INTRA-FIRM HIERARCHIES AND GENDER GAPS *

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Abstract

We study how changes in female representation at the top of a firm's organisation affect gender-specific outcomes across hierarchies within firms. We start by developing a theoretical model of a hierarchical firms, where gender representation in top organisational layers can affect gender-specific hiring and promotion probabilities at lower layers. We then exploit a recent French reform that imposed gender representation quotas in the boards of directors and test the model's predictions in the data. Our empirical results show that the reform was successful in reducing gender wage and representation gaps at the upper layers of the firm, but not at lower firm layers. A Panel VAR analysis confirms that the trickle-down effect of this policy was limited and suggests that interventions targeting the managerial layer, rather than the board, might have a more generalised effect across the firm.

Keywords: Gender Gap, Firm Organisation, Gender Quota, Trickle-Down Effect.
JEL codes: G38,J16,J3,L2

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1 Introduction

Gender differences in labour force participation, education and political participation have narrowed substantially in recent decades. Despite these significant advances, gender differences in the labour market remain large.[1] This is particularly evident in top leadership positions, where women continue to be severely under-represented and where gender wage gaps remain substantial. To address these issues, policy-makers have introduced gender quotas in corporate board of directors in many European countries.[2] In this paper, we investigate a similar reform that was enacted in France and study its effectiveness in improving female representation in publicly-traded French firms and in mitigating gender wage differences in those firms.

In France, the *Loi Copé-Zimmerman* was promulgated on 20th of January 2010.[3] This law mandated publicly-traded firms to have at least 20% representation of each gender in the board of directors by 1st of January 2014 and 40% by 1st of January 2017. Firms that failed to comply with the reform would have been fined, dissolved or banned from paying existing directors. The unanticipated nature of this policy introduction in France provides us with an opportunity to perform causal analysis about the effectiveness of this policy.

We start by developing a theoretical framework to guide our empirical analysis that follows. In contrast to the literature, we see the firm as an organisation where workers perform heterogeneous tasks that are organised in a ladder of layers with a clear hierarchical structure. External workers are hired to replace workers that exogenously leave the firm and incumbent workers can be internally promoted to jobs of higher complexity. Hiring and promotion decisions in a given layer are taken by workers one level above in the hierarchical structure of the firm. We assume that hiring managers observe only a noisy signal of the true ability of a candidate. We introduce gender differences in our model, allowing workers to be one of two types: males or females. We borrow from Flabbi et al.

[1] The literature on the evolution and causes of the gender wage gap is well-documented. A good summary of this literature can be found in Blau and Kahn (2016). Reasons cited to explain why such a wage gap exists in the first place includes differences in human capital, experience (Olivetti (2006)), choice of occupation and industry (Mulligan and Rubinstein (2008)), labour force participation decisions (Goldin et al. (2017)) and discrimination (Becker (1971)).

[2] To the best of our knowledge, similar quotas have been enacted in Norway, Belgium and Italy. Germany, Spain and the Netherlands enacted soft-law quotas with no sanctions. The UK opted for providing guidelines.(`https://www.economist.com/business/2018/02/17/ten-years-on-from-norways-quota-for-women-on-corporate-boards`)

[3] The text of the law and further details can be found here: `https://www.entreprises.gouv.fr/politique-et-enjeux/mixite-et-egalite-professionnelle-dans-entreprises`

(2019) and assume that female hiring managers are better at assessing signals from female candidates, implying that the variance of the signal they receive is lower.[4]

The model predicts that as long as the manager's profit function is concave in the true ability of workers, a female candidate is then more likely to be hired or promoted if a female manager is assessing her application. A change in gender composition at the top of the managerial hierarchy can therefore slowly trickle down the organisation, as more women are hired in each layer down the ladder. The dynamic nature of our model highlights that the effect is likely to propagate slowly, with a speed that depends on the turnover and promotion rate as well as on the gender ratio in the labour force.

We then move to the data and assess whether the reform had detectable effects at any level of the organisation and whether there is evidence of a trickle-down effect. We combine two data sources to answer this question by matching administrative employer-employee records with information on the composition of the board of director for publicly-listed firms using BoardEx.[5] Following Ahern and Dittmar (2012) and Bertrand et al. (2018), we exploit variation across publicly-listed companies in the pre-reform fraction of women on their board to identify the causal effect of the reform on firms. Given the share of women in corporate board can be correlated with firm unobservables (for instance, its management culture), we deal with this endogeneity problem by relying on an instrumental variable strategy. The intuition behind our IV is simple: companies that started with a larger share of women on their board had to make fewer changes to comply with the mandate, while companies that started with a smaller share had to make more changes. Finally, to verify if there are any significant trickle-down effects of the policy, we run a Panel-VAR on our data.

We find that the policy increases female employment and narrows the gender gap at the top layers of the firm, but *not* at the lower layers. For instance, an increase in the share of women on corporate boards from 10 to 20 percent raises the number of female new hires by 39 percent among senior executives and professionals in the treated sample and lowers the gender wage gap by nearly 2 percent. However, we find that the trickle-down effect of a rise in female board share is limited. Our counterfactual exercises suggest that in order to significantly shrink gender wage and employment gaps in lower layers of the firm, the share of women in middle management should be raised instead.

[4]There is a separate theoretical literature that considers a matching model of the labour market in the presence of uncertainty and learning about ability that provides a simple unified framework for analysing the dynamics of jobs and wages within firms and in the labour market. See for instance Pastorino (2015). Our model does not include learning about ability of worker over time.

[5]More information about the content of these data sources are provided under the data section.

Related Literature A growing literature has focused on the role of female leadership in determining gender-specific outcomes. While women in general are likely to be more sensitive to the issues of gender representation, discriminate less and be able to better assess their female coworkers (Cornell and Welch 1996) relative to men, women that do break the glass ceiling and do make it into top management positions might behave as their male counterparts[6]. Recent evidence from academic committees shows that having a higher share of women can have a negative effect on the probability that women is hired (Bagues et al. 2017, Deschamps 2018). In the context of firms a series of recent papers have looked for empirical evidence of an effect of female leadership on gender-specific outcomes. Contributions looking at the effect of female ownership (Cardoso and Winter-Ebmer 2010), female executives (Bhide 2019, Cardoso and Winter-Ebmer 2010) and female bosses (Kunze and Miller 2017) on the wage and representation of female workers/subordinates have generally found a positive impact[7].

Closer to our work, Bertrand et al. (2018) and Maida and Weber (2019) consider the role of female in the board of directors on firm-level gender outcomes, exploiting two similar board quota reforms in Norway and Italy respectively. Both these papers use a similar identification strategy, originally employed in Ahern and Dittmar (2012), and find no evidence of spillover effects on the representation of women at the top except the direct effect of raising the female membership on corporate boards. A related literature has considered the effect of female leadership on measures of overall firm performance, with mixed evidence. For example, Adams and Ferreira (2009) and Ahern and Dittmar (2012) study the effect of the gender composition of boards on firms' valuation and operating performance, while Matsa and Miller (2011) consider the probability of downsizing during the Great Recession.

In focusing on the role that organisational hierarchies play in propagating gender gaps we relate to a recent strand of literature on the importance of firms' internal hierarchies, including Caliendo et al. (2015) and Garicano and Van Zandt (2012). This literature has proposed models aimed at explaining the internal organisation of firms, how hierarchies are formed within firms as well as the assignment of workers across firm hierarchies. Yet, the literature has so far abstracted from the role that organisational structure has to play in determining gender-specific outcomes within firms. In this paper, we suggest that internal firm hierarchies aid our understanding of the effect of gender quotas on labour

[6]See the discussion in Adams and Funk (2012) on this point.

[7]A similar literature in political economy has discussed the impact of female political leadership on gender bias (e.g. Beaman et al. 2009 and Gagliarducci and Paserman 2012).

market outcomes across the firm. In particular, they facilitate predictions on the trickle-down effects of such a reform.

As such, our theoretical model borrows from the literature on internal labour markets (e.g. Pastorino 2015) and from papers studying the role of female leadership in determining the gender-specific outcomes of subordinates (e.g. Flabbi et al. 2019). Specifically, Flabbi et al. (2019) propose a simple signal extraction model where employers have incomplete information about workers' productivity, which is in turn influenced by their gender. They assume that executives are better-equipped to assess the skills of employees of the same gender. We borrow this assumption, in line with recent works in the socio-linguistic literature (e.g. Canary et al. 2009 and Scollon et al. 2011) and survey evidence (e.g. Angier and Axelrod 2014 and Ellison and Mullin 2014) suggesting the presence of communication frictions between men and women at work. Contrary to Flabbi et al. (2019), we allow for different managerial layers within firms and for the dynamic evolution of the gender composition in each layer. This helps us to endogenise potential trickle-down effects induced by changes at the top of the organisation and to explain the effect of quota policies on internal promotions.

Outline The rest of the article is organised as follows. In Section 2, we present the administrative data used in the paper. In Section 3, we describe the reform. In Section 4, we present our theoretical model. Section 5 introduces our empirical strategy and Section 6 displays our empirical results. In Section 7, we conclude our analysis and discuss further avenues of research.

2 Data

In this section, we first provide additional details about the data used in this paper. Next, we describe how we classify workers within firms into different hierarchical layers. Finally, we provide some descriptive evidence on the level and the evolution of the gender representation and wage gap over our sample period.

2.1 Data description

We merge two dataset in this article: French administrative data - DADS Postes and BoardEx.[8] It runs from 1994 onward[9] DADS Postes is based on mandatory annual reports filed by all firms with at least one employee. Our data therefore includes all private sector French workers except the self-employed. Hence, we are able to observe the entire workforce of a given firm. For each worker, the DADS reports gross and net wages, hours paid, occupation, gender and age. Although the data does not include worker identifiers, it tells us the worker's employment status, wage and occupation title in the previous year if the worker was employed in the same firm. Each firm in France is assigned a unique identifier (SIREN code) which allows us to keep track of them over time. The SIREN code also facilitates the merging of the DADS Postes with the BoardEx data.

The BoardEx data provides us valuable information about the composition of the board of directors for listed firms. The BoardEx data runs from 1999 to 2017 and contains information on the gender, age, experience, education and position of the members of the board of directors, as well as their year of entry and exit. Merging the BoardEx data and DADS Postes enables us to study the impact of the share of women in the board of directors on subordinates in the firm. For our analysis we eliminate firms with less than one full time equivalent employee as well as employees who worked less than 40 percent of a full-time equivalent worker.

2.2 Classifying occupations into layers

To study the effect of policy on different layers within the firm, we first need to categorise occupations into different layers. The French administrative data provides us the unique opportunity to look at the effects of this reform on different organisational layers within firms, especially layers at the top of the firm hierarchy. We borrow the concept of a layer from the theory of firm hierarchy proposed by Garicano (2000). According to this theory, a layer is a group of employees with similar characteristics who perform similar tasks within the organisation. Following Caliendo et al. (2015), we assign employees to different managerial layers based on their occupations and organise these layers into an hierarchy. The purpose of this exercise is not to separate employees in a firm according to the functional characteristics of the tasks they perform (eg. engineers, lawyers, accountants, managers) but rather on the basis of their hierarchical level in the organisation, that

[8] DADS stands for Déclaration Annuelle des Données Sociales in French. DADS Postes is a restricted data set and is administered by the French National Statistical Institute (INSEE).

[9] At the time of writing, the last year available of DADS Postes was 2016.

is, on the basis of the number of layers of subordinates that they have below them.

Recent research has shown that classifying the data by layers is economically meaningful.[10] In our specific context, organising the data in this manner is insightful because we are not only able to investigate the direct effect of the reform at the top of the firm hierarchy, where gender gaps are widest, but also the indirect effects on women employees in subordinate layers. In a hierarchical organisation, changes at the top managerial layer can trickle down the organisational ladder. One of the aims of our empirical analysis is to assess the propagation channel of a board reform on workers further down the hierarchical structure of the firm. Here, we follow Caliendo et al. (2015) and use the occupation codes observed in our data to categorise workers into four layers[11].

1. Chief Executive Officers, top management and firm owners (occupation codes 21-23)

2. Senior executives and professionals, comprising of senior management and senior technical professionals (occupation codes 31-38)

3. Intermediate professions, middle management and technicians (occupation codes 42-48)

4. Employees such as administrative staff, security workers, sales workers and blue-collar workers (occupation codes 52-56 and 62-69)

In the next subsection, we examine the differences in gender wage and representation gaps between these hierarchical layers.

2.3 Descriptive Statistics

Before investigating the differences in gender gaps across the four layers of firm hierarchy, it would be instructive to first consider some basic wage and employment statistics. In Table 1, we document the gender wage gap between across different layers in 1994 and 2016. We calculate the wage gap for each hierarchical layer as the ratio of the average male to female hourly wages. There are two key takeaways. First, the gender wage gap has been declining for all four layers of hierarchy from 1994 to 2016. Second, the gender wage gap is higher in top layers of firm hierarchy, with men earning on average 21 percent

[10] For more details refer to Caliendo et al. (2015) and references therein.

[11] Occupation codes in the French data are based Socio-Professional Categories. Additional information on these occupation codes can be found on `https://www.insee.fr/fr/information/2497958`

more than women at the top layer and only around 8 percent more at the bottom layer of firm hierarchy in 2016.

Furthermore, the share of women at top layers of firm hierarchy is on average lower at the top layers of firm hierarchy and higher at lower layers of firm hierarchy, as shown in Table 1. For instance, in 2016, layer 1 consisted of 20% of women, while 51% of total employment at the lowest layer (4) consisted of women. There has been noticeable improvement in female representation with the share of women in layer 2 (Senior professionals and Management) increasing from 20 percent in 1994 to over 35 percent in 2016. However, the share of women in the top layer has barely improved from 1994 to 2016.

Table 1: Descriptive Statistics

		Layers			
	Year	1	2	3	4
Gender Wage Gap	1994	42	19	15	11
(in %)	2016	21	15	9	8
Share of Women	1994	19	20	31	34
(in %)	2016	20	35	42	51
		Treated		Intent-to-treat	
		Male	Female	Male	Female
Gross Wages	Mean	36,654	25,631	35,671	24,920
(1994-2016)	St. Dev	81,038	30,074	80,072	29,947

Note: The Gender Wage Gap is calculated as the ratio of the average male to female hourly wage for each of the four layers. In tha above table, they are expressed in percentages. Share of women are calculated as fraction of total employment of women in each layer. Sample statistics on gross annual wages are separately calculated for treated vs. intent-to-treat firms for both men and women.

3 The Gender Quota Reform in France

On the 20th of January 2010, the French Parliament voted in favour of a law imposing a quota on female board membership for publicly-listed firms. This law was promulgated by the French president a year later on the 27th of January 2011. According to the law, women had to constitute 40 percent of corporate boards by 2017, with an interim deadline of 20 percent by 2014.

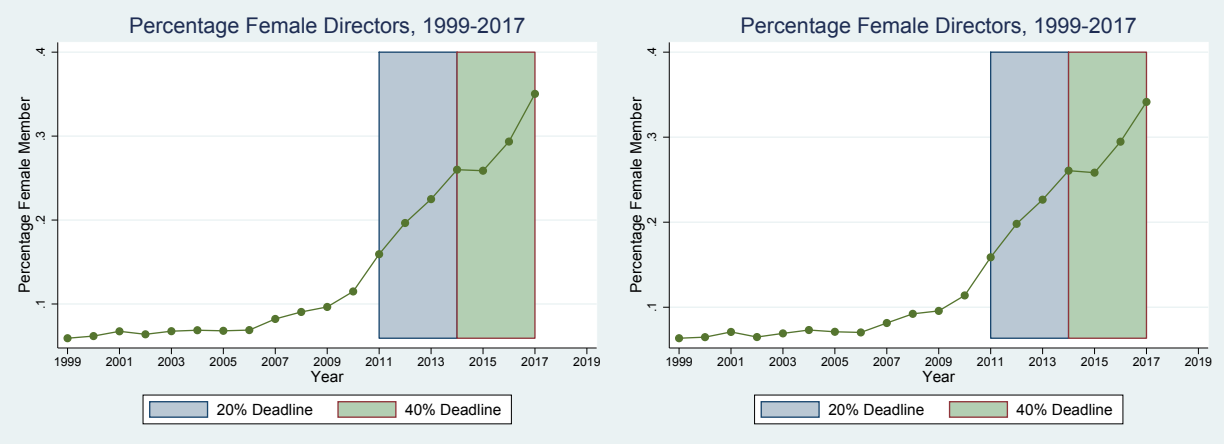
In the case of Norway, Ahern and Dittmar (2012) found that firms with a lower share of

female board members prior to the reform in 2003 were more likely to de-list, perhaps to avoid the gender quota. We address this concern by checking whether female board share in 2010 significantly affects the probability of exiting treatment. The results are presented in Table A1. A firm is considered to have exited treatment if it was listed in 2010 but subsequently de-listed after 2011. As can be seen from the OLS and Probit specifications, both with and without industry fixed effects, the share of female board members, FSB_{j2010}, has no significantly positive effect on the probability of exit. In addition, as will be shown in what follows, the share of women directors in the intent-to-treat and treated samples have very similar trends. As such, it is unlikely that firms selectively de-listed to avoid the gender quota in the case of France. Nevertheless, in our empirical analysis in the later section, we show results for both the intent-to-treat and treated samples as a robustness check. The intent-to-treat sample consists of firms that were publicly listed in 2011, regardless of whether they remained so, while the treated sample consists of firms that were listed in 2011 as well as throughout the entire reform period.

The law had an immediate impact on the share of women on corporate boards in publicly-listed firms, as can be seen in Figure 1. Figure 1a shows the share of women on the board of directors of firms that were publicly-listed in 2010, while Figure 1b presents the share of women in firms that were publicly-listed in 2010 and remained so after the reform was passed. From both figures, the average share of women on the board of directors hovered just above 10 percent in 2010 and increased sharply from 2011 , reaching over 25 percent by the 2014 and around 34 percent by 2017. This is the case for both the intent-to-treat and treated samples.

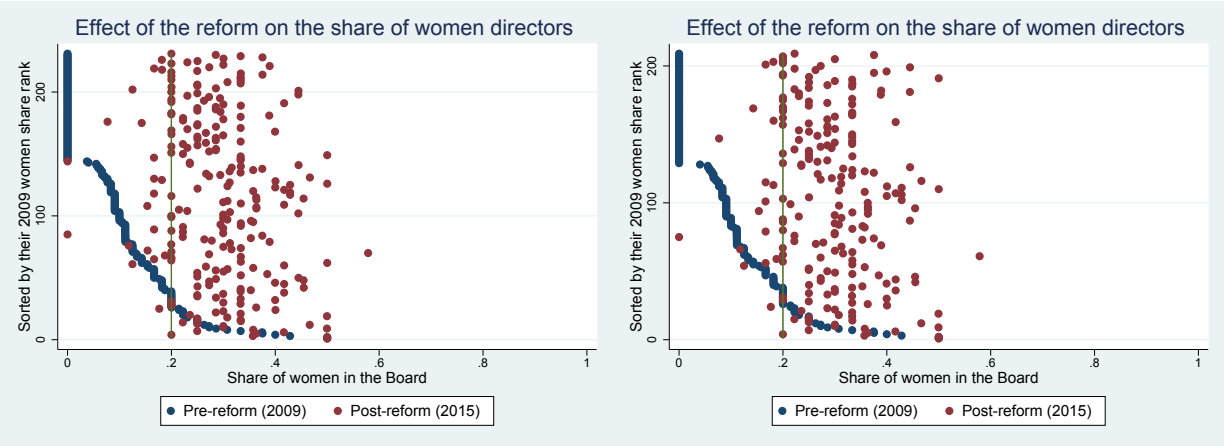
Next, we investigate how many firms met the 20 percent quota prior to the reform and after the first deadline in 2014. Figures 1c and 1d plot the share of women on the board of directors of each of the publicly-listed firms in our sample for the intent-to-treat and treated groups of firms respectively. Approximately, 50 percent of the publicly-listed firms in our data had no women in their board prior to the reform. The rest of the firms had a share of women between 10 and 50 percent. By 2015, approximately 95 percent of the firms complied with the reform in our sample. Evidence from these figures therefore suggests that the quota policy has succeeded in opening the doors of boardrooms to women.

While publicly-listed firms may have increased the share of women on their board of directors, women directors may not have been assigned to key roles on the board. This may then limit the ramifications of the reform on gender representation within the firm. Figure A1 presents the average share of CEOs who are women, the share of women in are



(a) Intent-to-Treat

(b) Treated



(c) Intent-to-Treat

(d) Treated

Figure 1: Compliance with gender quota reform

Executive Directors and Non-Executive Directors, as well the share of women who are on the HR Committee of the Board. From Figures A1a and A1b, there is some improvement in the share of CEOS who are women for both intent-to-treat and treated firms, from around 2 percent in 2010 to 5 percent in 2014 and 13 percent in 2017. From A1c and A1d, the share of Executive Directors who are women increases very modestly, with most of the increase in the share of women occurring among Non-Executive Directors. The limited increase in the share of women in these key roles on the board is in line with the findings given by Rebérioux and Roudaut (2019). Apart from occupying CEO and Executive roles, female directors may have a greater influence on labour market outcomes for women in the firm if they are in charge of HR. As such, Figures A1e and A1f display the share of women on the HR committee of the board of directors. The share of women directors in HR committees increases mostly in tandem with the share of women on the Board, increasing from under ten percent in 2010 to around 28 percent in 2014 and 40 percent in

2017.

We also expect that the characteristics of women on the board of directors may change due to the reform, which may attenuate the impact of female board share on gender gaps in the firm. For instance, if new female board members are less experienced sit on a greater number of boards than their male counterparts. Figure A2 shows the average age, number of current boards and the number of years of board experience of men and women directors for the intent-to-treat and treated sample. From Figures A2a and A2b, while women directors are younger on average than men, there is minimal change in the approximately 5 year age difference over the reform period. Also, contrary to what we might expect, the number of boards women directors currently sit on does not increase over the reform period, with women directors serving on average around 1.8 boards in 2010 and 2017, as seen in Figures A2c and A2d. In comparison, the average number of boards that men directors belong to has declined from 2.2 to just above 1.5, below that of women directors. Regarding the experience of board of directors, the average number of years of experience on corporate boards of men increased, both in absolute terms and relative to women. While the average years of experience of women declined from around 5 in 2010 to just above 4 in 2014 and rose again to just above 5 in 2017, that of men has increased from around 7.5 years to over 9 years in 2017. As such, the experience gap between men and women widens somewhat during the reform period. Nevertheless, similar to Norway, as explored in Bertrand et al. (2018) and Ahern and Dittmar (2012), the gender quota did not bring about a large decline in the age and experience of women directors.

In addition, we also consider whether firms met the gender quota by increasing the size of the board or by replacing men members of the board with women. From Figure A3, it is evident that firms did primarily the latter, as the average number of board members declined slightly, from 10 to just under 9 members between 2011 and 2017 in both the intent-to-treat and treated samples.

Hence, the Loi Copé Zimmerman faced strong compliance from publicly-listed firms, with the average share of women on boards increasing in both the intent-to-treat and treated samples. We find no evidence that firms selectively de-listed to avoid the gender quota. Also, while the board experience of women directors declined relative to men, the age and number of current boards did not vary differently across the genders. The impact of the reform on the female representation in key board positions was limited, as the share of women directors with CEO or Executive positions barely increased. However,

the share of women directors in a HR committee rose substantially during this period, in tandem with the increase in female representation on the boards. We would therefore expect the women directors to have some say on the hiring and wages of other employees in the firm. In the next section, we present a theoretical model that seeks to explain how the board quota reform may impact the gender wage and representation gaps across the firm hierarchy.

4 Theoretical Framework

The goal of our analysis is to investigate whether the board quota reform had any detectable effect on the gender wage and representation gaps among firms affected by the quota. How should a gender quota on the board of directors affect these gender gaps within a given firm? We discuss the effect of the reform within the framework of a simple theoretical model that we present in this section. The theoretical framework will serve as the basis for the empirical analysis we carry out in Section 6. The model considers the firm as a complex hierarchical organisation, where internal and external labour markets co-exist and frictions slow down the ability of firms to adjust to any change in their environment. The framework builds on previous work on gender inequality, internal labour markets and organisational hierarchies.

4.1 The Firm

We describe a (big) firm as a hierarchical organisation, consisting of a set of K layers of increasing hierarchical responsibility. Tasks in each layer are organised into jobs of varied level of complexity ω. Workers in layers $k-1$ are responsible for hiring workers in layer k and decide on promotions within the layer. Wages are set at the layer level according to a piece-rate contract θ_k, with jobs of complexity ω offering a wage $w_k = \theta_k \omega$.

Each layer is of a fixed size and jobs are exogeneously destroyed at a rate δ. Whenever a job in layer k is vacant, it is assigned to a randomly chosen worker in layer $k-1$ who is then responsible for the hiring process. When applying for a vacant job, applicants draw their job-specific skills level from a type specific observable distribution. Workers' realised job-specific skills on the other hand are not directly measurable. Whenever the hiring manager meets a potential candidate i she observes a noisy signal, s_i, of the candidate's true job-specific productivity, q_i as follows

$$s_i = q_i + \epsilon_i$$

$$\epsilon_i \sim \mathcal{N}(0, \sigma_\epsilon)$$

$$q_i \sim \mathcal{N}(\mu_i(\omega'|k), \sigma)$$

where ϵ_i is a random noise and μ_i is the worker i's average skill-level for a new job ω' in layer k.[12] Let us define a job as a tuple-(ω, k), with ω_0 representing non-employment. We further assume that all workers currently performing jobs of the same skill level ω draw their new job's (ω', k)-specific skill level from the same distribution. This implies that a worker's type at the moment the hiring decision is taken is summarised by her current job's skill level ω and her signal s_i. Under this assumption, $\mu_i(\omega'|k)$ can then be rewritten as $\mu(\omega', \omega|k)$.

Contracts are binding and separations occur only if the worker is hit by the exogenous separation shock or if she is promoted as described below. After the worker is hired, the firm pays a one-time productivity penalty $F_k(q_i)$, which is assumed to be a convex function of q_i and that can be thought of as a retraining cost. Once the productivity penalty is paid, production starts and per period profits from the firm-worker match are given by

$$\pi_k(\omega') = (1 - \theta_k)\omega'$$

Workers in a position ω receive a promotion offer for a job $\omega^p = \gamma\omega$ with an exogenous arrival rate δ^p where γ is the productivity of the new job relative to the current one, which is assumed to be fixed. We assume that whenever a worker is promoted the incumbent manager gets the continuation value of the destroyed match, implying that the value of a match for the hiring manager does not depend on the internal poaching probability. Given a subjective discount factor β, the value of hiring a worker i for a job ω' in layer k is then given by

$$\Pi_k(\omega', \omega|s_i) = E[F_k(q)|s_i, \omega] + \frac{1}{1 - \beta(1 - \delta)}\pi_k(\omega')$$

Whenever a job is destroyed a new job with type ω' drawn from the exogenous distribution $f_k(\omega')$ is created and a vacancy is posted on the external market. We assume that the external selection process is costly but not time consuming. A hiring manager post-

[12] Throughout the paper we use the superscript $'$ to define the characteristics of the new job a worker's i is being considered for. Accordingly, ω represents the productivity a worker's current job and ω' the productivity of the job she is being considered for.

ing a vacancy on the external market can screen a randomly drawn worker from the poll of unemployed workers at a cost $\chi_k(\omega')$. After screening a worker i the hiring manager observes the noisy signal s_i and takes the hiring decision. If the worker is not hired, the hiring manager can pay $\chi_k(\omega')$ and screen another worker. The hiring manager therefore hires the worker i if the value of hiring, $\Pi_k(\omega', \omega|s_i)$, is bigger than the value of waiting, $V_k(\omega')$. Given that $\Pi_k(\omega', \omega|s_i)$ is strictly increasing in s_i (conditional on ω), the hiring manager hires only if $s_i \geq \tilde{s}_k(\omega'|\omega)$, with $\tilde{s}_k(\omega'|\omega)$ the smallest value of s_i that makes hiring profitable. We further assume that $V_k(\omega') > \chi_k(\omega')$ such that it is always optimal to keep searching until the vacancy is filled.

Finally, a worker i that is being considered for a promotion is promoted if

$$\Pi_k(\gamma\omega, \omega|s_i) > \frac{1}{1-\beta(1-\delta)}\pi_k(\omega)$$

4.2 Gender and Discrimination

Next, we assume that workers differ in a second binary dimension. Namely, workers can either be males, m, or females, f. While the difference between these two types of workers/hiring managers can be modelled in several ways, we follow Flabbi et al. (2019) and assume that they differ only in their ability to screen a female worker's ability. More specifically, while the signal received by the hiring manager does not depend on their gender, their prior on the distribution of ϵ_i differs, with $\sigma^{mf} > \sigma^{ff}$ where σ^{mf} (σ^{ff}) is the prior on the variance of the noise when the hiring manager is a male (female) and the applicant is a female[13]. We assume that whenever a worker applies to a position in layer k her application is assigned to a randomly picked worker in layer $k-1$, who then take the hiring decision. We define a worker in charge of a recruitment as the hiring manager.

How does having a male rather than a female hiring manager affect the probability that a female candidate with given signalled ability s_i is hired? Note that the key difference between the two hiring managers is on the informativeness of the signal: for a given signal s_i the male hiring manager is more uncertain about the true quality q_i of the candidate. His belief about the distribution of possible q_i given an observed s_i is more dispersed, while having the same conditional mean. The effect of such difference in variances on the expected value of hiring depends on the second derivative of the profit function with respect to q_i. If the profit function is concave then a higher noise in the signal reduces expected profits, negatively affecting the probability of being hired. As a result a male hiring

[13]For simplicity we do not model differences in the case of a male applicant.

manager reservation signal for a female candidate $\tilde{s}_f$ will be higher than the reservation signal for a female candidate $\tilde{s}_m$.

The main implication for our model is simple: if a female candidate with signal s_i is assessed by a male hiring manager, her chances of being hired are lower than those of a male candidate with the same signal. In organisations where the share of men in layer $k-1$ is higher, the probability of a female candidate to be assessed by a male hiring manager is higher and she will be, on average, assigned to lower quality jobs offering lower wages. As a result these organisations will tend to have a higher gender wage gap in layer k.

Note that adding this additional dimension of heterogeneity implies that a worker i's-type at the time an hiring or promotion decision is taken is summarised by (s_i, ω, g), with $g \in (m, f)$ being the worker's gender. At the same time the hiring manager type is summarised by its gender $h \in (m, f)$.

Probability of Being Hired. Define the share of females (males) in layer k as $l_k(f)$ ($l_k(m) = 1 - l_k(f)$). The probability that a worker i of type ω and g being considered for a job ω' in layer k is hired is the sum of the probability of being hired conditional on the two types of hiring managers (female and male) weighted by their respective share

$$\sum_{h \in m,f} l_{k-1}(h) P(s_i > \tilde{s}_k(\omega' | h, g, \omega)).$$

As long as

$$\tilde{s}_k(\omega' | m, f, \omega) > \tilde{s}_k(\omega' | f, f, \omega),$$

a female candidate's probability of being hired will positively depend on the relative share of female and male workers in layer $k-1$, denoted $l_{k-1}(f)$. This implies that a change in gender representation gap in layer $k-1$ improves the probability that new women are hired in layer k.

Average Wage Change. The expected change in the wage for a worker in layer k is strictly related to the probability of promotion. The change in wage conditional on a promotion for a worker earning w in layer k is given by

$$\Delta w = \theta_k(\gamma - 1)\omega.$$

Since the wage increases only after a promotion, the expected change in a workers wage

is then just Δw weighted by the promotion probability

$$E_k[\Delta w|\omega, g] = \theta_k(\gamma - 1)\omega \left[\delta_k^p \sum_{h \in m,f} l_{k-1}(h) P(s > \tilde{s}_k(\gamma\omega|h, g, \omega)) \right],$$

where the term in squared brackets is the probability of promotion for a worker of type (ω, g) in layer k and δ^p is the promotion opportunities arrival rate in layer k.

4.3 Propagation of Gender Gaps

One of the key objectives of our analysis is to assess how the change in gender representation at the top of an organisation propagates to lower hierarchical layers. Our model gives us a way to formally inspect the channels of this *trickle-down effect*. In this section we present how our model predicts a change at the top propagates within the organisation and how these predictions can guide our empirical analysis.

Gender Representation Gap. The relative probability that an external hire is female or male plays a central role in the evolution of the share of each gender in a given layer. Let us define the share of unemployed workers of gender g as $l_0(g)$. The probability that a female worker is hired on the external market for a job ω in layer k is given by

$$P_k(f \text{ new hire}|\omega) = \sum_{h \in m,f} l_{k-1}(h) \frac{l_0(f) P(s > \tilde{s}_k(\omega'|h, f, \omega_0))}{l_0(f) P(s > \tilde{s}_k(\omega'|h, f, \omega_0)) + l_0(m) P(s > \tilde{s}_k(\omega'|h, m, \omega_0))},$$

which is simply equal to the probability that the first external worker (i.e. an ω_0 worker) being considered for the position is hired while being a female rather than a male. The probability that a male worker is hired on the external market for the same job is then $1 - P_k(f \text{ new hire}|\omega)$. Let us use the hat notation to define a firm-level variable in the next period. For big firms the law of motion for the share of females in layer k is then given by[14]

$$\hat{l}_k(f) = (1 - \delta) l_k(f) + \delta \int_\omega P_k(f \text{ new hire}|\omega) dF_k(\omega),$$

where the first term represents the contribution of the past representation gap and the second term accounts for the contribution of new hires. We define the current gender

[14] We consider a big firm to be a firm big enough to apply the law of large numbers in the derivation of the equations presented below.

representation gap in layer k as

$$\zeta_k = \frac{l_k(f)}{l_k(h)} = \frac{l_k(f)}{1 - l_k(f)}.$$

Gender Wage Gap Finally, in the gender specific average wage in layer k evolves as

$$\begin{aligned}\hat{W}_k(g) =&(1-\delta)[(1-\delta^p) + \delta(1-\delta^p)]W_k(g) \\ &+ \delta\theta_k \int_\omega \omega P_k(g \text{ new hire}|\omega) f_k(\omega) d\omega \\ &+ (1-\delta)\delta^p(\gamma-1)W_k(g) \int_\omega \sum_{h \in m,f} l_{k-1}(h) P(s > \tilde{s}_k(\gamma\omega|h,g,\omega)) l_k(\omega,g) d\omega,\end{aligned}$$

where the second term is the contribution of new hires and the third term is the contribution of stayers being promoted, with $l_k(\omega, g)$ being the joint distribution of gender, g, and job type, ω, in layer k. The gender wage gap then is simply given by

$$\Gamma_k = \frac{W_k(f)}{W_k(m)}$$

Discussion Our model highlights how the evolution of the gender wage and representation gaps depends on the model fundamentals. In particular it shows that the future period gender representation gap is a function of the current gender representation in layer k and $k+1$, conditional on the exogenous parameters determining the turnover rate, δ, and the distribution of new jobs, $f_k(\omega)$.

$$\hat{\zeta}_k = \zeta(l_k(h), l_{k-1}(h)|\delta, f_k(\omega)) \tag{1}$$

The model therefore provides us with a set of theoretically founded exclusion restrictions that can be used in our empirical analysis. A similar set of exclusion restrictions can be identified for the gender wage gap, Γ_k, defined as the ratio between $W_k(f)$ and $W_k(m)$ in line with the definition used in Section 2

$$\hat{\Gamma}_k = \Gamma(W_k(f), W_k(m), l_k(\omega, g), l_{k-1}(h)|\delta, \delta^p, f_k(\omega)) \tag{2}$$

As expected the first thing to note is that the adjustment triggered by a change in representation gap at layer $k-1$, $l_{k-1}(h)$, is gradual. The pace at which this adjustment takes place depends on the turnover rate δ and the promotion rate δ_p. As these two rates tend

to 1, a shock to $l_{k-1}(h)$ triggers an immediate adjustment to the gender gaps. On the other hand, as these rates tend to zero the adjustment becomes slower as the workforce slowly adjusts over time. Depending on the turnover and promotion rate the effect of a change at the top of the organisation might therefore be detectable only after a few periods. Second, note that in our model a change at the top has a direct effect only at the second highest layer in the organisation. Its indirect effect propagates to the lower layers only as long $l_k(h)$ slowly adjusts down the organisational hierarchy. Accordingly, the effect of a change at the top should be felt in the upper layer first and then slowly trickle down the organisation. In our empirical section we use these results to guide our analysis. We also estimate panel VAR models that we interpret as linear approximations to 1 and 2.

5 Empirical Strategy

Our model suggests that changes at the top of the organisation will slowly trickle down its hierarchical ladder. In Section 3 we have shown that the reform had a direct effect on the gender composition of the board. In the next two sections we examine if this change had any significant effect on gender differences in layers further down the organisational structure of the firm. To identify the causal effect of the change in the composition of corporate boards on different outcomes of interest, we use firms' pre-quota female representation in the board as a measure of the exogenous change in the composition of the board required by the quota. We describe our identification strategy in more details in this section.

5.1 Identification Strategy

We aim to estimate the following:

$$y_{kjt} = cons + \alpha \text{FSB}_{jt} + \beta^{'} X_{kjt} + \gamma_{kj} + \delta_t + \epsilon_{kjt} \tag{3}$$
$$\epsilon_{kjt} \sim \text{i.i.d}$$

where the kjt subscript refers to layer k at firm j at time t. y_{kjt} refers to the outcome variable of interest at the layer-firm level at time t, while FSB_{jt} refers to the share of female board members in firm j at time t. X_{kjt} refers to time-varying control variables for layer k of firm j at time t, γ_{kj} refers to unobservable layer-firm fixed effects and δ_t is a set of year

dummies. ϵ_{kjt} is the error term. The main challenge in estimating the effect of the share of female board members on any outcome of interest is endogeneity. In other words, the unobserved heterogeneity could potentially be contemporaneously correlated with FSB_{jt} and would bias our estimates of α. For instance, the estimated α may capture the effect of time-varying unobserved firm characteristics such as management style that could be uninformative about the true effect of the board's gender composition on the outcome of interest. More precisely,

$$\mathbb{E}(\text{FSB}_{jt} \times \epsilon_{kjt}) \neq 0$$

We follow Ahern and Dittmar (2012) and Bertrand et al. (2018) to address the endogeneity concerns: we use the pre-quota share of female board members as the instrument for the current share of female board members, albeit with a slightly different specification to allow for our consideration of hierarchical layers. The key intuition is as follows: the lower the share of female board members prior to the law, the further the firms are from the quota and the more they must increase the number of women on their board. Otherwise put, the gender quota law gives us the first-stage in our identification strategy. Therefore, we instrument the share of female board of directors by the pre-quota board share FSB_{j2010}. On one hand, for $t < 2010$, we expect FSB_{jt} to be uncorrelated with ϵ_{kjt}. Specifically, FSB_{jt} is instrumented as follows:

$$\text{FSB}_{jt} = \rho \times \text{FSB}_{j2010} \times \delta_t + u_{jt} \tag{4}$$

Given the reform, we expect ρ to be negative, since firms with higher pre-quota share of female corporate board members should increase their share of women by less during the quota imposition period. As seen from Table 2, this is indeed the case. Upon approaching the deadline for the 20 percent quota and then the 40 percent quota, firms with higher pre-quota shares of female board members experience significantly lower increase in female board shares relative to 2011. This is true for both the intent-to-treat and treated groups of firms. $\text{FSB}_{j2010} \times \delta_t$ therefore seems to be a relevant instrument for FSB_{jt}.

Having discussed the empirical strategy, we now move on to the regression results. In the next section, we investigate the impact of the share of women on the board of directors on the labour market outcomes on each layer of hierarchy in the firm.

Table 2: Checking instrument relevance: Estimates of first-stage regression

	ITT	ITT + FE	Treated	Treated + FE
Dependent Var: FSB_{jt}				
FSB_{j2010}	0.662^{***}		0.652^{***}	
	(0.047)		(0.054)	
$2012 \times FSB_{j2010}$	-0.160^{***}	-0.164^{***}	-0.108^{**}	-0.110^{**}
	(0.050)	(0.049)	(0.044)	(0.044)
$2013 \times FSB_{j2010}$	-0.267^{***}	-0.295^{***}	-0.223^{***}	-0.232^{***}
	(0.050)	(0.052)	(0.053)	(0.053)
$2014 \times FSB_{j2010}$	-0.381^{***}	-0.404^{***}	-0.367^{***}	-0.374^{***}
	(0.059)	(0.062)	(0.065)	(0.065)
$2015 \times FSB_{j2010}$	-0.362^{***}	-0.403^{***}	-0.382^{***}	-0.392^{***}
	(0.057)	(0.057)	(0.058)	(0.057)
$2016 \times FSB_{j2010}$	-0.411^{***}	-0.462^{***}	-0.443^{***}	-0.449^{***}
	(0.068)	(0.068)	(0.070)	(0.069)
Industry-Time effects	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	No	Yes
Observations	1296	1296	1133	1133

Note: The base year is 2011. All regressions include industry-year effects. Standard errors are reported in parentheses.

6 Results

We divide our empirical analysis into two parts. We start by presenting our results of the effect of the reform on firm-layer level outcomes. Next, we present our results using individual-level data.

6.0.1 Firm-layer level

We examine the impact of female board share on gender wage and representation gaps. At the firm-layer level, we define gender wage gap as the log difference in the average wage between men and women at layer k, firm j and time t. As for gender representation gaps, we study the number of newly-hired women and compared this to the number of new hires in total.

The first set of specifications that we test is based on Equation 3 and uses Equation 4 as first stage. For each outcome variable, we present the results from the OLS specification, followed by the IV specification, for both the intent-to-treat and treated samples. All regression specifications displayed in this subsection include industry-year effects and firm

fixed effects. In addition, due to the small number of firms with layer 1 (Top management and firm owners), the firm-layer level regressions are only run for layer 2 (Senior executives and professionals), layer 3 (Intermediate professions and middle management) and layer 4 (Administrative staff and blue-collar workers).

Recall that the model predicts that a higher share of females in layer k, should increase the hiring rate of women in layer $k+1$. To test this prediction, we consider the impact of the share of women directors, FSB_{jt}, on the number of women among new hires. In line with our model, we expect to see a greater effect on top layers. We consider workers to be new hires if they only joined the firm at time t. Conversely, workers are considered incumbents or non new-hires if they were present at the firm at time $t-1$. Table 3 displays the results from the OLS and IV regressions of the log number of female new hires and log number of new hires on the share of female board members and other controls. From the OLS specification in Table 3, a rise in female board share only has a negative and significant effect on the log sum of women newly-hired and the log sum of new hires in the lowest layer for the treated sample. On the contrary, female board share has a positive but insignificant effect on the log sum of women newly-hired and the log sum of new hires for layer 2 and a negative insignificant effect on layer 3. From the IV specification in Table 3, once we instrument female board share as described above, we find that female board share has a significant positive effect on the number of new hires and the number of newly-hired women for layer 2 in both the intent-to-treat and treated samples. For example, an increase in the share of women on corporate boards by from 10 to 20 percent raises the number of female new hires by $(e^{1.595}-1)*10 = 39.2$ percent for layer 2 for the treated sample, as displayed in column 7 of Table 3 . To compare this to the total new hires, column 8 of the same table shows that for the same change in female board share, the total number of hires increases by $(e^{1.675}-1)*10 = 43.3$ percent.

The model also predicts that an increase in FSB_{jt} should decrease the gender wage gap, in particular for top layers of the firm. Table 4 presents the results from the regression of the log gender wage gap among incumbents on the share of women on the board of directors. From the IV specification in columns 2 and 4, an rise in female board share significantly decreases the gender wage gap for layer 3 in both the intent-to-treat and treated samples. For instance, in the treated sample, an increase in female board share from 10 to 20 percent would narrow the gender wage gap by $(e^{-0.211}-1)*10 = 1.90$ percent. On the contrary, we find no significant impact on the gender wage gap in lower layers of firm hierarchy. To find out whether the narrowing of the gender wage gap caused by the rise in female board share in layer 2 is due to an increase in female wages in layer 2 or a decline in male wages,

Table 3: Effect of female board share on the number of new hires and newly-hired women

	Intent-to-Treat				Treated			
	OLS		IV		OLS		IV	
	Women	Total	Women	Total	Women	Total	Women	Total
				Layer 2				
FSB_{jt}	0.324	0.303	1.962**	1.906***	0.158	0.247	1.595**	1.674**
	(0.557)	(0.458)	(0.810)	(0.707)	(0.626)	(0.514)	(0.785)	(0.755)
Observations	672	672	672	672	575	575	575	575
				Layer 3				
FSB_{jt}	−0.152	-0.224	0.084	-0.064	0.499	0.088	-0.772	-1.009
	(0.868)	(0.730)	(1.223)	(1.096)	(0.966)	(0.766)	(1.560)	(1.178)
Observations	443	443	443	443	391	391	391	391
				Layer 4				
FSB_{jt}	−0.631	−0.958	−3.195**	−3.276*	−1.070*	−1.445**	−1.201	−1.972
	(0.576)	(0.641)	(1.609)	(1.950)	(0.619)	(0.651)	(1.557)	(1.683)
Observations	562	562	562	562	490	490	490	490

Note: All regressions include industry-year effects and firm-layer fixed effects. Controls include average female and male age, and average female and male age squared at the firm-layer level. Standard errors are clustered at the firm level and are reported in parentheses. Firm-layer observations are weighted by their employment size.

we re-run the regression at the firm-layer level with the average female wage and average male wage as the outcome variables. The results of these regressions are presented in Table A2 . For layer 2, we observe that a rise in FSB_{jt} significantly increases the mean wage of women in the treated group, while insignificantly increasing the mean wage of women in the intent-to-treat group. Also, higher female board share has a positive but insignificant impact on average male wage in layer 2. It has no significant impact on the mean wages of men or women in the lower layers. Hence, it seems that a higher female board share shrinks the gender wage gap among incumbent workers, but not at the expense of men in the second layer of the firm.

Contrary to incumbent workers, an increase in the share of female members on corporate boards on gender does not significantly impact the gender wage gap among new hires for all layers, as shown in the last 4 columns of Table 4. Table A2 suggests that this is due to the fact that an increase in FSB_{jt} significantly increases the average wage of men and women in layer 3 to a similar extent, such that the difference between them does not significantly change. For instance, a rise in the share of women on the board from 10 to 20 percent would increase the average wage of women by $(e^{0.428} - 1) * 10 = 5.34$ percent and that of men by $(e^{0.454} - 1) * 10 = 5.74$ percent in layer 2 for the treated sample of firms. As such, while a greater share of female board members significantly narrows the gender wage gap, it only does so for the next subordinate layer among incumbents and not among new hires.

Finally, we run two robustness checks. First, we confirm that the instrument is relevant at the firm-layer level. The results of the first stage at the firm-layer level are reported in Table A3. It is evident that, just as for the firm-level specification, firms with higher female board share in 2010 increase the share of women on their board by less relative to 2011.

Next, we check for evidence of different pre-reform trends in layer-level gender gaps among firms with varying-levels of female board share in 2010. Table A4 shows the results from the regression of the gender wage and representation gap on the female board share in 2010 interacted with a time trend for the pre-reform period, from 1999-2009, at the firm-layer level. From the interaction term $FSB_{j2010} * \text{Year}$, we find that pre-reform trends in gender wage and employment gaps in all layers do not vary significantly with female board share. This therefore suggests that prior to the reform, firms with higher female board share were not on different linear time trends compared to firms with lower female board share.

Table 4: Effect of female board share on the log gender wage gap among incumbents and new hires

	Incumbents				New Hires			
	Intent-to-Treat		Treated		Intent-to-Treat		Treated	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
				Layer 2				
FSB_{jt}	-0.022	-0.227^{***}	-0.019	-0.211^{**}	0.020	-0.062	0.006	0.025
	(0.036)	(0.086)	(0.041)	(0.101)	(0.088)	(0.181)	(0.094)	(0.165)
Observations	951	951	844	844	672	672	575	575
				Layer 3				
FSB_{jt}	-0.006	0.111	0.004	0.155	0.208^{*}	-0.019	0.197	-0.195
	(0.049)	(0.124)	(0.057)	(0.127)	(0.115)	(0.353)	(0.125)	(0.423)
Observations	647	647	568	568	443	443	391	391
				Layer 4				
FSB_{jt}	0.013	-0.063	0.097	0.100	0.082	-0.535	0.106	0.186
	(0.115)	(0.272)	(0.124)	(0.242)	(0.158)	(0.616)	(0.187)	(0.559)
Observations	741	741	652	652	562	562	490	490

Note: All regressions include industry-year effects and firm-layer fixed effects. Controls include average female and male age, and average female and male age squared at the firm-layer level. Standard errors are clustered at the firm level and are reported in parentheses. Firm-layer observations are weighted by their employment size.

To sum up this subsection, the firm-layer level regressions have shown that a higher share of women on corporate boards does narrow the gender wage gap among non new-hires, it only does so significantly for the closest subordinate layer of the firm - layer 2. In addition, we find evidence that a greater share of women on corporate boards increases the number of new women hired, but once again only for layer 2.

6.0.2 Individual level

While our IV strategy allows us to deal with unobserved time-varying firm effects, moving to an individual-level analysis allows us to control for firm-layer-time effects. In what follows, we exploit information dis-aggregated at the worker level. Specifically, we estimate the following statistical model using worker-level data:

$$y_{ijkt} = cons + \alpha_1 \text{female}_{ijk} + \alpha_2 \text{female}_{ijk} \times \text{FSB}_{jt} + \alpha_3 \text{FSB}_{jt} + \beta X_{ijkt} + \eta_{jkt} + \epsilon_{ijkt} \quad (5)$$

where FSB_{jt} is once again the share of women in the board of directors, female_{ijk} is a an indicator equal to 1 if a worker i is a women and zero otherwise, X_{it} consists of worker time-varying controls. In addition, η_{jkt} refers to time-varying firm-layer effects, while ϵ_{ijkt} is the error term. As before, we instrument FSB_{jt} with the share of women directors in 2010 interacted with year dummies. In addition, we instrument $\text{female}_{ijk} \times \text{FSB}_{jt}$ with the triple interaction between the share of women on the board in 2010, year dummies and the female dummy. Evidently, by controlling for firm-layer time-varying effects, the coefficient α_3 will not be identified. On the other hand, our coefficient of interest is α_2, which measures the impact of an increase in female board share on the outcome variable y_{ijkt} for women relative to men, remains identified from thanks from the residual within firm-layer-year cross gender variation.

Our model predicts that following an increase in female board share, the promotion rate of women with respect to men should increase, especially at the top layers. In our model promotions are synonymous with positive changes in individual hourly wages. Therefore, in Table 5 we consider the impact of greater female board share on changes in individual hourly wage for the intent-to-treat and treated samples respectively. Changes in individual hourly wage is calculated for incumbent workers by subtracting their log hourly wage at $t-1$ from their log hourly wage at t. The top panels of Tables 5 displays the OLS results while the lower panels give the IV results. For the intent-to-treat sample, the IV results show that women experience a greater gain in wages relative to men when female board share increases for layers 1 and 2. However, this is only significant for layer

2. For instance, an increase in female board share from 10 to 20 percent would lead to a $(e^{0.033} - 1) * 10 = 0.34$ percentage points larger growth in log hourly wage for women relative to men in layer 2 for the intent-to-treat sample. Conversely, the coefficient on the interaction term $\text{female}_i \times \text{FSB}_{jt}$ is negative for layers 3 and 4, albeit insignificant. The results are similar for the treated sample. From the last 4 columns of Table 5, the share of women directors has a significantly positive effect on the change in wages of women relative to men for both layers 1 and 2, at the 10 and 5 percent significance level respectively. For example, women in the first layer of the treated sample face a $(e^{0.625} - 1) * 10 = 8.68$ percentage points greater increase in hourly wages relative to men for the same increase in female board share. Just as for the intent-to-treat sample, women in layers 3 and 4 experience a smaller gain in wages relative to men when female board share increases, but this is statistically insignificant.

The theoretical model allows only for wage promotions within a given layer, which is the mechanism through which workers get a pay raise. Empirically, few workers manage to cross hierarchical layers, which is perhaps unsurprising, since the socio-professional categories are quite distinct across layers. From Table A5, most workers remain in their hierarchical layer from one period to another and workers that do move across layers tend to move only one layer up or down. Nevertheless, our individual-level analysis allows us to consider promotion across layers, which we do next.

Table 6 presents the impact of female board share on the probability of being promoted from layer k in period $t-1$ to layer $k-1$ in period t, where $k = 2, 3, 4$, for the intent-to-treat and treated samples respectively. From both tables, it appears that greater female representation on the board of directors has some positive impact on the probability of promotion across layers of women relative to men, particularly in layers 2 and 4. For women who were in layer 2 for instance, an increase in female board share from 10 to 20 percent increases the probability that women are promoted from layer 2 to layer 1 by 0.4 percentage points, significant at the 1 percent level, for both samples.

Interestingly, a rise in female board share also has a significantly positive and sizeable impact on the probability of promotion across layers for women relative to men in layer 4. For instance, for the treated sample, as shown in the last 4 columns of Table 6, a one percentage point increase in female board share raises the probability that women are promoted by 0.63 percentage points relative to men. While we would expect female board share to increase relative promotion rates of women since our theoretical model assumes that employees in layer $k-1$ manage workers in layer k, the positive impact on relative

promotion rates from layer 4 to 3 (and lack thereof from layer 3 to 2) in both samples is surprising. One possible explanation is that the difficulty of moving up the firm hierarchy is not homogeneous across layers. Indeed, it is plausible that moving women from layer 4 (blue-collar workers and administrative staff) to layer 3 (middle management and technicians) is more feasible than from layer 3 to 2 (senior executive and professionals). However, in the absence of a clear mechanism, we refrain from drawing conclusions for the relative promotion rates from layer 4 to 3.

To sum up, the results for the individual-level analysis cohere with those from the firm-layer level analysis. In particular, greater female representation on the board of directors narrows the gender wage gap at the top layers of the firm. Since there are more observations at the individual-level, we are able to study the impact not only for layer 2, but also for layer 1, which could not be included in the firm-layer level analysis. The individual-level regressions suggest that women layer 2 and to some extent layer 1 experience greater gains in wages than men when female board share increases. In addition, we are able to explore relative changes in promotion probabilities in the individual-level analysis and find that the relative promotion probability for women increases with female board share for some layers.

6.1 Panel VAR

Next, we look more closely for evidence of a trickle down effect induced by changes at the top of the organisation and exploit the long time dimension of our administrative data. From our theoretical model, changes in the share of women in layer k are predicted to first narrow gender wage and employment gaps in layer $k+1$, then trickle down layers $k+2$ and so on. To test for the presence of trickle-down effects, we run the following panel VAR (P-VAR) from 1999 to 2016 at the firm level:

$$Y_{jt} = A_0 + A_1 Y_{jt-1} + U_{jt}$$

where

$$Y_{jt} = (\text{FSB}_{jt}, \text{WG}_{2jt}, \text{FS}_{2jt}, \ldots, \text{WG}_{4jt}, \text{FS}_{4jt})^T$$

As before, FSB_{jt} is the share of female board members in firm j at time t, FS_{kjt} refers to the share of women in layer k firm j at time t, and WG_{kjt} refers to the log ratio of average

male to female wages in layer k firm j at time t, for $k \in \{2, 3, 4\}$. In line with our model we assume that outcomes in layer k only affects outcomes in layer $k + l$, with $l > 0$. Our identification therefore rests on the assumption that $U_{j,t}$ is a lower triangular matrix. Since the P-VAR analysis can only be conducted with firms containing layers $2 - 4$ of firm hierarchy and with non-zero employment of men and women in each layer, we are left with 720 firm-level observations. On average, firms are observed for 5.8 years.

To quantify trickle-down effects, we compute the orthogonalized impulse response functions from the P-VAR model. Figure 2a displays the impact of a one standard deviation increase in the share of female board members on the share of women employed in the three subordinate layers of firms. In line with our model predictions, an increase in the share of female board members has an immediate impact on the share of women employed in the second layer of a firm's hierarchy. A delayed rise in the share of women is observed in layer 3, while minimal impact is seen in layer 4. However, while the sign and timing of the change in female share across the layers is consistent with the model, the effects are not significant at the five percent level.

Next, we consider the trickle-down effects of a rise in female board share on the gender wage gap across firm layers. Figure 2b displays the IRFs from the same one standard deviation increase on the share of female board members on the log ratio of average male to female wages within the three subordinate layers. It is clear from the figure that an increase in female board members leads to an immediate significant decline in the gender wage gap in layer 2. However, the gender wage gap is not significantly impacted over time for layers 3 and 4.

From Figures 2a and 2b, it is apparent that a rise in the share of women on the board of directors has a significant impact on gender gaps only in layer 2. Trickle-down effects on layers 3 and 4 are limited and insignificant over time. Given that gender wage and employment gaps are larger in higher layers, as previously shown in Figures **??** and **??**, the impact of increasing the female share in the board on layer 2 is important. Yet, it is clear that such a change does not do much to improve the relative outcomes of women at lower layers of the firm.

Another benefit of the P-VAR analysis is that it allows us to conduct counterfactual exercises to examine whether increasing the share of women at other layers of firm hierarchy has a greater impact on female representation in the firm. Having considered the limited the impact of an increase in the share of women at the board level on the bottom two layers of firm hierarchy, we now investigate whether a one standard deviation rise in the

share of women in layer 2 (Professionals and managers), would have a greater impact on female representation and promotion in the firm. From Figure 3a, increasing the share of female professionals and managers increases the share of women employed in layers 3 and 4 significantly, immediately for layer 3 and with some lag for layer 4. Both responses are significant at the five percent level. However, as shown in Figure 3b, there is scant effect on the gender wage gap in layers 3 and 4. Hence, while the raising the share of women professionals and managers has some positive impact on the share of women hired on layer 3 and eventually layer 4, the impact on wage gaps is muted.

The last counterfactual exercise examines the effect of an increase the share of women in layer 3 (Intermediate professions including middle management and technicians) on gender wage and employment gaps in layer 4 (administrative staff and blue-collar workers). Figures 4a and 4b present the IRFs from a one standard deviation increase in the share of women in layer 3 on the share of women employed and gender wage gap in layer 4. From Figure 4a, the positive shock in the share of women in layer 3 has an immediate positive effect on the share of women hired in layer 4. Also, the effect is fairly persistent and is significantly positive for approximately 4 years. In addition, we find that a rise in the share of women in layer 3 significantly lowers the gender wage gap in layer 4 and does so for the next 4 years.

The P-VAR results hence suggests that while increasing the share of female board members does have a positive effect on gender wage and employment gaps at the upper layers of the firm, there is limited trickle-down effect on lower layers of the firm. Counterfactual exercises suggest that raising the share of women professionals and managers (layer 2) in the firm instead would have a greater impact on the share of women hired in the lower layers of firm hierarchy. Even so, the final counterfactual exercise presented in Figures 4a and 4b reaffirms the notion that the impact on gender gaps in the lower layers is greatest when the share of women in the adjacent superior layer is increased. Together, the IV regression and P-VAR results suggest that imposing quotas on female leadership in firms has some positive effects on female employment and wages in the top adjacent subordinate layers, these effects do not necessarily trickle down the firm hierarchy in a significant way. Given that the gender gaps are larger in the upper two layers of the firm hierarchy, the impact of greater female board membership is not inconsequential. However, other policies beyond board quotas should also be considered if the goal is to improve labour market outcomes for a broader segment of women in firms.

Table 5: Female board share and change in individual log hourly wage

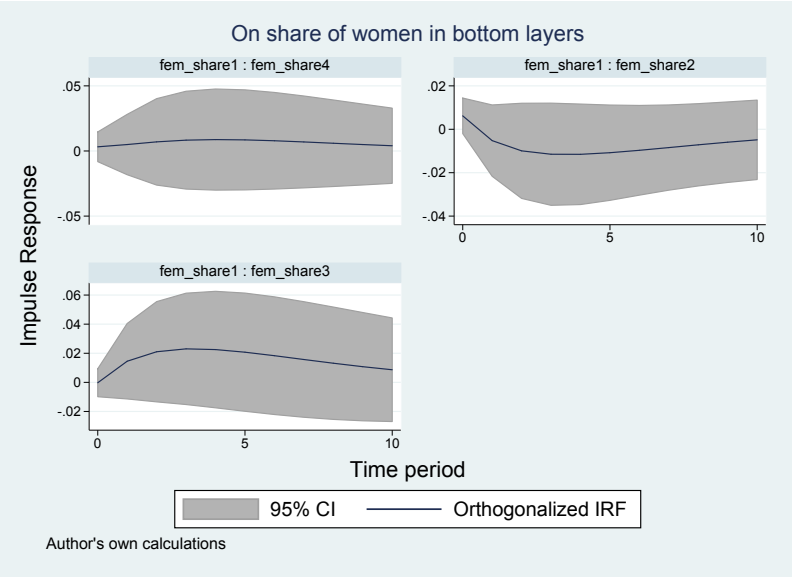
	Intent-to-Treat				Treated			
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 1	Layer 2	Layer 3	Layer 4
				OLS + Firm-Layer FE				
female_i	0.447	-0.008	-0.181	0.232	0.733	-0.012	-0.196	0.252
	(0.617)	(0.033)	(0.127)	(0.148)	(0.709)	(0.034)	(0.134)	(0.156)
$\text{female}_i \times \text{FSB}_{jt}$	-0.283	0.033^{***}	-0.026	0.061	-0.112	0.035^{***}	-0.027	-0.077
	(0.272)	(0.010)	(0.028)	(0.060)	(0.365)	(0.011)	(0.029)	(0.064)
				IV + Firm-Layer FE				
female_i	0.214	-0.008	-0.177	0.227	0.406	-0.013	-0.194	0.241
	(0.553)	(0.033)	(0.129)	(0.149)	(0.588)	(0.034)	(0.136)	(0.157)
$\text{female}_i \times \text{FSB}_{jt}$	0.277	0.034^{**}	-0.036	-0.050	0.625^{*}	0.038^{***}	-0.032	-0.058
	(0.228)	(0.014)	(0.043)	(0.090)	(0.321)	(0.014)	(0.046)	(0.098)
No. of observations	2269	795,586	393,081	279,513	1860	752,866	379,612	263,106

Note: The table reports coefficients form the individual-level specification. Controls include age and age-squared, and their interaction with the female dummy, as well as firm-year dummies. Standard errors are reported in parentheses.

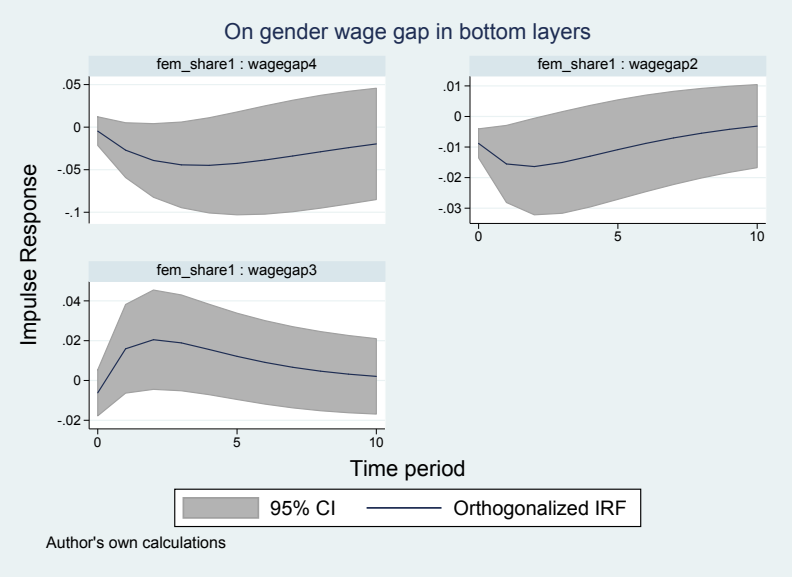
Table 6: Effect of reform on probability of being promoted across layers from previous period

	Intent-to-Treat			Treated		
	Layer 2	Layer 3	Layer 4	Layer 2	Layer 3	Layer 4
			OLS + Firm-Layer FE			
female_i	$-0.003^{***}-$	0.088^{*}	-0.083	-0.003^{***}	0.104^{*}	-0.086
	(0.001)	(0.052)	(0.057)	(0.001)	(0.057)	(0.060)
$\text{female}_i \times \text{FSB}_{jt}$	0.003^{***}	-0.111	0.126^{*}	0.003^{***}	-0.146^{*}	0.130
	(0.001)	(0.072)	(0.069)	(0.001)	(0.084)	(0.079)
			IV + Firm-Layer FE			
female_i	-0.004^{***}	0.100^{**}	-0.298^{***}	-0.003^{***}	0.117^{***}	-0.318^{***}
	(0.001)	(0.040)	(0.073)	(0.001)	(0.043)	(0.080)
$\text{female}_i \times \text{FSB}_{jt}$	0.004^{***}	-0.141^{*}	0.590^{***}	0.004^{***}	-0.176^{*}	0.628^{***}
	(0.001)	(0.085)	(0.193)	(0.001)	(0.092)	(0.212)
No. of observations	766,838	423,210	293,005	726,894	408,898	277,534

Note: The table reports coefficients form the individual-level specification. Controls include age and age-squared, and their interaction with the female dummy, as well as firm-year dummies. Standard errors are clustered at the firm-year level and are reported in parentheses. The dependent variable is a dummy equalling one if the individual was promoted across layers from layer k in the previous period, for $k = 2, 3, 4$.

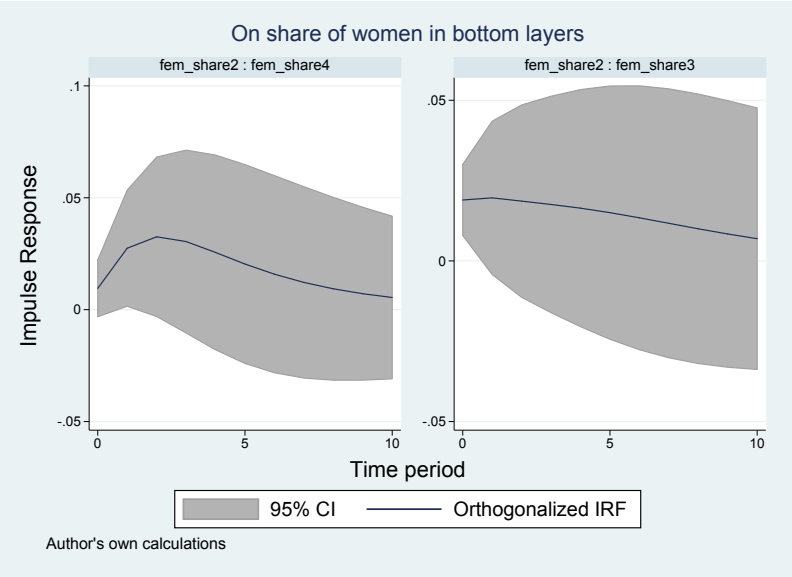


(a) On share of women hired

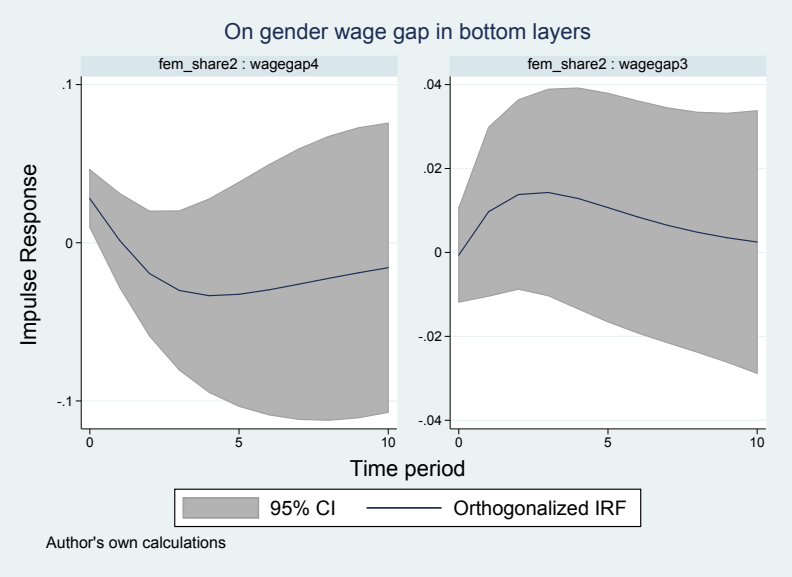


(b) On gender wage gap

Figure 2: Panel-VAR: Effect of an increase in the share of female board members lower layers

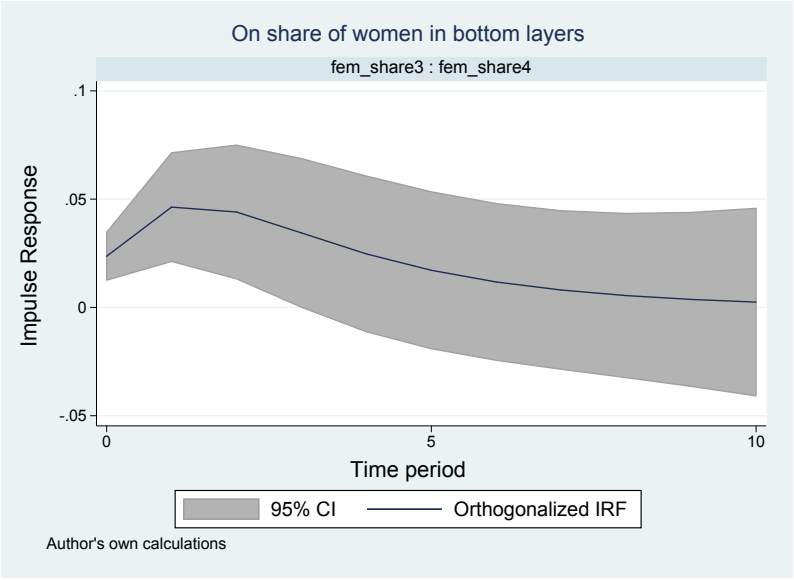


(a) On share of women hired

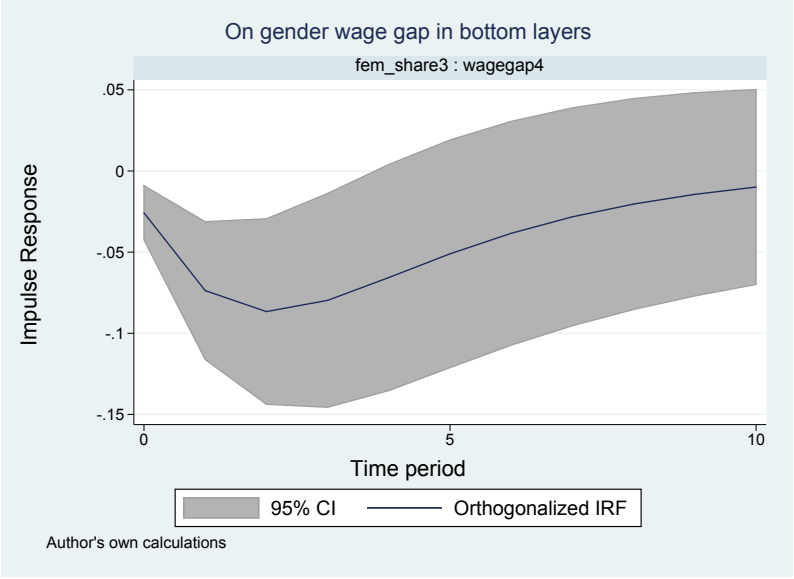


(b) On gender wage gap

Figure 3: Panel-VAR: Effect of an increase in the share of female professionals and managers on lower layers



(a) On share of women hired



(b) On gender wage gap

Figure 4: Panel-VAR: Effect of an increase in the share of female middle managers and technicians on lower layers

7 Conclusion

In this paper, we have considered the impact of a recent reform in France seeking to increase in female representation in corporate boards on gender-specific wage and representation outcomes across hierarchies within firms. This reform occurred amidst a series of similar reforms that imposed gender quotas on the board of directors across Europe. Our paper questioned whether a greater share of women on corporate boards would have any discernible ramifications for women in other layers of the firm hierarchy.

Given the nascent literature on the impact of these reforms on the relative labour market outcomes of women, we construct a theoretical model with testable empirical predictions. The model assumes that employees in a given firm layer made hiring and wage-setting decisions for women in the adjacent subordinate layer. Another key assumption is that women received a more precise signal on their subordinate women's abilities. With a concave profit function, this implies that conditional on the signal, the expected profit from hiring or promoting a subordinate female employee will be increasing in the share of women in the adjacent superior layer of the firm. Hence, the model predicts that an exogenous increase in the share of women at the top layer will have a direct impact on gender wage and employment gaps in the second layer, which will trickle down the firm hierarchy over time. The speed and magnitude of the propagation will vary, depending on the turnover rate and the distribution of new jobs.

Using the characterisation of firm hierarchical layers by Caliendo et al. (2015), we examine whether the model's predictions hold empirically. In particular, we investigate the impact of a rise in female board share on the relative wages of men to women and female employment for each firm layer. Since the share of women on corporate boards is likely to be endogenous, we follow Bertrand et al. (2018) and Ahern and Dittmar (2012) in using the share of women on corporate boards pre-reform interacted with year dummies, as IVs. Our empirical analysis both at the firm-layer level and individual level confirm our prior that a rise in female board share significantly increases female employment and narrows the gender wage gap at the upper layers of the firm, but not for the lower firm layers. To check for the presence of significant trickle-down effects, we run a Panel VAR analysis and find that the trickle-down effect of a rise in female board share is limited. Our counterfactual exercises show that exogenously increasing the share of women in layers 2 (Professionals and senior managers) as well as layer 3 (Intermediate professions such as middle managers) would do more to significantly shrink gender wage and employment gaps in lower layers.

As such, while gender quotas on corporate boards improve the labour market outcomes of women relative to men in upper layers of the firm where the gender gaps are widest, other policies should be explored if the goal is to narrow gender gaps for a broader segment of the labour market. Also, while we have so far assumed that the share of women at the top of the firm should linearly affect wages and employment gaps in subordinate layers, this may not be the case in reality. For instance, there may be a threshold of female share that has to be attained before greater impact on subordinate layers can be observed, or more complex internal decisions at the top layers that we do not capture here. Gathering and analysing data on these internal decisions is an interesting avenue for future research and, we believe, the next step to undertake in this literature.

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Appendix

Table A1: Probability of firms exiting treatment sample

	Probability of exit			
	OLS	OLS	Probit	Probit
FSB_{j2010}	0.113	0.138	0.422	0.555
	(0.242)	(0.249)	(0.893)	(0.958)
Industry-Time effects	No	Yes	No	Yes
Observations	239	239	239	227

Note: All regressions above are at the firm level. Probability of exit refers to the probability of firms previously listed in 2010 that delisted during the period 2011 to 2015.

Table A2: Effect of female board share on the wages of men and women

	Incumbents				New Hires			
	Intent-to-Treat		Treated		Intent-to-Treat		Treated	
	Women	Men	Women	Men	Women	Men	Women	Men
					Layer 2			
FSB_{jt}	0.414	0.187	0.520**	0.308	0.565**	0.502*	0.428***	0.454**
	(0.270)	(0.253)	(0.258)	(0.238)	(0.225)	(0.274)	(0.186)	(0.223)
Observations	951	951	844	844	672	672	575	575
					Layer 3			
FSB_{jt}	0.075	0.187	-0.028	0.126	0.323	0.304	0.620	0.424
	(0.423)	(0.367)	(0.481)	(0.413)	(0.358)	(0.306)	(0.499)	(0.453)
Observations	647	647	568	568	443	443	391	391
					Layer 4			
FSB_{jt}	−0.176	−0.239	−0.330	−0.230	−1.373**	−1.909**	−1.107*	−0.921
	(0.229)	(0.297)	(0.332)	(0.366)	(0.662)	(0.833)	(0.586)	(0.646)
Observations	741	741	652	652	562	562	490	490

Note: All regressions include industry-year effects and firm-layer fixed effects. Controls include average female and male age, and average female and male age squared at the firm-layer level. Standard errors are clustered at the firm level and are reported in parentheses. Firm-layer observations are weighted by their employment size.

Table A3: First-Stage - Occupation level regressions (New entrants and Incumbents)

	Intent-to-treat		Treated	
	NE	IC	NE	IC
	Layer 2			
$2012 \times FSB_{j2010}$	-0.540^{***}	-0.503^{***}	-0.647^{***}	-0.614^{***}
	(0.123)	(0.126)	(0.114)	(0.123)
$2013 \times FSB_{j2010}$	-0.684^{***}	-0.620^{***}	-0.734^{***}	-0.701^{***}
	(0.114)	(0.104)	(0.132)	(0.108)
$2014 \times FSB_{j2010}$	-0.468^{***}	-0.486^{***}	-0.535^{***}	-0.591^{***}
	(0.171)	(0.174)	(0.173)	(0.183)
$2015 \times FSB_{j2010}$	-0.252^{*}	-0.215	-0.358^{**}	-0.394^{***}
	(0.145)	(0.146)	(0.137)	(0.112)
$2016 \times FSB_{j2010}$	-0.244^{*}	-0.226	-0.320^{**}	-0.373^{***}
	(0.127)	(0.160)	(0.138)	(0.140)
Observations	672	951	575	844
	Layer 3			
$2012 \times FSB_{j2010}$	-0.621^{***}	-0.502^{***}	-0.667^{***}	-0.564^{***}
	(0.194)	(0175)	(0.234)	(0.177)
$2013 \times FSB_{j2010}$	-0.907^{***}	-0.617^{***}	-0.950^{***}	-0.662^{***}
	(0.136)	(0.165)	(0.151)	(0.182)
$2014 \times FSB_{j2010}$	-0.518^{***}	-0.302^{**}	-0.559^{***}	-0.378^{**}
	(0.180)	(0.142)	(0.205)	(0.146)
$2015 \times FSB_{j2010}$	-0.372^{*}	-0.244	-0.493^{***}	-0.388^{***}
	(0.191)	(0.165)	(0.179)	(0.139)
$2016 \times FSB_{j2010}$	-0.467^{**}	-0.363	-0.632^{***}	-0.553^{***}
	(0.186)	(0.219)	(0.136)	(0.187)
Observations	443	647	391	568
	Layer 4			
$2012 \times FSB_{j2010}$	-0.356^{**}	-0.420^{***}	-0.494^{***}	-0.408^{***}
	(0.159)	(0.117)	(0.141)	(0.135)
$2013 \times FSB_{j2010}$	-0.555^{***}	-0.604^{***}	-0.675^{***}	-0.589^{***}
	(0.167)	(0.135)	(0.152)	(0.146)
$2014 \times FSB_{j2010}$	-0.243	-0.391^{***}	-0.430^{***}	-0.438^{***}
	(0.199)	(0.136)	(0.120)	(0.140)
$2015 \times FSB_{j2010}$	-0.140	-0.213^{**}	-0.410^{***}	-0.427^{***}
	(0.232)	(0.140)	(0.095)	(0.112)
$2016 \times FSB_{j2010}$	-0.170	-0.449^{***}	-0.355^{**}	-0.493^{***}
	(0.229)	(0.120)	(0.178)	(0.127)
Observations	562	741	490	652

Note: All regressions include industry-year effects and firm fixed effects, mean age and mean squared age for men and women. Standard errors are clustered at the firm level and are reported in parentheses. Firm-occupation observations are weighted by their employment size.

Table A4: Female Board Share and Firm Outcomes Pre-Reform

	Incumbent Wage Gap		Share of Female New Hires	
	Intend	Treat	Intend	Treat
		Layer 2		
	0.002	−0.003	0.027	0.018
	(0.014)	(0.012)	(0.036)	(0.038)
Mean female age_{kjt}	−0.040	0.001	0.070	0.064
	(0.036)	(0.036)	(0.044)	(0.049)
Mean male age_{kjt}	−0.048	−0.093*	0.020	0.019
	(0.047)	(0.048)	(0.058)	(0.062)
Mean squared female age_{kjt}	0.000	−0.000	−0.001	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)
Mean squared male age_{kjt}	0.000	0.001**	−0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1039	860	874	715
		Layer 3		
$FSB_{j2010} * Year$	−0.016	-0.012	0.019	0.030
	(0.015)	(0.017)	(0.044)	(0.044)
Mean female age_{kjt}	−0.028	−0.015	0.072**	0.081***
	(0.019)	(0.022)	(0.029)	(0.030)
Mean male age_{kjt}	0.083***	0.075	−0.096***	−0.102**
	(0.024)	(0.026)	(0.035)	(0.040)
Mean squared female age_{kjt}	0.000	−0.000	−0.001*	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Mean squared male age_{kjt}	−0.001***	−0.001**	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	715	575	656	538
		Layer 4		
$FSB_{j2010} * Year$	−0.034*	−0.035*	0.043	0.061
	(0.020)	(0.020)	(0.067)	(0.069)
Mean female age_{kjt}	−0.157***	−0.155***	0.102***	0.090**
	(0.026)	(0.028)	(0.038)	(0.040)
Mean male age_{kjt}	0.098***	0.102***	−0.016	−0.004
	(0.031)	(0.033)	(0.035)	(0.039)
Mean squared female age_{kjt}	0.001***	0.001***	−0.001**	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Mean squared male age_{kjt}	−0.001***	−0.001**	0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	755	625	623	527

Note: All regressions above are conducted for the time period 1999-2009. All regressions include industry-year effects and firm fixed effects. Standard errors are clustered at the firm level and are reported in parentheses. Firm-occupation observations are weighted by their employment size.

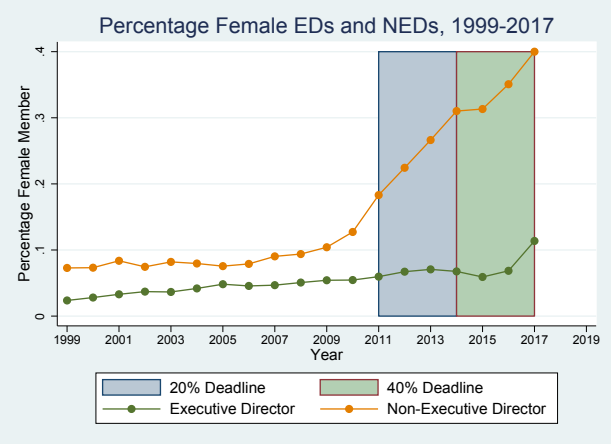
Table A5: Layer transitions among incumbent workers

	Layer at t-1				
Layer at t	Layer 1	Layer 2	Layer 3	Layer 4	Total
Layer 1	2426	455	30	27	2938
Layer 2	385	715,266	45,495	19,573	780,719
Layer 3	18	30,611	348,452	28,018	407,099
Layer 4	59	20,578	29,319	245,443	295,399
Total	2888	766,910	423,296	293,061	1,486,155

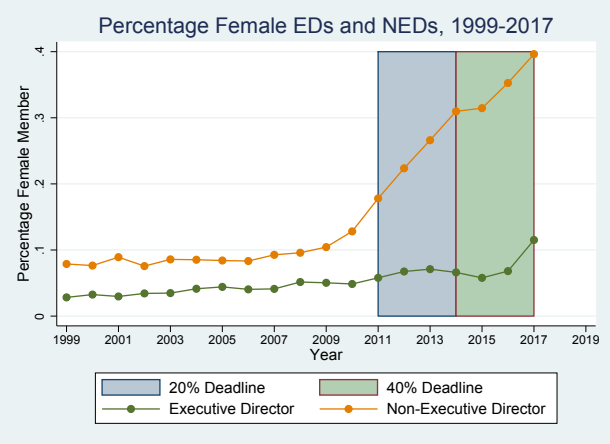
Figure A1: Average Share of women in various BoD roles

(a) CEO (Intent-to-Treat)

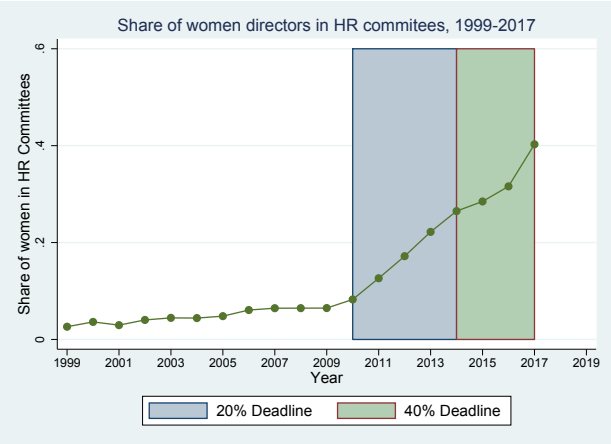
(b) CEO (Treated)



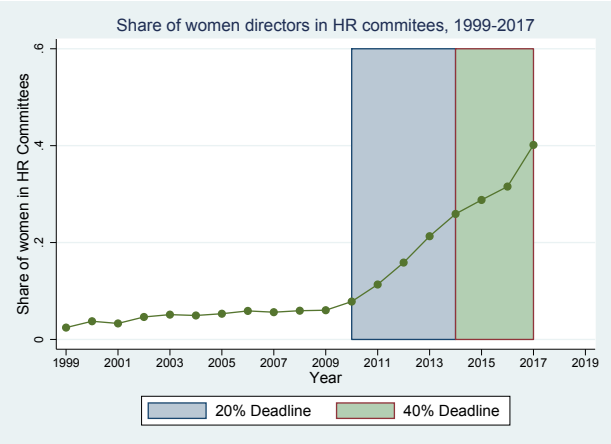
(c) Excecutives or not (Intent-to-Treat)



(d) Excecutives or not (Treated)

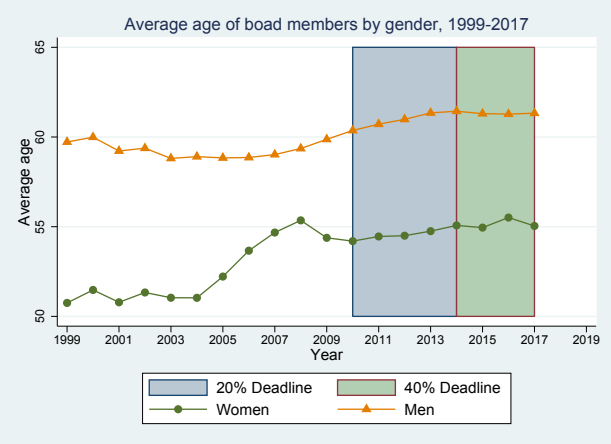


(e) HR committee (Intent-to-Treat)

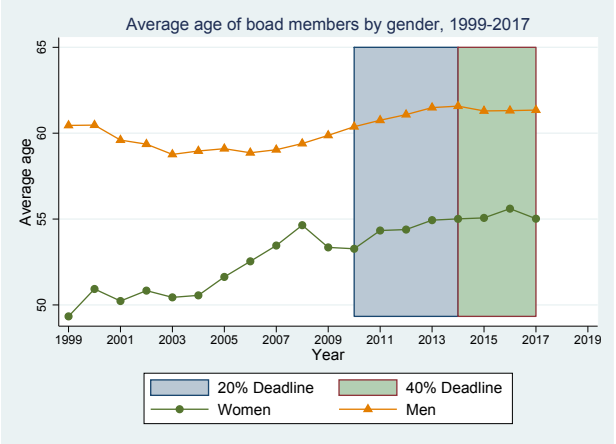


(f) HR committee (Treated)

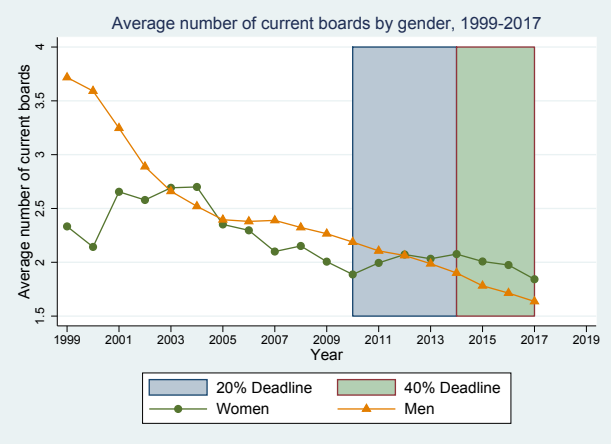
Figure A2: No. of boards, age and experience of BoD members by gender



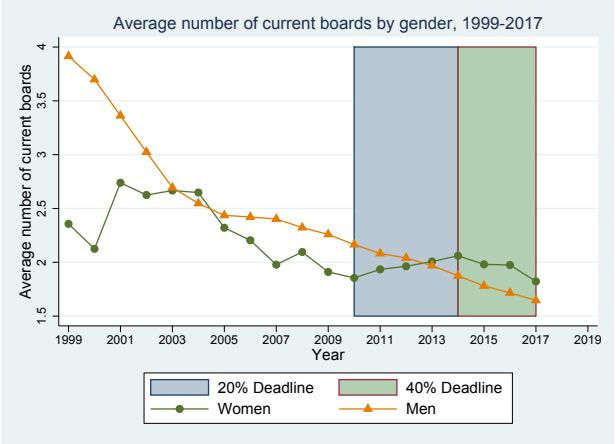
(a) Age (Intent-to-Treat)



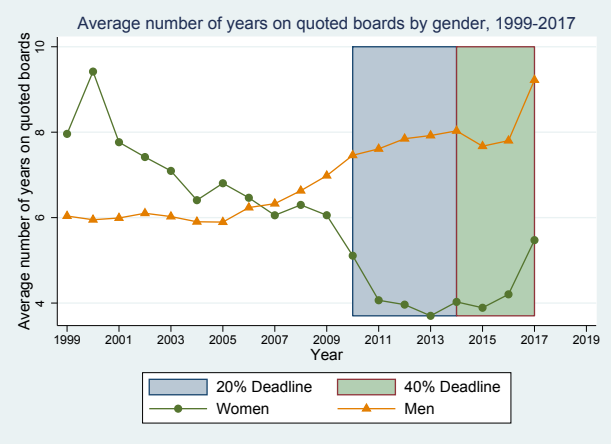
(b) Age (Treated)



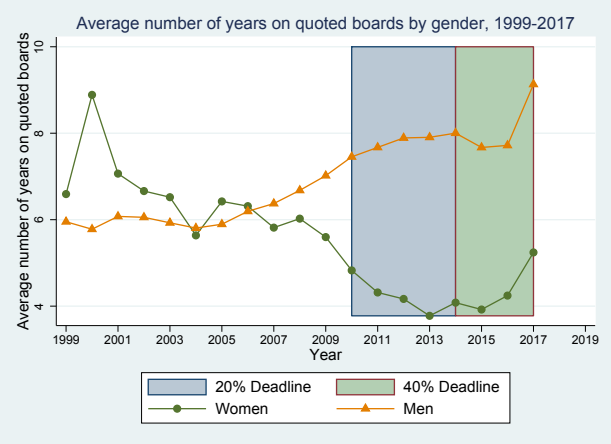
(c) No. of current boards (Intent-to-Treat)



(d) No. of current boards (Treated)

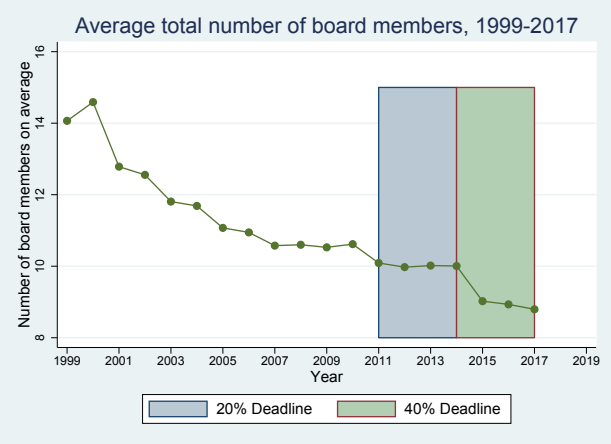


(e) No. of years on boards (Intent-to-Treat)

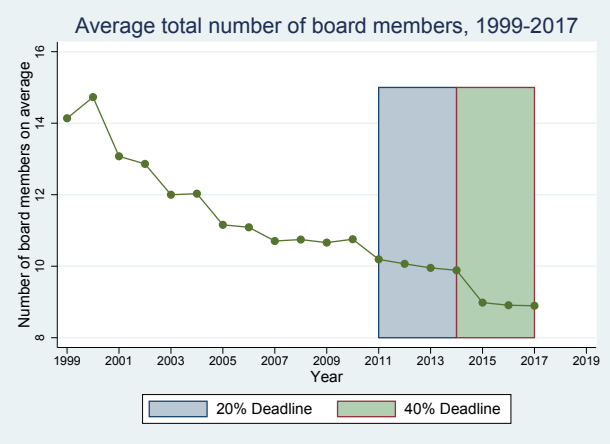


(f) No. of years on boards (Treated)

Figure A3: Average size of boards



(a) Intent-to-Treat



(b) Treated