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Gender board diversity spillovers and the public eye

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Abstract

A range of policy recommendations mandating gender board quotas is based on the idea that "women help women". We analyze potential gender diversity spillovers from supervisory to top managerial positions over three decades in Europe. Contrary to previous studies which worked with stock listed firms or were region locked, we use a large data base of circa 2 000 000 firms. We find evidence that women do not help women in corporate Europe, unless the firm is stock listed. Only within public firms, going from no woman to at least one woman on supervisory position is associated with a 10-15% higher probability of appointing at least one woman to the executive position. This pattern aligns with signaling, stakeholder and institutional theories, suggesting that external visibility influences corporate gender diversity practices. The study implies that diversity policies, while impactful in public firms, might have limited effectiveness in promoting gender diversity in corporate Europe..

Keywords:

gender inequality, gender wage gaps, board composition, corporate governance, women representation

JEL Classification

J31, J71, J16

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1 Introduction

This paper studies gender board diversity spillovers in the context of public eye scrutiny. The existing literature argues forcefully that the presence of women on the supervisory boards is conducive to greater gender diversity among the top management (e.g. Matsa and Miller 2011, Elkinawy and Stater 2011, Matsa and Miller 2013, Kunze and Miller 2017, Guldiken et al. 2019, Kirsch and Wrohlich 2020). This result underlies a range of policy recommendations mandating gender board quotas. Already sixteen countries have implemented such policies (see Dale-Olsen et al. 2013, Wang and Kelan 2013, Terjesen et al. 2015, Schwartz-Ziv 2017) and the EU has introduced a directive, with mandatory implementation as of 2026. However, policies and studies focus primarily on publicly listed (public) companies, that is, companies subjected to the scrutiny of the public eye. Meanwhile, most companies remain private (not listed) and thus often they are not subject to public scrutiny.

The existing studies typically focus on identifying firm-level correlates of women's share among top management in stock-listed companies (the so-called C-suite). A rich body of literature analyzes the spillovers in the context of public firms in the US (Harrigan 1981, Farrell and Hersch 2005, Elkinawy and Stater 2011, Matsa and Miller 2011, Guldiken et al. 2019, Knippen et al. 2019), Germany (Kirsch and Wrohlich 2020, Bozhinov et al. 2021), Europe (Schoonjans et al. 2023). Gender board diversity spillovers among private rather than listed companies have been subjected to much less scrutiny, mostly due to the shortage of data (to the best of our knowledge, the available literature concerns Germany and Scandinavian countries, see Matsa and Miller 2013, Kunze and Miller 2017, Smith et al. 2013, Smith and Parrotta 2018, Bossler et al. 2020).

We compare private companies with stock-listed companies and explore similarities and differences in patterns of gender board diversity spillovers. We deploy a novel source of data: Gender Board Diversity Database (Draskowski et al. 2024). This unique data covers nearly 30 million firms from 42 advanced and emerging European countries. The firms in our sample report over 200 million board members and cover a substantial share of output and employment in the analyzed countries. In addition to being vast, this data set is particularly advantageous as the authors provide novel gender attribution based on linguistic rules. Thanks to that, genders can be attributed to individuals for the period spanning early 1990s until 2020s. Therefore, this data provides unique insights into gender board diversity: it covers a long period of time and a broad range of companies across many countries.

Our study provides a novel result: the positive spillovers from women on supervisory boards to gender diversity among management are limited to listed companies and do not exhibit among the non-listed companies. Specifically, we replicate the result of Matsa and Miller (2011) for the stock-listed (public) companies. Then, we expand the sample to include non-listed (private) companies and compare the nature of gender board diversity spillovers in these two groups of companies. We show that, in fact, there is no link between gender diversity among supervisory (non-executive) directors and among top managers in private companies. We provide a variety of robustness checks to study the reliability of this result for alternative conceptualizations of public eye scrutiny. We also validate our approach with a placebo test.

This article is structured as follows. Section 2 introduces relevant theoretical and empirical works. In addition to reviewing the literature, we also provide a comprehensive catalog of empirical studies, discussing the data used, as well as their findings. Second, in section 3 we present the data. Although our paper uses a dataset developed by Draskowski et al. (2024), we explain in detail our specific treatment of this data

and the methodological approach adopted. We move to the results in Section 4. The paper concludes with the policy and methodological implications of our study.

2 Literature

Research identifies two main explanations for the pervasive underrepresentation of women at the top of the organizational hierarchy (Matsa and Miller 2011, Gabaldon et al. 2016, Schoonjans et al. 2023). On the one hand, there are supply-side explanations, which attribute this gender gap to differences in preferences (Niederle and Vesterlund 2007), differences in education and career decisions (Hill et al. 2010), and work-family considerations (Straub 2007), causing a shortage of women for said positions. On the other hand, demand-side factors, where the dominance of men in leadership and executive positions and, subsequently, processes of similarity attraction (Byrne 1969) and social categorization (Tajfel et al. 1971) and ensuing statistical and taste-based discriminatory practices against the outgroup, prevent women from climbing the corporate ladder (Zhu et al. 2014, Knippen et al. 2019).

Taking affirmative action in the form of appointing women to the top of the organizational hierarchy is often regarded as a remedy against the low representation of women executives and breaking the proverbial glass ceiling. These women can challenge and reshape traditional discriminatory practices, enhancing the assessment and recognition of the skills and capabilities of women in the workforce (Flabbi et al. 2019). Their leadership also narrows gender disparities by implementing fair hiring and retention strategies that attract highly qualified women, signaling better career prospects (Ridgeway 1997). Furthermore, female leaders can serve as role models and mentors, significantly impacting the personal and professional development of other women within the organization (Athey et al. 2000).

These women, however, must be willing to address these gender inequalities and must have sufficient influence to effect change (Cohen and Huffman 2007). Therefore, it should not be automatically assumed that women in such positions view the promotion of gender equality as their responsibility. Furthermore, existing research identifies a phenomenon known as the "queen bee" effect, where women achieve personal success in male-dominated environments by adapting to the dominant masculine culture and thus abstain from engaging in encouraging similar advancement of other women (Staines et al. 1974, Derks et al. 2016). Thus, appointing women to higher positions in the organizational hierarchy might not necessarily pave the way for other women to achieve similar career trajectories (Kunze and Miller 2017).

In line with a diverse theoretical predictions, the empirical evidence is mixed. Matsa and Miller (2011) examined a sample of 1,500 S&P companies and found that a 10 percentage point higher share of women among non-executive directors is associated with a 1.4 percentage point higher share of women among the top 5 executives. Similar positive gender board spillovers are observed in the US, where Cook and Glass (2015), using a sample of Fortune 500 firms, demonstrate a significant and positive relationship between gender diversity on the board and the appointment of a female CEO. Gould et al. (2018), on a sample of nearly 1,400 firms listed on the Australian Securities Exchange, find that a 10 percent increase in women's board representation increases the women's executive representation by 38 percent (from 10 percent to 13.8 percent). Relying on data from 149 publicly listed companies in Germany, Bozhinov et al. (2021) find that an additional woman on nominating committee of the supervisory boards increases the probability of at least one woman on the management board by 7.5 percentage points. For German stock-

listed companies, Kirsch and Wrohlich (2020) finds that companies subject to quotas exhibit greater gender diversity compared to those without such mandates, controlling for regulations.

Literature studies separately vertical gender spillovers, i.e., those from top corporate ladder down to lower organizational ranks. For German plants (Bossler et al. 2020) finds that managers tend to promote the same gender candidates more often. Kunze and Miller (2017) find evidence that a higher share of women in higher ranks is associated with lower gender gaps in promotion among the workers at the lower ranks within the same organization. Bertrand et al. (2018) and Garcia-Blandon et al. (2023) focus specifically on women in the boardroom. Exploiting a gender quota reform, they find that increasing women's representation does not generate positive spillovers. Garcia-Blandon et al. (2023) find evidence that the gender quota in supervisory roles had a negative impact on the gender diversity among executive directors in the case of Norway. This result proves to occur in other countries as well. Maida and Weber (2022) confirm it for a sample of Italian firms, and Fleischer (2022) on a sample of firms from German DAX. Schoonjans et al. (2023) take the sample of nearly 3,400 listed firms and find no significant spillovers from gender board diversity to women's executive representation.

Given this mixed evidence, we theorize that corporate visibility and thus the public eye scrutiny are one of the missing elements which helps to explain the puzzle. The public opinion and reputational pressures as well as corporate activism mediate the potential spillovers from gender board diversity to executive positions. We conjecture that firms perceived as more visible are more likely to engage in socially desirable appointments to the boards. This visibility can stem from being publicly listed, large, having a brand recognized by consumers etc. – which in turn affects how it responds to societal expectations and pressures. Such firms, aware of the public eye scrutiny, may adopt policies and practices that promote gender diversity as a means of bolstering their reputation and aligning with social expectations towards them.

The gap between the corporate visibility theories and the gender board diversity spillovers theories is bridged by the concept of descriptive social norms. These norms shape members' decisions by setting expectations concerning what is socially desirable from an organization. The descriptive social norms provide insight into which behaviors are considered effective or beneficial (Cialdini 2007). Agents use them as heuristics for decision-making and often see them as appropriate or wise behavior. The descriptive social norms define also what is socially acceptable. By acting in accordance with the established behaviors of the group, an organization avoids the risks associated with being seen as an outlier, undermining its legitimacy (Desai 2011). Entities that deviate from these established norms are much more likely to be identified as exceptions and face reputational costs (Schultz et al. 2007, Ahmadjian and Robinson 2001, Zavyalova et al. 2012). To manage public perception, organizations often engage in impression management strategies, particularly in areas under intense scrutiny such as behaviors and practices (Bolino et al. 2008, Elsbach et al. 1998). If social norms are not met, the public might organize boycotts (McDonnell and King 2013). The media might reinforce scrutiny, influencing the public perceptions of the value of an organization. Furthermore, policymakers might devise regulations penalizing some corporate behaviors (Aguilera et al. 2007, Campbell 2007).

Greater visibility places firms under heightened external scrutiny. Research on corporate visibility has shown its impact in various contexts. Public pressure compels firms to pursue behaviors that seek or enhance legitimacy, such as corporate social performance initiatives (Gardberg and Fombrun 2006, Chiu

and Sharfman 2011). Brammer and Millington (2004) demonstrated that larger firms - a common indicator of corporate visibility - and those with a stronger consumer focus - an alternative measure of visibility - tend to make higher charitable donations than less visible firms, such as smaller ones or those operating in B2B markets. Corporate visibility has also been linked to voluntary climate change disclosures (Dawkins and Fraas 2011), suggesting that more visible companies are more likely to engage in practices that demonstrate environmental responsibility. Furthermore, the relationship between executive pay and performance appears to be moderated by corporate visibility, with the link less pronounced in more visible firms (Rayton et al. 2012). Additionally, larger firms and firm headquarters, markers of high visibility, are more likely to exhibit diversity in management, particularly non-white diversity, following anti-discriminatory lawsuits (Knight et al. 2022).

Corporate visibility and external scrutiny also motivate firms to pursue gender (board) diversity initiatives, suggesting that the public and market's perception can drive corporate governance practices toward more inclusive. Brammer et al. (2009) demonstrate a positive relationship between women's representation on boards and corporate reputation, but this association is more pronounced in the more visible consumer service industry. Knippen et al. (2019) show that firms increase gender diversity in their boards differently, depending on the external pressure exerted on the firm. Chang et al. (2019), studying stock-listed US firms, observe that visibility is related to conforming to descriptive social norms about gender board diversity when deciding on number of women on boards.

We argue that corporate visibility impacts gender board diversity spillovers. These impacts can be understood through three theoretical lenses: signaling theory, stakeholder theory, and institutional theory. Signaling theory (Spence 1973) posits that some firms may be willing to signal inclusivity by appointing women to supervisory roles (low effort action), but not all of them are able to follow through consistently across all levels of governance (high effort activity). Public eye scrutiny increases the costs of not following through, effectively raising the bar for the credibility of the signal. Consequently, fewer firms appoint women to supervisory roles, but those who do will observe strong spillovers to executive roles and all corporate ranks. By contrast, stakeholder theory (Freeman 1983) posits that organizations are occupied with the interests of its stakeholders. In response to the demands of diverse stakeholders, companies may manage diverse expectations by appointing women to supervisory roles (thus satisfying the demands of gender diversity). Whether or not a firm actually intends to become more inclusive for the managerial positions depends on the views and forcefulness of the stakeholders. Thus, through the lens of this theory, the spillovers may emerge if there is a reasonable consensus among the stakeholders that diversity in top management roles is desirable. Public eye amplifies the power of the most vocal stakeholders. With the social norms becoming increasingly inclusive, likely this may push firms towards stronger gender diversity spillovers. Institutional theory (DiMaggio et al. 1983) highlights the general norms, values and expectations in shaping organizational behavior. The highly visible firms are more likely to conform to prevailing societal norms and regulations, including those related to gender diversity, due to increased public and regulatory attention. These firms adopt gender diversity not merely for compliance, but to legitimize their standing within the broader socio-economic environment. As diversity occurs in supervisory positions, the public eye reinforces the change in social norms on diversity, making the governance practices increasingly egalitarian. Thus, through the lens of institutional theory, diversity in the public eye begets diversity in general, leading to positive gender diversity spillovers.

In summary, the three theories provide distinct, yet complementary explanations for the link between public eye and gender diversity spillovers. The initial adoption of diversity practices in supervisory positions may serve multiple strategic purposes. Stakeholder theory highlights that these non-executive roles, often more engaged with a variety of external stakeholders, reflect diverse interests and demands, including those advocating for broader gender diversity. Signalling theory emphasizes that not all firms will engage in raising diversity in supervisory roles. If it is to signal gender egalitarian organizations – as opposed to token appointments without further diversifying in executive and management positions – public visibility makes the signal stronger. Indeed, incongruity is more easily exposed with public visibility. Publicly visible firms unable to introduce diversity in all ranks will thus not be able to appoint women as non-executive directors. With private firms effective signalling becomes impossible, because there is no or little cost for non-egalitarian firms if they do not follow through with diversity in all ranks. Consequently, more private firms may appoint one or more women to non-executive roles, without spillovers. Institutional theory suggests that diversity institutionalizes to executive level mostly in firms with high public profile.

Conversely, in less visible firms, the dynamics around diversity spillovers may differ significantly. For instance, diversity might be concentrated only in non-executive roles where it serves limited or symbolic purposes without extending to executive decision-making roles, reflecting a lack of external pressure or institutional drive for deeper organizational change. Also, signalling is less credible among firms with less visibility, hence it is no longer a credible signal of diverse governance practices. In some cases, there may be minimal or no emphasis on diversity at any level, possibly due to a lack of external scrutiny or because the firm does not perceive significant immediate benefits from these practices. Women may be present in management roles primarily due to internal motivations or operational needs rather than as a result of spillover from non-executive positions.

3 Data and methods

This paper explores the Gender Board Diversity Database (GBDD) developed by Drazkowski et al. (2024). GBDD draws on comprehensive firm-level Orbis data, collected originally by Bureau van Dijk and now maintained by Moody's Analytics. This proprietary dataset contains registry and financial records of European firms. The Orbis data was originally released in waves, detailing up to ten years of a firm's history. More recently, Orbis Historical Database (OHD) was made available as well. GBDD combines and harmonizes 11 waves of the Orbis data along with the OHD from 2020.¹ The data spans from 1985 to 2020 and includes firms from 29 European countries.

Orbis data has previously been used to study gender board diversity (Christiansen et al. 2016). However, this study was based on a single wave of Orbis data and focused on a small subsample of firms for which complete financial records were available. In contrast, GBDD relies on registry information, which offers a more comprehensive overview than financial records alone. Kalemli-Özcan et al. (2015, 2022) provide detailed guidelines on constructing longitudinal firm-level data for European countries using the Orbis database.²

The unique feature of the Orbis data, and by extension the GBDD, is that it encompasses essentially

¹We use 2000, 2002, 2003, 2004, 2006, 2008, 2010, 2012, 2014, 2016 waves and the 2020 edition of OHD.

²While Kalemli-Özcan et al. (2015) work with a single wave of Orbis data, (Kalemli-Özcan et al. 2022) provide guidelines on how to work with the OHD.

a universe of companies. Orbis relies on local information providers, who collect data from registries and public records for all those business entities which have reporting obligation under legislation of their country. While reporting obligations differ across countries, for the countries in our sample companies which are legally mandated to have a board of directors (e.g. limited liability companies) have also a reporting obligation. Drzakowski et al. (2024) harmonize registry information to obtain board members for all eligible firms. Subsequently, they deploy linguistic heuristics to identify the gender of those board members, and thus obtain measures of gender board diversity. Since the data is proprietary, GBDD disseminates measures of gender board diversity. In this study, we use original individual-level and firm-level data to study board diversity spillovers.

Our sample covers countries with one-tier system, two-tier system and a mixed system. Drzakowski et al. (2024) use information about the name of a position for each board member. This way, they are able to assign individuals to executive (management) positions as well as supervisory (non-executive) positions. For some individuals, it is not possible to unequivocally determine the position. For example, the description of the position reads "Member of the board". To account for this feature of the data, we construct two identifications of the non-executive directors. First, we use a strict definition which relies on assignment to supervisory (non-executive) board. We label this group as strict BoD. Second, we use also all those positions which are unequivocally part of the board, but for which we do not have sufficient information to attribute them to management (executive) positions. We label this group as broad BoD.

Table 1: Sample descriptives

	# of unique obs.	# of obs.	# of observations in		
			management	BoD strict	BoD broad
Firms	1,822,687	10,958,286	10,958,286	665,370	10,190,632
Listed	8,295	47,083	47,083	29,960	31,264
People	8,257,278	36,880,786	15,033,946	2,091,772	19,828,658
Men	6,323,657	27,902,136	12,326,033	1,625,791	14,010,478
Women	1,815,450	8,605,904	2,583,649	451,303	5,584,319
Women % in total	22.31	23.57	17.33	21.73	28.50

We use data for non-financial companies with board(s). Our data covers 29 European countries spanning 1995-2020.³ In this sample, 1,822,687 firms report board members for at least two years. These companies are present in the sample for 7 years on average. Overall, this gives us 13,381,990 firm-years observations. Since our specifications, in parallel to Matsa and Miller (2011) require lagging variables on the right-hand-side of the equation by one period, our final sample reduces to 10,958,286 firm-year observations. Table 1 provides descriptive statistics.

Public (stock-listed) constitute roughly 0.4% of the sample. Note that our sample coverage of the public companies is fairly comprehensive. For example, Matsa and Miller (2011) work with 1500 companies. Private (nonlisted) companies constitute the vast majority of our sample. The same applies to the board members: while public companies on average report a larger number of board members, the vast majority of our (executive and non-executive) directors come from private companies. Table 2 reports the samples

³GBDD originally covers 42 European countries. However, in some countries majority of companies which ought to report board members, have missing information. We restrict the sample of countries to those where at least 50% of companies mandated to report boards actually do so. The countries included in our sample are: Albania, Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK

used in earlier literature in comparison to ours.

Table 2: Samples used in gender board diversity spillover literature

Study	# Firms / # obs.	Public / Private	Countries	Sample
Harrigan (1981)	112 / 221	Public	USA	Fortune 500
Farrell and Hersch (2005)	300 / 2972	Public	USA	Fortune 500 & Service 500
Elkinawy and Stater (2011)	n.a. / 31,594	Public	USA	ExecuComp
Matsa and Miller (2011)	1,500 / 13,491	Public	USA	ExecuComp
Matsa and Miller (2013)	1,207/1,664	Both	Nordic	Orbis & Norwegian Register
Smith et al. (2013)	3,053 / 57,632	Both	Denmark	Statistics Denmark
Kunze and Miller (2017)	4,000 / 744,531	Private	Norway	Statistics Norway & NHO survey
Gould et al. (2018)	1,387/ 10,330	Public	Australia	Sirca
Smith and Parrotta (2018)	3,625 / 47,125	Both	Denmark	Statistics Denmark & Experian
Guldiken et al. (2019)	184 / 747	Public	USA	BoardEx
Knippen et al. (2019)	1,699 / 14,325	Public	USA	BoardEx, COMPUSTAT
Bossler et al. (2020)	33,237 / 148,131	Both	Germany	IEB of IAB
Kirsch and Wrohlich (2020)	200 / 1,400	Public	Germany	DIW Berlin
Bozhinov et al. (2021)	149 / 673	Public	Germany	German annual reports
Schoonjans et al. (2023)	3,353 / 27,486	Public	17 European	Orbis
Our paper	1,822,687 / 10,958,286	Both	29 European	Orbis (GBDD)

Notes: the number of observations refers to firm-years, except for Elkinawy and Stater (2011), Smith et al. (2013) and Kunze and Miller (2017), where the observations refer to person-years.

Using information about individuals within each company we construct two key variables. First, we define a dummy variable taking on the value of one if a company reports at least one woman in management board. Second, we obtain an analogous dummy variable taking on the value of one if the board of (non-executive) director comprises at least one woman. We do this separately for the two definitions of the BoD (strict and broad). These two variables are key for our estimations.

3.1 Methods

We follow the standard specification to gauge gender board diversity spillovers. For firm i at time t , we estimate the following equation:

$$woman_{i,t}^M = \alpha_0 + \alpha_i + \beta woman_{i,t-1}^{BoD} + \delta private_{i,t} + \gamma private_{i,t} \times woman_{i,t-1}^{BoD} + \xi controls_{i,t} + \epsilon_{i,t}. \quad (1)$$

In this notation, $woman^M$ is a dummy variable taking on the value of one if a company reports at least one woman as an executive director. Similarly, $woman^{BoD}$ is a dummy variable taking on the value of one if a company reports at least one woman as a non-executive member of the BoD. We use two definitions of BoD: broad and strict. Finally, $private$ is a dummy variable which takes on the value of one when a firm is private (non-listed) and zero when it is public (stock-listed).

Our coefficient of interest is the estimate of γ . This coefficient signifies an *additional* role of women in BoD among private (non-listed) companies as compared to stock-listed (public) companies. Our specifications adjust for firm-level fixed effects.

We include a variety of control variables. In addition to time effects, we have time-invariant sector fixed effects. We use three-digit NACE codes to obtain sector indicators.⁴ As time-varying sector-level indicator we include Hirschman-Herhfinahl index of competitive pressure. This indicator is computed using shares in

⁴NACE codes are harmonized for the entire sample covered by GBDD, see Kalemli-Özcan et al. (2022), Drazkowski et al. (2024).

employment, at two-digit NACE sector.

An important issue in this type of studies is related to individuals migrating between executive and non-executive positions. If one specific person was to move from BoD in one year to management position in the next year, then our specification would inadequately identify such shifts as a positive gender board diversity spillover, when the adequate classification is a career promotion. We thus construct a dummy variable taking on the value of one when the same individual is reported on BoD and management within the same firm and zero otherwise.

We estimate the equation (1) using a linear probability model. We consider it important to provide a variety of fixed effects, including firm-fixed effects in a panel setting. Deploying fixed effects reduces the panel data bias, whereas our vast samples make us reasonably confident that efficiency is not an issue. Given these objectives, non-linear estimators (such as probit or logit) are not applicable. We cluster standard errors at firm-level.

4 Results

This section is organized in three substantive parts. Given that our data is new and has not been used previously in empirical research on gender board diversity spillovers, our first steps ought to be replicating the existing results. We take on the specification of Matsa and Miller (2011) and show that our data produces results very similar to theirs on the sample of stock-listed (public) companies. Next, we move to our main research in this study: the comparison of gender board diversity spillovers between the stock-listed (public) companies and non-listed (private) ones. We provide a variety of sensitivity analyses and explore the potential mechanisms behind our findings. Finally, we provide a placebo specification, with the objective to contextualize our estimates.

4.1 Replicating Matsa and Miller (2011)

We estimate on our sample of stock-listed (public) companies the models presented in columns (1) and (3)-(5) of Table 2 Matsa and Miller (2011) study. They regress the shares of women in what they classify the top5 executive positions on the female share of boards of directors (BoD) from the previous year. They exclude executives from the BoD. We pursue an analogous strategy.

For the top5 executive positions we rely on GBDD classification of the management board. Conceptually, the two approaches are quite similar, but GBDD is more detailed due to the nature of the data that they work with. Our study covers a wide range of corporate setups: one-tier, two-tier and mixed. To define BoD in line with Matsa and Miller (2011) we take the women's share in supervisory (non-executive) board in GBDD. Thus, we regress women's share in management board on lagged women's share in all board positions which are not assigned to management in GBDD.

Our estimates reported in Table 3 are in line with the findings of Matsa and Miller (2011). We draw the same inference both in terms of sign and in terms of significance. Even the magnitudes of the estimated coefficients are fairly similar, despite our sample covering a wider selection of countries and a longer period of time.

For robustness, we provide also a more restrictive definition of BoD: supervisory (non-executive) board in GBDD. In Panel A a less restrictive definition of BoD is followed, whereas Panel B reports the results

Table 3: Replication of Matsa and Miller (2011)

Table 2 of Matsa and Miller (2011)	(1) Column (1)	(2) Column (3)	(3) Column (4)	(4) Column (5)
Panel A: BoD comprises of all board members not assigned to management (executive) board, broad BoD				
Share of women in BoD in t-1	0.050*** (0.008)	0.14*** (0.014)	0.015 (0.010)	0.034*** (0.004)
Share of women in management board in t-1				0.83*** (0.006)
Number of observations	49,423	49,172	49,423	45,115
Panel B: BoD consists <i>only</i> of supervisory (non-executive) board members, strict BoD				
Share of women in BoD in t-1	0.042*** (0.009)	0.12*** (0.012)	0.015 (0.012)	0.025*** (0.004)
Share of women in management board in t-1				0.78*** (0.007)
Number of observations	29,026	28,840	29,026	27,607
Time FE	Year	Year	Year	Year
Firm FE	-	Industry	Firm	Industry

Notes standard errors clustered at a firm level reported in parentheses. *** signifies statistical significance at 0.1% level. The estimates come from a linear model. The number of observations signifies the number of firm-years in our sample. Panel A includes all those stock-listed firms for which BoD could be identified. The definition of BoD includes all board members who are not assigned to management (executive) positions in GBDD. In Panel B the BoD consist of positions unequivocally assigned to supervisory (non-executive) board. If a company does not report individuals on such board in a given year, it is not included in the sample. Thus, the sample is smaller in Panel B than in Panel A. The sample is larger in Panel A, because less restrictive definition of BoD is applied.

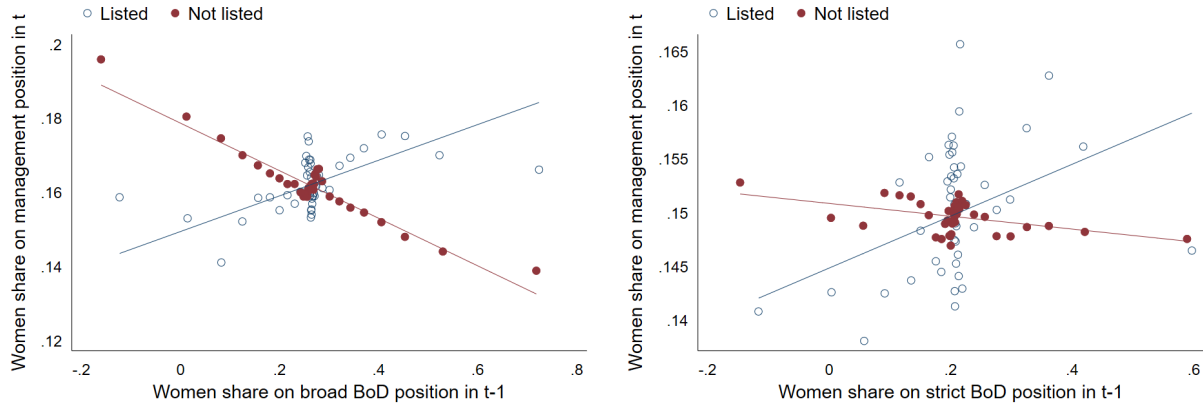
for the narrow definition of BoD allowing only those firms, where GBDD identifies a supervisory (non-executive) board, reducing sample sizes. Indeed, the findings of Matsa and Miller (2011) are comparable between Panel A and Panel B: varying the definition of BoD does leaves the main conclusion unaffected. Note that similar estimates in Panel B, as compared to Panel A, implies that a narrow definition of the BoD implies smaller sample sizes without much gains in terms of precision or implications. The definition of BoD from Panel A remains our preferred specification for the remainder of this paper, and we provide systematically a sensitivity analysis for the more restrictive BoD definition as in Panel B.

4.2 Comparing public and private companies

Our main interest in this paper lies in comparing gender board diversity spillovers between the public (stock-listed) companies and the private (non-listed) ones. Our empirical approach is similar to Matsa and Miller (2011). However, we work with dummy variables rather than shares. This choice is dictated by the fact that a relatively large share of our sample has few board members, which makes some shares (such as 0%, 25% or 33%) particularly common. To avoid implications of this fact for the measurement of the LHS and the main RHS variables, we utilize indicators which take on the value of 1 if a given firm has (had) a woman in executive (non-executive) positions and 0 otherwise. Our main specification takes the non-executive board to comprise all individuals who we are sure are board members and whose positions are not classified as management position by GBDD.

Our results are portrayed by Figure 1. The binned scatters and fitted lines for the stock-listed (public) companies reflect the positive gender board diversity spillovers reported in Table 3. The results for the non-listed (private) firms reveal a *negative* slope. The difference in patterns is stark: the slopes are of the opposite signs with wildly different intercepts as well.

Figure 1: Gender board diversity spillovers: public (stock-listed) and private (non-listed) firms



Note: The left panel uses our preferred specification with BoD consisting of all GBDD board members except those classified as management board. The right panel narrows the sample to specifically supervisory (non-executive) board members in GBDD. The results presented in both panels adjust for a broad range of control variables: firm fixed effects, time fixed effects, sector fixed effects and HerfindahlHirschman index. The binned scatter groups the data into equal-sized bins along the horizontal axis. The dots are the means of both variables within each of the bins. The curves are fitted linear regressions on residualized variables.

We explore the statistical robustness of this result in Table 4. One potential concern could be related to the distribution of BoD gender diversity. We provide regressions on dummy variables to mitigate the consequences of the fact that the distributions of gender board diversity within firm tend to be concentrated on a few frequent values. Our regressions operate on prevalence of women on boards rather than on shares of women in those boards.

The estimation results prove that the patterns revealed in Figure 1 are reliable. On average, we find *negative* spillovers of prevalence of women in BoD to prevalence of women in top managerial position. This is portrayed in column (1) in Panel A of Table 4 which reports a simplified version of equation (1).⁵ Note that as we move to the next columns of Table 4, the interpretation of the estimated $\hat{\beta}$ coefficient changes from the average in the sample to the average among stock-listed (public) firms. This is because of changing the model specification to include the base level and the interaction term for the type of firm.

Finally, the estimated $\hat{\gamma}$ coefficient provides the additional effect of prevalence of women in BoD among the private (non-listed) firms. Recall that the interpretation of the estimated $\hat{\delta}$ coefficient is not particularly useful: it informs about the average prevalence of women in top management among private (non-listed) firms which have no single woman on BoD (as compared to stock-listed firms with no single woman on BoD).

In columns (2) and (3) we estimate our full model. The coefficient of interest $\hat{\gamma}$ is negative and robust across all specifications in both panels. In other words, prevalence of women among BoD in private (non-listed) companies is associated with a *lower* probability of appointing women to management positions. In column (3) our specifications adjust for firm-level fixed effects, and inference remains unaffected.

Columns (4)-(6) provide several sensitivity checks of robustness of our estimations. First, we saturate the model to time fixed effects in addition to firm-level fixed effects. These results are reported in column (4). This specification also includes two types of controls for sector specificity. First, we include sector fixed effects. These are time invariant. As a time variant control we include a degree of competitiveness in a

⁵The coefficient is positive in Panel B, where the sample is restricted to companies for whom specifically supervisory (non-executive) boards constitute BoD.

Table 4: Gender board diversity spillovers: private (non-listed) and public (stock-listed) companies

Woman in management board in t	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: BoD comprises of all board members not assigned to management (executive) board, broad BoD						
Woman in BoD in $t - 1$ (β)	-0.015*** (-22.81)	0.16*** (19.99)	0.16*** (17.07)	0.14*** (15.06)	0.12*** (7.44)	0.093*** (5.95)
Private (non-listed) in t (δ)		0.041*** (6.02)	0.050*** (5.49)	0.024** (2.31)	0.0044 (0.20)	0.028 (1.35)
× Woman in BoD in $t - 1$ (γ)		-0.18*** (-22.08)	-0.19*** (-20.34)	-0.18*** (-19.22)	-0.17*** (-9.96)	-0.15*** (-9.37)
% of firms w/ 1+ woman (private)	0.21	0.21	0.21	0.21	0.21	0.21
% of firms w/ 1+ woman (public)	0.29	0.29	0.29	0.29	0.29	0.29
# of observations	10,958,286	10,958,286	10,958,286	9,687,341	9,687,341	9,687,341
# of firms	1,822,687	1,822,687	1,822,687	1,710,905	1,710,905	1,710,905
Panel B: BoD consists <i>only</i> of supervisory (non-executive) board members, strict BoD						
Woman in BoD in $t - 1$ (β)	0.037*** (17.47)	0.13*** (13.06)	0.12*** (9.96)	0.097*** (7.88)	0.085*** (3.19)	0.057** (2.29)
Private (non-listed) in t (δ)		0.00081 (0.09)	0.030* (1.93)	0.00067 (0.03)	-0.015 (-0.26)	0.033 (0.60)
× Woman in BoD in $t - 1$ (γ)		-0.10*** (-10.05)	-0.11*** (-8.65)	-0.10*** (-8.14)	-0.10*** (-3.63)	-0.084*** (-3.25)
% of firms w/ 1+ woman (private)	0.24	0.24	0.24	0.24	0.24	0.24
% of firms w/ 1+ woman (public)	0.34	0.34	0.34	0.34	0.34	0.34
# of observations	640,334	640,334	640,334	577,489	577,489	577,489
# of firms	133,425	133,425	133,425	133,127	126,103	126,103
Firm fixed effects	-	-	YES	YES	YES	YES
Sector fixed effects	-	-	-	YES	YES	YES
Time fixed effects	-	-	-	YES	YES	YES
HHI	-	-	-	YES	YES	YES
Country weights	-	-	-	-	YES	YES
Eliminating self-promotion	-	-	-	-	-	YES
Log of number of people on boards	-	-	-	-	-	YES

Notes: standard errors clustered at firm level, t-statistics reported in the parentheses. *** denotes significance at 0.01% level. Panel A includes all those stock-listed firms for which BoD could be identified. The definition of BoD includes all board members who are not assigned to management (executive) positions in GBDD. In Panel B the BoD consist of positions unequivocally assigned to supervisory (non-executive) board. If a company does not report individuals on such board in a given year, it is not included in the sample. Thus, the sample is smaller in Panel B than in Panel A. The sample is larger in Panel A, because less restrictive definition of BoD is applied. HHI signifies Herfindahl-Hirschman index.

given sector. Using the data on value added provided in the GBDD financial records, we obtain sector-level measures of market share concentration. We use HerfindahlHirschman index, but our results are robust to including alternative measures.

Next, in column (5) we want to adjust for the fact that some countries receive better coverage in Orbis data, and thus GBDD. Specifically, a few relatively small countries have a substantial number of firms reporting their board composition due to local legislation, whereas for some larger countries reporting obligations are less strict for companies. To better reflect the size of the economy (rather than the size of the sample), we incorporate country-specific weights, which reflect the population of a country. Our weights assign more importance to observations which come from larger economies and less to observations which come from smaller economies. In this specification, the estimates of $\hat{\delta}$ coefficients become insignificant, but our main inference related to $\hat{\gamma}$ remains unaffected. Note that adjusting for country size reduces $t - statistics$ by a factor of approximately two.

Finally, in column (6) we address the issue of the same individuals being on BoD in time $t - 1$ and among top management in time t . This problem was emphasized by Matsa and Miller (2011). We generate a dummy variable taking on the value of one if the same individual occurs on both sides of the equation and zero otherwise. The estimated $\hat{\gamma}$ coefficient becomes marginally smaller, but the inference remains unaffected.

Our estimated coefficients ought to be interpreted as follows. In line with the literature, among the stock-listed companies the positive spillovers occur. Going from no woman on BoD to at least one woman on BoD implies a 10-15% higher probability of appointing at least one woman to the management (executive) position. In a heavily restricted sample where BoD is defined as strictly supervisory (non-executive) positions this coefficient is somewhat lower: 6-12%.

However, among private (non-listed) companies, which operate outside the eye of public scrutiny, there appears to be a very different dynamic. Specifically, the prevalence of women in BoD is associated with a lower probability of having at least one woman in management position. This result stems from the fact that, among public firms, fewer report no single woman on the management board than among private firms.

4.3 Extension: the alternative ways to identify public eye scrutiny

Being listed on a stock exchange is by far not the only way to make a firm susceptible to public eye scrutiny. For example, there are several globally recognized brands which operate as private firms and yet remain in the spotlight of the public opinion as regards their corporate policies. For example, Walmart is a family company, but is closely monitored by many stakeholders.

Our sample includes roughly two million unique firms, so we cannot feasibly work on popular firm names, or another similar ad hoc heuristic. To have a systematic approach to public eye scrutiny, we focus on (i) the largest firms and (ii) firms producing final consumer goods. Note that we work with substantially smaller samples. For example, not all firms report sector identification, which makes it impossible to match the information about final consumption share. To identify the producers of consumer goods, we rely on the input-output tables developed by the OECD and identify those five sectors in each country where the share of final consumption is the highest.⁶ Similarly, to identify large firms, we add employment at firm

⁶We take input output tables from OECD. The most recent edition (IOTS2021), the data ends in 2018, which restricts the

level to the hitherto used registry information. Unfortunately, employment data is missing for some firms, which also reduces the sample as compared to our main specification. We calibrate the threshold size of employment so that the prevalence of public firms was comparable to our main specification. For sectors with high final share of consumption, we use top three sectors.

We replicate specifications (5) and (6) from Table 4. We do that with two alternative approaches to defining public eye scrutiny: one percent of largest employers in a country at a given point in time; and firms in top five sectors with final consumption share in output in a given country and year. The specifications are identical to Table 4 with the only difference that in these alternative specifications whether or not a firm is considered exposed to public eye scrutiny depends on its size or sector.

In our sample, out of roughly 11 million firm-year observations utilized in Table 4, roughly 47 thousand are stock-listed. When compared to the largest employers, roughly 14 thousand firm-year observations overlap and roughly 30 thousand do not. For the classification based on proximity to the final consumer, the sample of public firms is much larger, as the classification is obtained at a sector level, see Table A.1 and A.2 in the Appendices

We report the results for the alternative operationalizations of the public eye in Table 5. Columns (5a) and (6a) report specifications analogous to (5) and (6) from Table 4 for the employment sensitivity analysis and columns (5b) and (6b) do that for the consumer proximity criterion. Our sensitivity analyses report two main findings. First, for the employment criterion (which is similar in prevalence of “public eye”) we get almost identical results. Second, for the consumption criterion (in which case the “public eye” operationalization is much more prevalent) we analogous main conclusion: in private firms there are no spillovers. However, our criterion proves to be too broad in a sense that in the public firms the positive spillovers of Matsa and Miller (2011) no longer reproduce.

4.4 Placebo

Our findings are somewhat in contrast to the existing literature. While we argue that the scrutiny of the public eye constitutes a plausible and appealing explanation for these findings, we also provide context to interpret the coefficients reported in Table 4. We do so by the means of a placebo test inspired by a proverbial statement that there were more men by the name of John in NYSE listed companies than all women together.⁷ In this spirit, we provide regressions analogous to those estimated as our core results. The main difference is that instead of gender board diversity spillovers, we study board spillovers of the most popular men’s names. There is a priori no reason to expect that a man named John in BoD should promote another John to the management board simply because they share the first name. Thus, any positive or negative coefficients have no meaningful interpretation and serve as benchmark for the gender board diversity spillovers. Furthermore, there should be no differences due to the public eye scrutiny: the artifact ought to be the same for private (non-listed) and public (stock-listed) companies.

We obtain coefficients analogous to β , δ , and γ for eight countries in our sample: France, Germany, Ireland, Norway, Spain, Sweden, Switzerland, and the UK. We use these eight countries based on popularity of the men’s names. We include those countries where there is a clear drop in popularity from three most

sample. Further, while OECD data is the most comprehensive, in some cases data is missing for some sectors (specifically: 824 sectors out of 34,560 observations for country \times sector \times year are missing, this is the most frequent in mining and energy producing sectors).

⁷Apparently, 2023 is the first year in history when this statement is no longer factually correct.

Table 5: Gender board diversity spillovers: alternative operationalizations of the public eye

Woman in management board in t	High employment		Final goods producers	
	(5a)	(6a)	(5b)	(6b)
Panel A: BoD comprises of all board members not assigned to management (executive) board, broad BoD				
Woman in BoD in $t - 1$ (β)	0.075*** (4.24)	0.044*** (2.58)	-0.032*** (-7.85)	-0.042*** (-10.41)
Private in t (δ)	0.0089 (4.56)	0.010 (3.75)	0.0029 (0.61)	0.0012 (0.27)
× Woman in BoD in $t - 1$ (γ)	-0.11*** (-6.27)	-0.091*** (-5.33)	-0.0077* (-1.88)	-0.0090** (-2.22)
# of observations	8,437,975	8,437,975	6,974,531	6,974,531
# of firms	1,698,270	1,698,270	1,311,737	1,311,737
Panel B: BoD consists <i>only</i> of supervisory (non-executive) board members, strict BoD				
Woman in BoD in $t - 1$ (β)	0.081*** (3.22)	0.056** (2.29)	-0.042 (-1.14)	-0.045 (-1.20)
Private in t (δ)	0.012 (1.45)	0.017 (1.01)	-0.0032 (-0.09)	-0.010 (-0.30)
× Woman in BoD in $t - 1$ (γ)	-0.096*** (-3.69)	-0.081*** (-3.22)	0.030 (0.80)	0.021 (0.55)
# of observations	528,603	528,603	420,263	420,263
# of firms	115,046	115,046	98,096	98,096
Firm fixed effects	YES	YES	YES	YES
Sector fixed effects	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES
HHI	YES	YES	YES	YES
Country weights	YES	YES	YES	YES
Eliminating self-promotion	-	YES	-	YES
Log of number of people in C-suite	-	YES	-	YES

Notes: standard errors clustered at firm level, t-statistics reported in the parentheses. ***, ** and * denote significance at 0.01%, 0.1% and 1% level, respectively. Panel A includes all those stock-listed firms for which BoD could be identified. The definition of BoD includes all board members who are not assigned to management (executive) positions in GBDD. In Panel B the BoD consist of positions unequivocally assigned to supervisory (non-executive) board. If a company does not report individuals on such board in a given year, it is not included in the sample. Thus, the sample is smaller in Panel B than in Panel A. The sample is larger in Panel A, because less restrictive definition of BoD is applied. HHI signifies Herfindahl-Hirschman index.

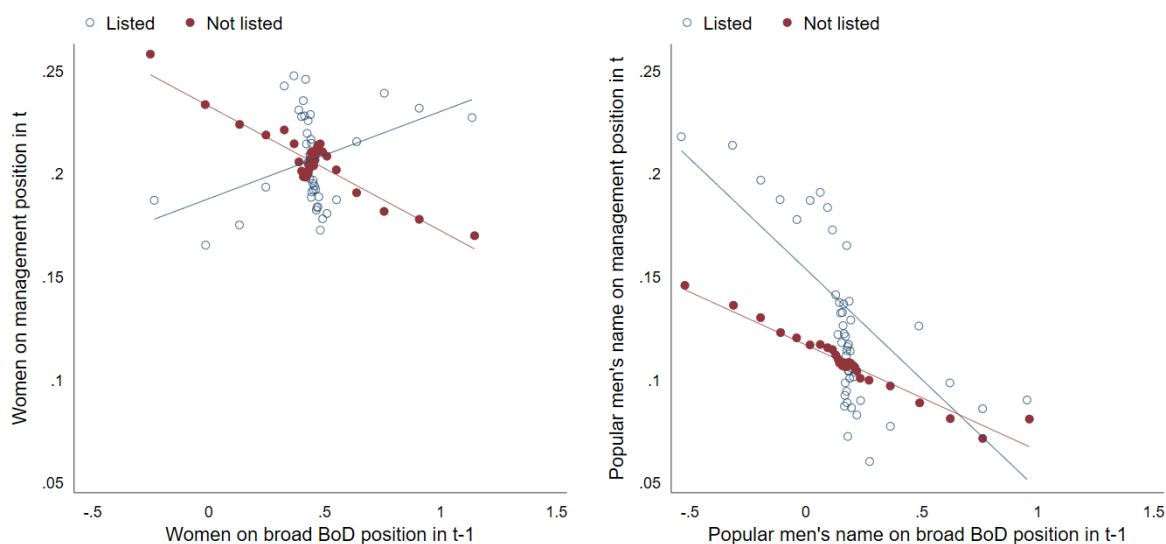
popular names to the fourth one.

For the eight countries, we obtain our standard binned scatter plots and regressions for gender board diversity. For each of them, we provide an analog set of estimates with the placebo specification for popular men's names. In analogy to gender board diversity, we include all the observations. The only cases which we drop from estimation the few cases where there is no "spillover", but the most popular names exist. For example, if BoD in Sweden has a Lars among members, and the management board has an Anders, then this is not considered a spillover, even though both of these names belong to the three most popular men's names in Sweden. The results of placebo are reported in the right panels of Figure 2. The left panel of this figure reports on gender board diversity spillovers. The results of estimations for the placebo analogous to Table 4 are relegated to the Appendix.

We replicate the negative slope for the private (non-listed) companies for the subsample of the eight countries. As one would expect from a meaningful relationship for gender board diversity, the slope remains positive in our reduced sample of eight countries among the public (stock-listed) companies. Next, we compare the gender board diversity spillovers to the placebo estimates of men's most popular names. We find that the non-listed firms display essentially the same slope as in the case of gender board diversity

spillovers. By contrast, among listed firms the slope is negative (with a higher intercept), which hints that appointments to men with a popular name occur actually more frequently among listed than private firms, their likelihood is decreasing in the number of men with the same name in the non-executive positions. Note that the intercept is higher for women among the private (non-listed firms, in the left panel) than in the case of placebo suggest that women are in general more likely in management positions than men with three most popular names. The fact that the slope among the private (non-listed) firms is similar for women (left panel) and placebo (right panel) suggest that there is that there is no strong spillovers. However, this negative slope is essentially the same as placebo for three of the most popular men's names. We offer the following interpretations of this fact: the negative slope among private (non-listed) firms in placebo is actually the "reference zero", a statistical artefact equivalent to no meaningful board spillovers. Clearly, our methodology does not exclude other potential explanations.

Figure 2: Comparing gender board diversity spillovers to placebo (residualized values)



Notes Binned scatter plot of respective presence of women or one of the three most popular men's name adjusted to control variables. The left panel is analogous to Figure 1, estimated on a sample of eight countries for which we do the placebo test: France, Germany, Ireland, Norway, Spain, Sweden, Switzerland and the UK.

Data is grouped into equal-sized bins along the horizontal axis. The dots represent the means of both variables within each of 10 bins after they have been residualized. The variables included in residualization are: firm fixed effects, time fixed effects, sector fixed effects, HerfindahlHirschman index, self promotion indicator, log size of board (see Table B.1). The lines are fitted linear regressions on residualized variables. Results for eight countries, with three distinct most popular men's names: France (Philippe, Olivier, Laurent), Germany (Thomas, Michae, Andreas), Ireland (John, Patrick, Michael), Norway (Jan, Per, Bjoern), Spain (Antonio, Manuel, Francisco), Sweden (Lars, Jan, Anders), Switzerland (Markus, Andreas, Daniel) and the UK (David, Paul, John). These names were the most popular during the 1960s decade, which is realistic for the cohorts of BoD and Management Board members during the period 1995-2019.

5 Discussion and conclusions

In this paper we study whether there are spillovers from diversity in nominating committees to management positions. In an influential paper, Matsa and Miller (2011) argue positive spillovers from non-executive gender diversity to more women in executive positions using evidence for the stock-listed companies. This result is frequent in the literature, though often enough the spillovers are weak and insignificant (Smith et al. 2013, Schoonjans et al. 2023, for stock-listed European firms). Our aim in this study was to explore

the characteristics of gender board diversity spillovers, with focus on the role of public eye scrutiny.

We conceptualize public eye as a mechanism that makes firms concerns for reputation stronger. It is increasingly common that companies lacking diversity among the executive and non-executive directors are singled out for being discriminative. While public, stock-listed companies face this risk – private companies receive little public attention and are rarely subjected to evaluation by indirect stakeholders. Public eye scrutiny clearly feeds into managerial practices. We theorize that firms beyond public eye scrutiny are less likely to display gender board diversity scrutiny.

We put our conjectures to empirical test using data for 29 European countries and spanning the period 1990-2020. We compare stock-listed companies and private companies. We replicate the result that positive spillovers exist among the former group of firms. We show, however, that there are at best no spillovers among the private firms. In fact, we find that in some cases there can be negative spillovers.

Our study yields several implications for theoretical research. First, the theories related to corporate visibility can be more strongly linked to the leadership literature. Our conceptualizing and our empirical work suggest that these may be relevant avenues for further research. Second, understanding better the prerequisites of corporate visibility seems imperative, especially if they were to exhibit differently in how “public eye” scrutiny is able to affect corporate policies and implementations. Finally, our research clearly demonstrates that gender board diversity spillovers need to be conceptualized and studied outside the context of the stock-listed firms, as the private firms may differ substantially from the public ones.

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A Alternative operationalizations of public eye

Table A.1: Subsamples identified as public: big employers vs stock-listed

Stock-listed	Big Employer			Total
	Yes	No	Unable to classify	
Yes	15,492	27,834	3,757	47,083
No	31,408	9,146,325	1,733,470	10,911,203
Total	46,900	9,174,159	1,737,227	10,958,286

Table A.2: Subsamples identified as public: final goods producers vs stocklisted

Stock-listed	Final goods producers			Total
	Yes	No	Unable to classify	
Yes	2,243	30,897	13,943	47,083
No	274,876	6,666,515	3,969,812	10,911,203
Total	277,119	6,697,412	3,983,755	10,958,286

B Placebo - regressions for results displayed in Figure 2

Table B.1: Homophilia of popular men's names: private (non-listed) and public (stock-listed) companies

Popular name in management board in t	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: BoD comprises of all board members not assigned to management (executive) board						
Name in BoD in $t - 1$ (β)	-0.012*** (-12.97)	-0.072*** (-7.64)	-0.072*** (-6.76)	-0.074*** (-6.87)	-0.090*** (-5.52)	-0.097*** (-5.99)
Private (non-listed) in t (δ)		-0.14*** (-18.99)	-0.14*** (-16.32)	-0.13*** (-15.73)	-0.15*** (-11.67)	-0.12*** (-9.72)
× name in BoD in $t - 1$ (γ)		0.060*** (6.29)	0.053*** (4.98)	0.054*** (5.00)	0.061*** (3.70)	0.059*** (3.62)
Share of firms w/ 1+ name (private)	0.09	0.09	0.09	0.09	0.09	0.09
Share of firms w/ 1+ name (public)	0.22	0.22	0.22	0.22	0.22	0.22
Number of observations	6,118,236	6,118,236	6,118,236	5,824,528	5,824,528	5,824,528
Number of firms	702,408	702,408	702,408	702,408	685,937	685,937
Firm fixed effects	-	-	YES	YES	YES	YES
Sector fixed effects	-	-	-	YES	YES	YES
Time fixed effects	-	-	-	YES	YES	YES
HHI	-	-	-	YES	YES	YES
Country weights	-	-	-	-	YES	YES
Eliminating self-promotion	-	-	-	-	-	YES
Log of number of people on boards	-	-	-	-	-	YES

Notes: standard errors clustered at firm level. T-statistics reported in the parentheses. *** denotes significance at 0.01% level. Panel A includes all those stock-listed firms for which BoD could be identified. The definition of BoD includes all board members who are not assigned to management (executive) positions in GBDD. In Panel B the BoD consist of positions unequivocally assigned to supervisory (non-executive) board. If a company does not report individuals on such board in a given year, it is not included in the sample. Thus, the sample is smaller in Panel B than in Panel A. The sample is larger in Panel A, because less restrictive definition of BoD is applied. HHI signifies Herfindahl-Hirschman index.