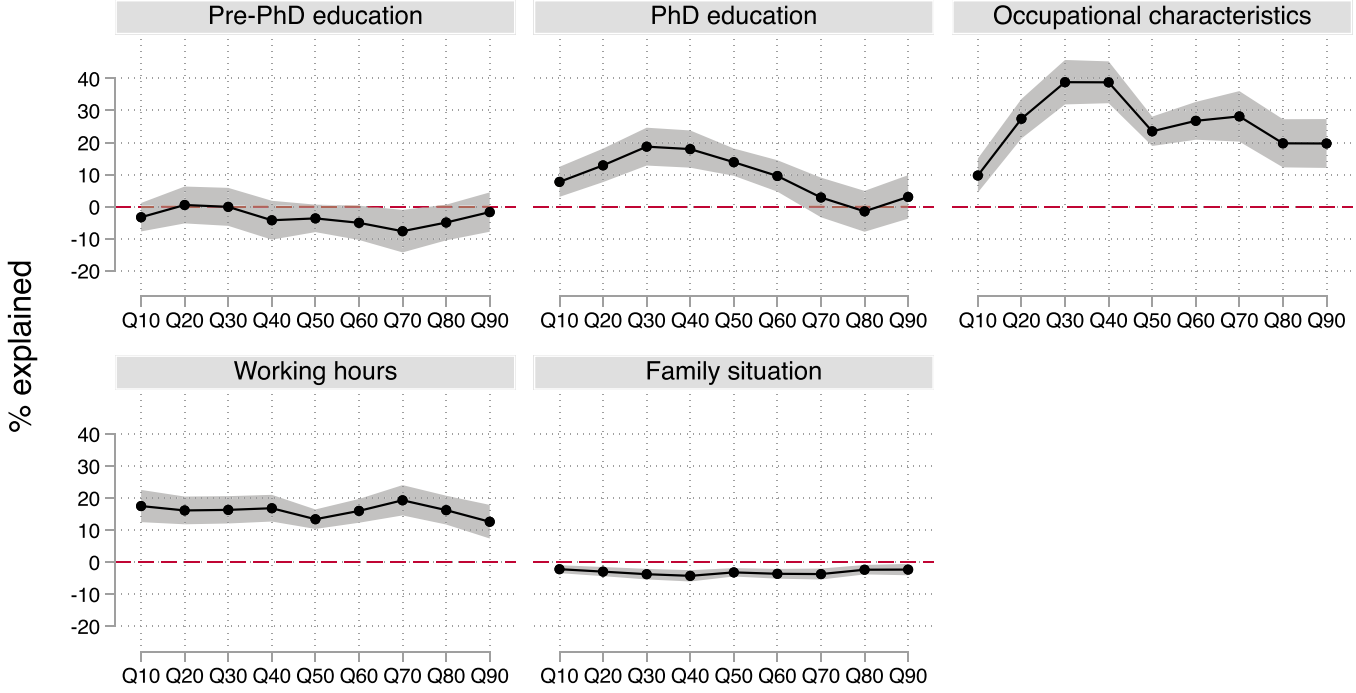

Fig. 4. Percentage of the raw gender gap along the earnings distribution explained by endowments: broad categories.

percentile) is wider than the one identified by two recent studies on the Italian general population (estimates between 0.12 and 0.13; Castagnetti & Giorgetti, 2019; Piazzalunga & Di Tommaso, 2019). Our estimate for the gap in the upper tail (90th percentile) lies between those reported by these two studies (0.12–0.30). Direct comparisons with studies that focused on the general population are difficult due to the variation in the definition of the outcome. Many studies factor out the gender imbalance in working hours by concentrating on hourly wages, thereby likely obtaining smaller estimates. However, there is no clear-cut evidence that the GEG is lower among the educational elite than in the general population in Italy. Moreover, distributional dynamics are overall similar among PhDs and the general population, that is, characterized by larger gaps in the tails and a larger unexplained fraction of the gap in the upper part of the distribution.

The wide array of individual characteristics we considered explains less than half of the GEG at the mean, up to more than two-thirds in the middle-lower part of the earnings distribution, and only around one-third in the tails. The unexplained GEG is strikingly largest in the tails, a pattern that is coherent with the arguments regarding the existence of both "glass ceilings" and "sticky floors" in academia and highly skilled segments of the labor force. Yet, it is difficult to attribute the unexplained part of the GEG solely to discrimination processes as it could also be due to unmeasured individual characteristics (or measurement errors in the observed variables). For example, a recent study found that 14 % of the unexplained GEG is attributable to lower willingness to commute among women, who are less likely to move far away from home to find a job (Le Barbanchon et al., 2021), a factor that has rarely been considered in previous works (Del Bono & Vuri, 2011). The absence of information on this factor artificially inflates the unexplained component and, when this unexplained component is attributed uncritically to discriminatory practices, also overestimates discrimination against women. We support a prudential interpretation and limit ourselves to the observation that traditional predictors of earnings appear to be of weak importance in explaining why the women's penalty is widest in the tails of the earnings distribution. The evidence is consistent with the idea that discretionary hiring and promotion decisions on the employers' side, individuals' attitudes and preferences, and other individual factors that we were not able to measure matter more for the explanation of the GEG in the tails of the distribution than in the middle or on average. Further research is needed to better quantify the extent of discriminatory processes and distinguish them from the influence of other unmeasured individual characteristics.

There are some notable contradictions to our expectations. In line with previous studies on tertiary graduates (García-Aracil, 2007; Triventi, 2013), human capital factors do not seem crucial to explaining the average GEG. All in all, it seems difficult to attribute women's penalty to their allegedly lower level of skills and qualifications. Interestingly, the field of study also explains a relatively small fraction of the GEG. Although women and men tend to enroll in different fields of study at the doctoral level, women are not overly segregated in the fields that systematically lead to lower-paid jobs. For instance, women's access to and graduation from the field of medicine has grown over time and is even higher than men's in recent cohorts (Triventi, 2010).

Occupational destinations play a crucial role in explaining the GEG. However, only some specific job characteristics appear to make a difference. The most important aspects are working abroad and the type of contract, whereas the occupational sector does not contribute significantly to explaining women's penalties. Women are more likely to be employed with a temporary contract, and access to fixed-term contracts also entails a penalty in Italy. In the same vein, men are more likely to work abroad, and such decisions yield high economic returns.

The contribution of both human capital and occupational factors to the explanation of the GEG is stronger in the middle-low part of the distribution. This result is consistent with the idea that men disproportionally avoid overeducation and access specific segments of the labor market that protect them from receiving very low pay. Along with more classical indicators of labor-market position, working hours seem to be of critical importance to the explanation of gender differences in monthly earnings. Notably, their contribution is rather constant along the earnings distribution, thus not providing support for non-linear wage-hours schedules among Italian PhD graduates (Goldin, 2014).

In sum, the GEG among the educational elite seems to be driven primarily by differentiation in terms of where (abroad), how long (hours), and under which conditions (contract type) men and women work for a living after obtaining a PhD. Despite the selectivity of the population under scrutiny, key factors that are relevant to the whole population appear to be important among doctoral degree holders as well. Working hours are a primary example. Whether differences in working time reflect external barriers or individual choices is an unsettled debate. Nonetheless, it is likely that even highly selected female PhDs' paths are not free of obstacles to occupational success in a society characterized by rather traditional gender norms.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.rssm.2023.100796.

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