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The Eco Gender Gap in Boardrooms

Finance Working Paper N° 861/2022
October 2023

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Abstract

Using firm- and facility-level measures from 2002 to 2021, we show that having female directors leads to more environmental-friendly business operations. To establish the causal effect, we resort to plausibly exogenous variations in the share of female directors and a California law change. We show that neither board qualifications nor standard diversity measures supersede the share of female directors in explaining corporate environmental performance, suggesting that director gender is likely a holistic measure of female directors' values and perspectives, and that female directors contribute to diversity of thought. Our findings highlight positive externalities among firms' environmental, social, and governance engagement.

Keywords: female directors; boards; corporate environmental performance; pollution prevention; emissions; board gender quota

JEL Classifications: G30; G38; G41

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"Boards with a diverse mix of genders, ethnicities, career experiences, and ways of thinking have, as a result, a more diverse and aware mindset. They are less likely to succumb to groupthink or miss new threats to a company's business model. And they are better able to identify opportunities that promote long-term growth."

– BlackRock CEO Larry Fink's Annual Letter to CEOs, January 19, 2018

1. Introduction

As the popular press and much of the academic literature tend to view corporate social responsibility (CSR) as a monolithic goal, much less attention has been paid to the potential externalities resulting from the three pillars of firms' environmental, social, and governance (ESG) performance. In this paper, we study the role of female directors in influencing – and more specifically improving – corporate environmental performance at firm- and facility-level.[1]

Investments in corporate environmental performance are characterized by a prolonged period of resource commitment that generates positive externalities to stakeholders, community, and the natural environment. Our conceptual framework (see Section 2) builds on a number of well-established gender differences in values and psychological traits, such as "other-regarding" preferences (or pro-social preferences, whereby an individual internalizes the utility of others in society) and long-term orientations (Beutel and Marini 1995; Silverman 2003; Schwartz and Rubel 2005; Castillo, Ferraro, Jordan, and Petrie 2011), that have implications for corporate decision-making related to environmental performance. Consistent with these gender differences in values, PwC's 2019 Annual Corporate Directors Survey finds that 71% of surveyed female directors support a broader stakeholder model of governance, compared to 54% of surveyed male directors.[2] Moreover, the non-business

[1] Despite increasing attention and scrutiny from policy makers, regulators, and institutional investors regarding gender diversity in boardrooms – an important marker for social performance, as of 2020, only 28% of board directors in the U.S. are female (Catalyst 2021). Since 2003, ten European countries have responded to lack of gender diversity in boardrooms by adopting quotas. On September 30, 2018, California became the first U.S. state to set female director quotas for firms headquartered in California (Senate Bill 826 2018).

[2] See the survey at: http://www.circulodedirectores.org/wp-content/uploads/2019/12/pwc-2019-annual-corporate-directors-survey-full-report-v2.pdf

backgrounds and expertise of female directors (e.g., Hillman, Cannella, and Harris 2002; Kim and Starks 2016) could also enrich boards' decision-making process regarding complex issues such as sustainability (echoing our opening quotation). Malenko (2014) develops a model showing that more diverse boards communicate more effectively, leading to efficient decision-making.

On the other hand, Adams and Funk (2012) and Lewellen (2022) find that self-selection and professional expertise reduce, or even eliminate, some gender differences in preferences (e.g., risk-taking). Donaldson, Malenko, and Piacentino (2020) note that, in a dynamic setting, directors' heterogeneous preferences may exacerbate board deadlock, resulting in no decision-making. Whether and how female directors influence corporate environmental performance remain unanswered empirical questions.

Using Refinitiv's three environmental component scores, along with a summary score, to capture corporate environmental performance from 2002 to 2021, and using BoardEx to capture the share of female directors on a board, we first document a positive and significant association between board gender diversity and corporate environmental performance. This relation holds when we include firm fixed effects accounting for time-invariant general corporate attitudes towards CSR that correlate with both the share of female directors and corporate environmental performance. Further, we document a critical mass effect whereby having more than one female director is required to enhance corporate environmental performance.

To establish the causal effect of female directors on corporate environmental performance, we first employ the instrumental variables approach, with three instruments that capture different sources of plausibly exogenous variations in the share of female directors on a board. The first two instruments capture the cross-sectional variation in opportunities for women in states where directors went to college and the temporal variation (i.e., passage of

the Civil Rights Act of 1964 that made it illegal for college admissions to discriminate on the basis of race or gender) in discrimination against women when directors were college age (Huang and Kisgen 2013; Field, Souther, and Yore 2020). More specifically, these two instruments measure the economic opportunities and legal protections for women that made it possible for them to advance in their careers and eventually become directors. The third instrument exploits different degrees of gender-egalitarianism in firms' headquarters counties (McLean, Pirinsky, and Zhao 2023), based on attitudes of country residents (according to the 1900 U.S. Census) toward women. We show that the instrumented female director ratio is positively and significantly associated with different measures of corporate environmental performance.

We next take advantage of a 2018 Bill in California that mandated female directors for public firms headquartered in the state. Here we employ a difference-in-differences specification, comparing changes in environmental performance between treated California firms and a) a matched control sample outside California (both without any female directors before 2018); and b) an alternative matched control sample of California firms already having multiple female directors. These two different control samples help establish the causal effect from *increasing* the female director ratio—instead of from the pre-shock level of the ratio, or any other contemporaneous, state-wide trends in California—on corporate environmental performance.

Given that corporate environmental ratings by various data providers may be highly subjective (Berg, Koelbel, and Rigobon 2022), we employ facility-level data from the Toxic Release Inventory (TRI) database of the U.S. Environmental Protection Agency (EPA) to construct alternative measures of corporate environmental performance. The TRI database covers both pollution prevention activities and the production of toxic chemicals at the facility-year level. Our facility-level analysis suggests that an increase in the share of female

directors is associated with a significant increase in the number of new pollution prevention activities and with a significant drop in the amount of toxic pollutants produced. Such associations hold when we control for facility- and firm-level characteristics and for a comprehensive set of fixed effects. These results support our thesis that firms with female directors take more actions to prevent toxic emissions and thus effectively reduce industrial pollution, providing micro-level evidence for some real effects of female directors on corporate environmental performance.

Motivated by the literature on gender differences in personal values, qualifications, and monitoring roles (see, for example, Hillman, Cannella, and Harris 2002; Schwartz and Rubel 2005; Adams and Ferreira 2009; Kim and Starks 2016; Adams, Akyol, and Verwijmeren 2018; Field, Souther, and Yore 2020), we posit and explore a number of non-mutually exclusive channels through which female directors help enhance corporate environmental performance.

Using detailed director- and board-level data from the BoardEx data set supplemented by the Refinitiv ESG Board Member data set from 2001–2020, we first show that, in the same firm-year, compared to male directors, female directors are younger, have shorter board tenure, and are more highly educated. Importantly, female directors are more likely than male ones to have professional experiences in non-business sectors such as academic, government and policy, and community, as well as to have expertise related to sustainability and risk management; they are less likely to have backgrounds or expertise traditionally valued by boards such as general management, entrepreneurship, and mergers and acquisitions (M&As) (e.g., Kim and Starks 2016; Adams, Akyol, and Verwijmeren 2018). These results suggest that female directors bring diverse perspectives into boardrooms.

To determine whether improved corporate environmental performance stems from female directors' contribution to specific skills, from specific facets of board diversity, or

from their collective contribution to diversity of thought, which by nature is hard to measure due to lack of information on deliberations inside boardrooms, we conduct a number of exploratory analyses. We find that the positive and significant relation between the share of female directors and corporate environmental performance continues to hold when we control for a long list of board qualification measures. We further show that firms are more likely to increase their female director share when any of the standard diversity measures of their current board is low (e.g., skill sets or sector experiences). Importantly, when we run a horse race between the share of female directors and those board diversity measures, the latter fail to load significantly or to supersede the former in explaining corporate environmental performance. The cumulative evidence suggests that director gender is likely a holistic measure of some potentially unmeasurable female directors' values and perspectives (due to lack of granular data and disclosure), and that more female directors increases the diversity of thought in the boardroom.

Finally, we show that, in the same firm-year, compared to male directors, female directors are more likely to sit on sustainability-related committees if these exist, and on key monitoring committees. Moreover, firms with female directors are more likely to have an ESG (executive) committee and to link executive pay to corporate ESG performance. These results provide supporting evidence for the unique governance role of female directors in influencing corporate environmental performance.

Our paper makes three contributions. First, our results highlight important complementarity among the three pillars of corporate ESG performance. The popular press and much of the academic literature focus on whether firms adopt ESG policies and practices (and whether society and policymakers should promote such actions); less attention has been

paid to the synergies or even potential tradeoffs among those pillars.[3] Exploring both deep-rooted historical determinants of local gender attitudes and policies targeting board gender diversity, our paper suggests that corporate leaders' social attitudes could have spillover effects on their environmental performance, potentially through board advising stemming from female directors' non-business backgrounds and expertise, as well as through their monitoring roles.

Second, by highlighting that board gender diversity can affect firm decisions through female directors' personal values and preferences (Beutel and Marini 1995; Silverman 2003; Schwartz and Rubel 2005; Castillo et al. 2011), our findings also add to the growing literature on board diversity.[4] Despite the extant research, Knyazeva, Knyazeva, and Naveen's (2021, p. 308) survey of diversity on boards points out that "the dearth of research on the important question of the effects of board diversity on other stakeholders (and more generally, society at large) offers fruitful opportunities for future research." Our evidence suggests that director gender is a holistic measure of different values and perspectives that female directors bring to the table, and that female directors contribute to diversity of thought and to more pro-stakeholder decision-making in the boardroom.

Finally, by centering around a stakeholder model of governance for boards, our paper complements the emerging literature on how financial markets and capital market

[3] There are a number of notable exceptions, mostly using international data. In a cross-country study, Dyck et al. (2023) show that board renewal mechanisms could be important governance channels through which investors' preferences for sustainability are materialized in better corporate environmental performance. Farzamfar, Foroughi, and Ng (2020) highlight the tradeoffs, showing that U.S. firms invest more to address the environmental concerns at the expense of their social performance. Using an international sample, Kreutzer and Pinerby (2022) show that boards with financial or industry-specific skills or a high share of female directors are associated with lower green gas emissions. Using French data, Ginglinger and Genteet-Raskopf (2021) establish a positive association between female board members and firms' environmental and social (E&S) performance.

[4] Using a rich set of board diversity measures, Anderson, Reeb, Upadhyay, and Zhao (2011) find a positive association between their board diversity index and firm performance, whereas Adams, Akyol, and Verwijmeren (2018) find that boards with greater skill diversity do not performance better. Bernile, Bhagwat, and Yonker (2018) show that greater board diversity leads to lower firm risk and better performance. Using Korean data, Kang, Kim, and Oh (2022) show that board demographic diversity is associated with more effective monitoring and higher firm value.

participants can influence firms' production technologies and resultant pollution. Prior literature largely has focused on the roles of shareholders and creditors.[5] We provide new empirical evidence to highlight how directors' personal values and stakeholder orientation influence their firms' toxic emissions and long-term risk. Such a "real effect" has implications for not only financial markets but also governments and policymakers with mandates to mitigate the negative externalities of economic activities.

2. Conceptual Framework

Our conceptual framework builds on a number of well-established gender differences in personal values and preferences that have implications for corporate decision-making related to environmental performance.

Beutel and Marini (1995) show that females in their U.S. sample are more likely than males to express concern and responsibility for the well-being of others. Schwartz and Rubel (2005) find that, across cultures, men consistently attribute more importance to self-enhancement values (achievement and power), whereas women emphasize self-transcendence values (universalism and benevolence). These gender differences in personal values are also confirmed in a sample of Swedish directors by Adams and Funk (2012). Relatedly, experimental and survey evidence in psychology indicates that women, on average, are more patient than men when trading off present versus future values (Silverman 2003; Castillo et al. 2011). As such, male directors may be more short-term oriented and shareholder focused in their approach to corporate strategy, whereas female directors may be willing to bear the higher costs and focus more broadly on a wide range of stakeholders with a longer-term outlook.

[5] For an extensive list of the role of shareholders in corporate ESG, please refer to surveys by Matos (2020) and Gillan, Koch, and Starks (2021). In addition, the influence of creditors on firms' toxic emissions has been documented in Akey and Appel (2021), Kacperczyk and Peydro (2021), Bellon (2022), and Ivanov, Kruttli, and Watugala (2022).

Consistent with these gender differences in personal values and preferences, PwC's 2019 survey of over 700 public company directors finds that 71% of surveyed female directors support a broader stakeholder model of governance compared to 54% of surveyed male directors. In addition, 62% of female directors agree that tackling ESG issues has a positive financial impact on long-term company performance, compared to just 45% of male directors.

There could be a number of non-mutually exclusive channels through which female directors help enhance corporate environment performance. First, gender differences in personal values and preferences result in female directors pursuing non-business career paths (to become directors), which make them more attentive to sustainability. Hillman, Cannella, and Harris (2002) note that male directors tend to have more leadership experience in large corporations, whereas female directors tend to have more experience in community and service organizations. Second, the non-business backgrounds and expertise of female directors could contribute to diversity of thought in the boardroom, which enriches the decision-making process for complex issues such as sustainability. Baranchuk and Dybvig (2009) develop a model of board decision-making and show that directors with different information sets disagree more, suggesting that more diverse boards have more debate in their decision-making process than more homogeneous ones. Malenko (2014) further notes that more diverse boards communicate more effectively, suggesting efficient decision-making. Third, the quality and diverse expertise that female directors bring to boards may also provide better monitoring and alignment between executive compensation and corporate environmental performance. Anderson et al. (2011) find that heterogeneity in directors' backgrounds and experiences improves board monitoring and firm performance. Adams and Ferreira (2009) show that gender-diverse boards are tougher monitors. Kang, Kim, and Oh

(2022) show that board demographic diversity brings different perspectives in a boardroom, resulting in more effective monitoring and higher firm value.

Taken together, we expect that board gender diversity may boost corporate environmental performance because of female directors' (tendency toward) "other-regarding" preferences and long-term orientations (Beutel and Marini 1995; Silverman 2003; Schwartz and Rubel 2005; Castillo et al. 2011), both of which align well with investments in environmental performance. Having women on boards brings non-business backgrounds and expertise and thus fosters diversity of thought, allowing boards to better assess the needs of different stakeholders and ultimately improve corporate environmental performance.

On the other hand, Adams and Funk (2012) and Lewellen (2022) provide evidence suggesting that self-selection and professional expertise reduce, or even eliminate, some gender differences in personal values and preferences (e.g., risk attitudes).[6] Donaldson, Malenko, and Piacentino (2020) model board deadlock, which is the inability of a board to make decisions. Their dynamic model predicts that board diversity (with directors having heterogeneous preferences) exacerbates board deadlock, resulting in no decision-making. Garlappi, Giammarino, and Lazrak (2017) model how group disagreement leads to inefficiency in corporate investments. Ultimately, whether board gender diversity results in improved corporate environment performance remains an empirical question.

3. Data and Sample Formation

3.1. Firm-level data

We employ a number of data sources to measure corporate environmental performance. Our primary data source is Refinitiv, a wholly-owned subsidiary of the London

[6] Adams and Funk (2012) find that female directors emphasize benevolence more, and that they are less power- or accomplishment-oriented. Moreover, in contrast to findings for the population, they find that female directors are less tradition- and security-oriented and more risk-embracing than male directors. Lewellen (2022) finds no evidence that gender differences in preferences for risk or altruism affect decision making of hospital CEOs.

Stock Exchange Group (LSEG), which produces one of the most comprehensive ESG databases. The Refinitiv database covers over 80% of global market capitalization, including most of the key global index constituent firms—and encompasses more than 12,000 public and private companies globally. Refinitiv dates back to 2002 and has been used in several recent ESG studies (e.g., Dai, Liang, and Ng 2021; Li, Liu, Mai, and Zhang 2021; Dyck et al. 2023). Refinitiv's ESG score consists of more than 630 data items that span most common environmental, social, and governance issues (Refinitiv 2022).

To measure corporate environmental performance from 2002 to 2021, we focus on Refinitiv's emissions reduction, innovation, and resource use scores, all of which fall under Refinitiv's environmental pillar.[7] These scores range from 0 to 1. A high score reflects a firm's good performance in a specific dimension captured by the measure. We use the average across these three scores to capture a firm's overall performance (*E score*).

Our board and director data mainly come from BoardEx, which contains information such as board composition, committee composition, and biographic and professional background (in free-form text) of directors for more than 20,000 companies since 1999. The data coverage is more comprehensive after 2000, which explains why our sample period begins in 2001. We manually code director academic degree, field, and skill following Kim and Starks (2016) and Adams, Akyol, and Verwijmeren (2018). The Appendix contains a more detailed description of our coding process and the creation of academic degree, field, and skill categories. We supplement BoardEx data with board and director data from the Refinitiv ESG Board Member data set.

[7] The emissions reduction score measures a company's commitment and effectiveness towards reducing environmental emissions in its production and operational processes. The resource use score measures a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management. The innovation score measures a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes, or through eco-designed products.

We collect firms' financial data from Compustat. We obtain institutional ownership data from the Thomson Reuters Institutional Holdings (13F) data set. We extract firms' (historical) headquarters states and industry classifications (based on the Standard Industry Classification (SIC) codes) using the Augmented 10-X Header Data downloaded from Bill McDonald's website.[8]

3.2. Facility-level data

As our alternative measures of corporate environmental performance, we employ facility-level data on pollution prevention (P2) activities and the production of toxic chemicals from the TRI database maintained by the EPA. Both measures are based on regulatory reporting and hence are not subject to the common criticism that corporate environmental ratings may be subjective in nature. We provide more detailed description of the TRI database in Appendix IA1 in the Internet Appendix. According to the EPA's waste management hierarchy, both of our facility-level measures are at the top of the hierarchy and thus are more likely to be visible to corporate boards and to be potentially influenced by female directors.

The EPA requires that facilities meeting the following criteria report their new source reduction practices (with the aim to prevent pollution) in File Type 2A of the TRI database every year: (1) in the mining, utility, manufacturing, publishing, hazardous waste, or federal industry; (2) manufacturing, processing, or otherwise using a TRI-listed chemical in quantities above certain threshold levels set by the EPA in a given year; and (3) having ten or more full-time equivalent employees. Each facility reports the newly implemented source reduction practices by choosing one or more predefined codes (W-codes) that correspond to a specific practice within the following eight categories: raw material modifications, product

[8] https://sraf.nd.edu/data/augmented-10-x-header-data/

modifications, cleaning and degreasing, surface preparation and finishing, process modifications, spill and leak prevention, inventory control, and good operating practices. Each facility is also required to specify which toxic chemical's production is reduced due to the source reduction practice that it implements. Prior literature uses the number of these practices to capture facility-level initiatives to prevent pollution at the annual frequency (Akey and Appel 2021; Bellon 2022).

We employ two facility-level pollution prevention measures in a year: (i) *#Source reduction practices by chemical* denotes the total number of a facility's source reduction practices weighted by the number of toxic chemicals to which a specific practice is applied; and (ii) *#Source reduction practices by facility* denotes the total number of a facility's unique source reduction practices applied to different toxic chemicals. For example, if a facility implements two source reduction practices W1 and W2 in a year (both W1 and W2 are applied to toxic chemicals A and B, and W2 is also applied to toxic chemical Z), then the facility's *#Source reduction practices by chemical* is 5, and its *#Source reduction practices by facility* is 2.

The EPA also requires that eligible facilities report their production and management of 775 toxic chemicals in 33 chemical categories (as of August 2022).[9] The TRI database contains the amount of chemical pollutants (in pounds) produced and released, and their names.[10] We use the total quantity of all TRI-listed toxic chemicals produced by a facility to measure its industrial pollution (as an inverse measure of a facility's environmental performance, see, for example, Li and Zhou 2017; Hsu, Li, and Tsou 2022).[11]

[9] In our facility sample, 7.7% of facility-year observations do not report production wastes.
[10] For the detailed list, please refer to https://www.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals. The EPA's Office of Inspector General performs audits, evaluations, and investigations of the EPA and its contractors to prevent and detect fraud, waste, and abuse. In addition, the EPA regularly implements an extensive quality analysis of the TRI reporting data and offers analytical support for enforcement efforts led by its Office of Enforcement and Compliance Assurance (OECA).
[11] We provide some additional information about the TRI database in Appendix IA1 in the Internet Appendix. Also see https://www.epa.gov/toxics-release-inventory-tri-program/common-tri-terms.

We obtain the following facility-level variables from the National Establishment Time-Series (NETS) database (2020 version): facility-level SIC code, estimated sales or revenue created, the number of employees hired, and credit score, which allow us to control for a facility's scale and operating/financial condition.[12]

3.3. Sample overview

Table 1 Panel A lists the steps taken and filters applied to form our main sample of 21,534 firm-year observations for a sample of 3,174 firms over the period 2002–2021. Panel B lists the steps taken to form our facility-level sample of 48,373 facility-year observations for a sample of 4,671 facilities associated with 618 firms over the same period. Detailed variable definitions are provided in the Appendix.

Table 2 Panel A presents the summary statistics for the firm sample. In terms of corporate environmental performance, the average *E score* is 0.212, and the average emissions reduction, innovation, and resource use scores are 0.241, 0.150, and 0.245, respectively. Over our sample period, the average share of female directors is 15%, the average board size is 11 directors, and the average share of female CEOs is about 4%.

Figure 1 plots the temporal trend in the share of female directors over the period 2001–2020. Consistent with the increasing attention and scrutiny from policy makers, regulators, and institutional shareholders regarding gender diversity in boardrooms, we see a clear upward trend in the share of female directors over the sample period, from about 10% in early 2000s to over 20% by the end of the sample period. The rise in the female director share is steeper since 2017, when the Big Three asset managers—BlackRock, Vanguard, and

[12] The TRI database offers the crosswalk between TRIFD and dunsnumber, which allows us to merge the two data sets. For more details about the NETS database, please refer to https://maryannfeldman.web.unc.edu/data-sources/longitudinal-databases/national-establishment-time-series-nets/.

State Street —adopted a policy requiring at least one female director on every board of their portfolio firms (Gormley et al. 2021).

Table 2 Panel B presents the summary statistics for the director sample. We show that at the firm-director-year level, the average probability that a director is a female is 17.9%. The average director age is 62 years old, and the average director tenure is 8 years. The sample directors on average possess 3.3 skills based on our classification. It is worth noting that this statistic is similar to that reported in Adams, Akyol, and Verwijmeren (2018).

Panel C presents the summary statistics for the facility sample. We show that facilities in our sample on average adopt 0.189 unique pollution reduction practices (and 0.345 weighted by the number of toxic chemicals applicable) and generate 1.270 million pounds of TRI pollutants.

Panel D presents the correlation matrix for the firm sample. Here we show a positive and significant correlation between the share of female directors and *E score*. Examination of the correlation matrix generally suggests that multicollinearity is unlikely an issue.

4. Female Directors and Corporate Environmental Performance

4.1. Baseline results

To examine the relation between the share of female directors on a board and corporate environmental performance, we start with the following lead-lag panel data regression specification:

$$E\ performance\ measure_{it}$$
$$= \alpha_0 + \alpha_1 Female\ director\ ratio_{it-1} + \alpha_2 Governance\ characteristics_{it-1}$$
$$+ \alpha_2 Firm\ characteristics_{it-1} + Industry \times Year\ FE$$
$$+ \varepsilon_{it}, \qquad (1)$$

where the dependent variables are *E score* and its three component scores provided by Refinitiv. The control variables include an indicator variable for female CEO, a composite governance index *Board governance*, ownership by the Big Three asset managers, and firm characteristics (e.g., M/B, firm size, and ROA). Our variable of interest is *Female director ratio.* The choice of our control variables largely follows prior work (e.g., Starks, Venkat, and Zhu 2020; Dyck et al. 2019, 2023). We include (three-digit SIC) industry times year fixed effects to control for industry-specific time-trends in both the share of female directors and corporate environmental performance. Standard errors are clustered at the firm level to account for possible intertemporal dependence in a firm's environmental scores.

Table 3 reports the regression results using the specification in Equation (1), with different environmental scores in different columns. We show that the coefficients on *Female director ratio* are positive and significant in all columns. In terms of economic significance, a one-standard-deviation increase in *Female director ratio* is associated with an increase of 0.025 (= 0.232 × 0.107) in *E score*, about 9.8% of its standard deviation (12% of its mean). The economic magnitude of the effect of female directors on *Emissions reduction score* is similar to the magnitude of the female director effect on *Resource use score*, whereas the economic magnitude of the effect of female directors on *Innovation score* is only half the magnitude of the female director effect on *Emissions reduction score* or *Resource use score*.

Panel A in Table IA1 in the Internet Appendix illustrates that our main findings remain when controlling for the share of female top executives, the average age of directors on a board, the average age of top executives, or ownership by the socially responsible investment (SRI) funds. In Panel B, we further show that our main findings remain when controlling for director cultural heritage at the board level following Pan, Siegel, and Wang (2017, 2020) or controlling for a board's political leaning based on directors' political donation data from the Federal Election Commission.

Several hard-to-measure omitted variables could potentially bias our ordinary least squares (OLS) estimates above in either direction. On the one hand, the management literature highlights the glass cliff phenomenon—women and minorities are more likely to take leadership positions in struggling firms (e.g., Ryan and Haslam 2007). If failing firms likely have poor environmental performance (i.e., firms in crises are positively correlated with *Female director ratio*, and negatively correlated with *E score*), then not properly controlling for this firm characteristic will lead to a downward bias in the OLS estimates of the coefficient on *Female director ratio*. On the other hand, if a firm's strategic position on ESG issues positively correlates with its position on board gender diversity (i.e., a firm's corporate vision is positively correlated with both *Female director ratio* and *E score*), then not properly controlling for a firm's strategic position on ESG will lead to an upward bias in the OLS estimates of the coefficient on *Female director ratio*.

To examine the causal effect of female directors on corporate environmental performance, we explore some plausibly exogenous variations, both cross-sectional and temporal, in *Female director ratio*. First, we use the instrumental variables approach, which aims to capture exogenous variation in the share of female directors on a board based on historical and institutional determinants. Second, we take advantage of the board gender quota introduced by California (SB 826) in 2018 and employ a difference-in-differences specification to examine changes in the environmental performance of California firms subject to the Bill, versus changes in that of similar firms headquartered outside California not subject to the Bill, or changes in that of similar California firms already having multiple female directors.

4.2. Identification using the instrumental variables approach

Our first two instruments follow Huang and Kisgen (2013) and Field, Souther, and Yore (2020), that aim to capture exogenous variations in female representation on corporate

boards. The first instrument, *Gender Equality Index (GEI)*, is the historic Gender Equality Index of the state where a director obtained her undergraduate degree. The index assesses "the extent to which women have the same access to economic resources, legal rights, or positions of political power as men" (Sugarman and Straus 1988, p. 234). Sugarman and Straus (1988) constructed the index using data from the State and Regional Indicators Archive from 1977–1983, when many of our sample directors would have begun their career. Note that while the index itself varies by state, the variable *GEI* we construct is at the director level. The second instrument, *Civil Rights Act*, takes the value of one if a director was 18 years old or younger when Congress passed the Civil Rights Act of 1964. The Act made it illegal for college admissions to discriminate on the basis of race or gender, and thus improved higher education opportunities and job mobility for minorities and women. At the director-year level, these instruments satisfy the relevance condition by influencing the likelihood of observing women becoming directors at a particular firm. Given that our primary analysis is at the firm-year level, for each instrument, we calculate the firm-year average across all directors on a board.[13]

One concern about these two instruments is that they may reflect a firm deliberately choosing certain types of directors in order to improve its environmental practices. While this selection does not necessarily conflict with the role of female directors, we introduce a third instrument that exploits different degrees of gender-egalitarianism in a firm's headquarters county (McLean, Pirinsky, and Zhao 2023), based on cultural attitudes of county residents (according to the 1900 U.S. Census) toward women. As noted by Knyazeva, Knyazeva, and Masulis (2013), headquarters locations are chosen in the early life of a firm, even before

[13] One concern about our Civil Rights Act–related instrument, *Civil Rights Act*, is that in a nutshell, it could be a proxy for director (young) age and hence young directors' more positive attitude towards ESG issues. However, the *GEI*-related instrument is less likely to be subject to such concern, given its cross-sectional nature. Nonetheless, Table IA1 Panel A in the Internet Appendix shows that our main findings remain when controlling for the average age of directors on a board and the average age of top executives.

going public, for reasons unrelated to its demand for certain director characteristics (hence certain board composition). McLean, Pirinsky, and Zhao (2023) find that inherited beliefs about gender roles affect local director (and executive) labor market conditions, thus the gender composition of corporate leadership. We explore this variation in our third instrument.

Table 4 presents the results from the instrumental variables (IV) approach. Column (1) tabulates the first-stage regression results, and confirms that the three variables together are valid and strong instruments for *Female director ratio*. The first-stage F-statistic at 31 is far larger than 10, the conventional cutoff for weak instruments.

Columns (2)-(5) tabulate the second-stage regression results. We note that we fail to reject the overidentification (Hansen's J) test, consistent with our argument that the instruments are valid statistically. Similar to the OLS regression results in Table 3, we show that *Female director ratio* is positively and significantly related to *E score* and its three component scores. The IV-based estimates of the coefficient on *Female director ratio* are larger than those OLS estimates, but still within the same order of magnitude, which could result from the fact that our instruments are less subject to the omitted variable bias associated with the existence of a "glass cliff," as laid out in Section 4.1.

4.3. Within-firm temporal variations

Next, we examine within-firm temporal variations in the share of female directors in relation to within-firm temporal variations in corporate environmental performance by controlling for firm fixed effects in Equation (1). Table 5 presents the results.

After controlling for potential time-invariant determinants of both the share of female directors and corporate environmental performance, for example, a firm's corporate vision related to ESG issues or stakeholder orientation, we show that *Female director ratio* is still positively and significantly correlated with *E score* in column (1). We note that with firm fixed effects, however, the magnitude of the effect of female directors becomes much

smaller, about one third of that in the specification without firm fixed effects (see Table 3). This smaller effect suggests that some time-invariant factors, such as a firm's strategic position on ESG and/or its stakeholder orientation, are likely associated with both its share of female directors and its environmental performance. At the same time, because the variation in our key variable of interest, *Female director share,* largely comes from across firms (instead of from within-firm over time), firm fixed effects regressions, which rely on within-firm temporal variations, might under-estimate the true effect of *Female director share* on corporate environmental performance. This issue has been raised in prior studies involving slowly changing explanatory variables (e.g., Zhou 2001).

To explore a possible nonlinear effect of the number of women on a board, we use the spline regression in column (2) based on the quartiles of *Female director ratio* (the quartile cutoffs are below 0.08, between 0.08 and 0.14, between 0.14 and 0.22, or above 0.22). We show that the significant and positive effects from female directors concentrate in the third and fourth quartiles, although the slopes in these two intervals are not significantly different, suggesting that it might be the importance of diversity of thought introduced by a critical mass of female directors rather than a monotonic effect from any particular characteristic(s) specific to female directors.[14]

4.4. Identification using 2018 California SB 826

To further examine the causal effect of female directors on corporate environmental performance, we take advantage of California's SB 826, the first female director quota in the U.S. signed into law on September 30, 2018. This Bill required public companies

[14] To address the concerns that our baseline results may be affected by time-varying local economic conditions and/or by different state-level laws and regulations, we include the following fixed effects in Equation (1) in addition to industry times year and firm fixed effects: headquarters state times year fixed effects and incorporation state times year fixed effects. The former absorbs the effects of local economic conditions related to firms' business operations (including their shares of female directors and environmental performance), and the latter absorbs the effects of various state-level laws and regulations related to social and environmental issues. Table IA2 in the Internet Appendix presents the results. We show that our main findings remain.

headquartered in California to have at least one female director by the end of 2019, and, depending on board size, some firms were required to have multiple female directors by the end of 2021.

We employ a difference-in-differences (DID) specification to examine changes in both the share of female directors and corporate environmental performance between treated and control firms around passage of SB 826 in 2018. Our three-year pre-event window is 2015 to 2017, and our three-year post-event window is 2019 to 2021. The treated firms are public firms without a female director in 2018 and headquartered in California. To find control firms, we first search for public firms headquartered outside California without a female director in 2018. For each treated firm, we then find a control firm in the same (three-digit SIC) industry, with the smallest total (normalized) absolute difference in total assets and *E score* in 2018 to the treated firm.[15] After the above steps, we end up with 50 treated firms and their matched control, spanning a number of industries (e.g., pharmaceutical, electronic components, real estate, and business services).

Table IA3 Panel A in the Internet Appendix tabulates the average values of *Female director ratio* and *E score,* for the treated and control firms, in the time period before and after the Bill. These summary statistics may be viewed as the simplest DID analysis without any control variables, showing that the treated and control firms have similar shares of female directors as well as similar environmental performance in the period before the Bill. However, these values diverge between the treated and control firms after the Bill.

Table 6 Panel A presents the sanity check—the impact of SB 826 on the share of female directors in the treated firms compared to the share of female directors in the control

[15] To pick control firms, we proceed as follows. First, for each treated firm, we identify all potential control firms in the same size quartile and *E score* quartile with the same three-digit SIC code as the treated firm in 2018. Second, for each possible control firm, we compute the absolute size (*E score*) difference between the control and treated firms, and we normalize the difference by the standard deviation of the difference across all possible treated-control pairs. Third, we add up the two normalized differences and pick a control firm with the smallest total (normalized) difference in both size and *E score* to the treated firm.

firms. In column (1), we regress *Female director ratio* on *Treated* × *Post*, an interaction term between the indicator variable, *Treated*, and the indicator variable, *Post*, for the post-event window (from 2019 to 2021). As before, we control for firm characteristics, as well as industry times year and firm fixed effects. These fixed effects absorb the standalone indicator variables *Treated* and *Post*. We cluster standard errors in this DID specification by headquarters states, as this is the level at which treatment is assigned and cross-firm dependence in the error term may occur (e.g., Bertrand, Duflo, and Mullainathan 2004; MacKinnon, Nielsen, and Webb 2022). We show that the coefficient on the interaction term *Treated* × *Post* is positive and significant, suggesting that the treated firms significantly increase their shares of female directors relative to the control firms, once the Bill is passed. In column (2), we employ a dynamic DID specification by interacting *Treated* with the year indicators for each year within the event window examined. The omitted baseline interaction term is *Treated* × *Year 2018*. The coefficients on the first three interactions (from 2015 to 2017) confirm what we find using summary statistics (see Table IA3 Panel A in the Internet Appendix); before the Bill, both the treated and control firms have very few female directors. After the Bill is passed, the gap between the two groups in *Female director ratio* grows wider over time.

Panel B presents the DID analysis using the environmental scores as the dependent variables. In column (1), we regress *E score* on *Treated* × *Post* and find a positive and significant coefficient, suggesting that, once the Bill is in effect, the increase in the number of female directors stipulated by SB 826 leads to better environmental performance of the treated firms in California compared to the control firms outside California. The dynamic DID specification in column (2) confirms that there are similar levels of *E score* and temporal trends in *E score* before the Bill, whereas the treated firms exhibit significantly

better environmental performance, relative to the control firms, in the post-event period of 2019 to 2021.[16]

We note that the treated firms in our main DID analysis do not have a single female director before SB 826, despite being headquartered in California. That is, the treated and matched control firms exhibit similar patterns in the share of female directors and environmental performance before 2018 but then start to diverge since 2019. In other words, the identification strategy in this section focuses on the within-firm temporal change in the share of female directors, thus complementing the identification strategy focusing on the cross-sectional variation in the share of female directors in Section 4.2. Moreover, since we control for firm fixed effects in this test, any time invariant differences that could be correlated with both the share of female directors and corporate environmental performance, such as a firm's ESG vision or stakeholder orientation, are unlikely to be drivers of our main findings. Finally, we do not find any major changes of regulations targeting industrial pollution around SB 826 in California, which mitigates the concern of other confounding regulatory changes driving our results.

Table IA3 Panel C repeats the DID analysis in Table 6 using the same treated firms, while control firms are chosen from those headquartered in California with at least two female directors in 2018; as a result, those control firms are not required to add additional female directors.[17] We find the closest control firm for each treated firm by matching on (three-digit SIC) industry, firm size, and *E score* in 2018. The coefficients on the interaction

[16] Table IA3 Panel B repeats the DID analysis using 2016 as the pseudo event year. We show that the coefficients on the interaction term *Treated × Post* are not significantly different from zero when the dependent variables are *Female director ratio* and *E score*, suggesting that the estimated treatment effects in Table 6 are not random, but attributable to SB 826.

[17] We choose firms headquartered in California with at least two female directors as the control group because some firms were required to have multiple female directors by the end of 2021 as discussed earlier. It is worth noting that our DID findings remain if we use control firms headquartered in California with at least one female director in 2018.

term *Treated × Post* are positive and significantly different from zero, suggesting that, compared to peer California firms without the pressure to add female directors, the treated firms experience significant increases in *Female director ratio* and *E score* after passage of SB 826. We interpret this finding as supporting evidence that the treatment effect is likely driven by an increase in the number of female directors mandated by SB 826, rather than other California state-level regulations or any specific factors that only affect California firms.

In summary, using different identification strategies and exploring some plausibly exogenous variations in both the cross-section and time-series of female representation on boards, we identify a potential causal effect of female directors (as opposed to, for example, other director characteristics) on corporate environmental performance.

5. Female Directors and Facility-level Environmental Performance

To provide novel micro-level evidence on the positive association between the share of female directors and corporate environmental performance, specifically pollution-related outcomes, we employ facility-level data from the EPA that are based on regulatory reporting and thus immune to the aforementioned criticisms of ESG ratings.

We run the following lead-lag panel data regressions:

$$
\begin{aligned}
Facility-level\ outcome_{jit} &= \alpha_0 + \alpha_1 Female\ director\ ratio_{it-1} + \alpha_2 Facility\ characteristics_{jt-1} \\
&+ \alpha_3 Governance\ characteristics_{it-1} + \alpha_4 Firm\ characteristics_{it-1} \\
&+ \theta Facility\ FE_j + \gamma_1 Firm\ industry \times Year\ FE \\
&+ \gamma_2 Facility\ industry \times Year\ FE \quad + \gamma_3 Firm\ HQ\ state \times Year\ FE \\
&+ \gamma_4 Facility\ state \times Year\ FE \\
&+ \varepsilon_{jit}, \qquad (2)
\end{aligned}
$$

where $Facility-level\ outcome_{jit}$ is the natural logarithm of one plus the value of one of the following three measures of facility *j* of firm *i* in industry *s* in year *t*: 1) facility *j*'s number of source reduction practices weighted by the number of toxic chemicals applicable; 2) facility *j*'s number of unique source reduction practices applied to different toxic chemicals; and 3) facility *j*'s total production waste. Our variable of interest is $Female\ director\ ratio_{it}$, which denotes the share of female directors in firm *i* in year *t*. $Facility\ characteristics_{jt}$ include facility *j*'s sales (in logarithm), number of employees (in logarithm), and credit ratings in year *t*. Other control variables are similar to those included in Equation (1) for our firm-year level analysis. We control for facility fixed effects ($Facility\ FE_j$) that absorb facility-level, time-invariant factors. We also control for firm industry times year and facility industry times year fixed effects that absorb industry-specific time trends. We further control for firm headquarters state times year fixed effects and facility state times year fixed effects to absorb time-varying local factors (e.g., economic conditions) related to firms and facilities. We cluster standard errors at the firm level to account for firm-level treatment (i.e., the share of female directors) and possible interdependence within a firm across its facilities in industrial pollution-related outcomes.

Table 7 presents the results using the regression specification in Equation (2). In Panel A, where the dependent variable is the number of source reduction practices weighted by the number of toxic chemicals applicable, we show a positive and significant association between the share of female directors and the number of source reduction practices across different specifications. The coefficients on *Female director ratio* are in the range between 0.206 to 0.212 across different models. In terms of economic significance, using column (4) as an example, an increase from zero to 0.086 (the standard deviation of the female director ratio in the facility-level sample) in *Female director ratio* is associated with an increase of 0.025 in facilities' pollution prevention activities, which corresponds to 7.2% of the sample

mean.[18] A similar pattern is found in Panel B based on the number of unique source reduction practices by each facility in a year. We conclude that the share of female directors is positively associated with more corporate initiatives to reduce industrial pollution.

In Panel C, where the dependent variable is *Total production waste*, we find that the share of female directors is negatively and significantly associated with the facility-level quantity of production waste across different model specifications. The coefficients on *Female director ratio* range between -0.172 to -0.175. In terms of economic significance, using column (4) as an example, an increase from zero to 0.086 (the standard deviation of the female director ratio in the facility-level sample) in *Female director ratio* is associated with a decrease of 3.4% in facilities' total quantity of production waste, which corresponds to 2.7% of the sample mean.[19]

One potential concern surrounding our facility-level analysis is that firms may opportunistically relocate some of their most polluting production across facilities to help improve their environmental ratings. Including facility fixed effects in our facility-level regressions helps mitigate this concern. Moreover, our facility-level method controls for the scale of a facility in terms of production output and employee headcount and thus helps rule out the possibility that a facility's drop in waste production is due to its opportunistic cut of production scale. Our results indicate a positive association between within-facility temporal change (which is the same as within-firm temporal change) in the share of female directors, and within-facility temporal improvement in environmental performance, as measured by pollution prevention and toxic chemicals produced.

[18] When a firm increases its female director ratio from 0 to 0.086, its facility is associated with a 0.025 (= (1 + 0.345) × (exp(0.086 × 0.212) − 1)) increase in its number of pollution prevention activities. Such increase corresponds to 7.2% of the average number of pollution prevention activities (0.345).
[19] When a firm increases its female director ratio from 0 to 0.086, its facility is associated with a –0.034 (= (1 + 1.270) × (exp(0.086 × (–0.174)) − 1)) drop in total quantity of production waste produced. Such drop corresponds to 2.7% of the average of total quantity of production waste (1.270).

Given the concerns raised by Cohn, Liu, and Wardlaw (2022) about implementing OLS regression estimation for count-based dependent variables, we also estimate Poisson regressions for Equation (2) when the dependent variables are the two measures of source reduction practices. Table IA4 in the Internet Appendix presents the results. Our main findings remain.

Finally, instead of controlling for location times year fixed effects, we again explore the effect of California's SB 826 on facility-level outcomes for the treated and control firms, defined in Table 6, before versus after the Bill. The sample size is small: We have data on production waste for only 18 facilities of the treated firms, and 32 facilities of the control firms, which limits the analysis.[20] Still, both summary statistics (Panel A) and regression results (Panel B) in Table IA5 in the Internet Appendix suggest that the drop in total production waste in treated facilities before and after SB 826 is significantly greater than the drop in control facilities.[21] Again, we control for facility fixed effects, which helps mitigate the concern about California firms reallocating facilities to different states after SB 826. In summary, our facility-level results provides micro-level evidence for some real effects of female directors on corporate environmental performance.

6. Director Qualifications, Board Diversity, and Monitoring

In our conceptual framework, we posit that board gender diversity may influence corporate environmental performance through the following non-mutually exclusive channels. Female directors with their "other-regarding" preferences and long-term orientations, bring non-business backgrounds and expertise (such as sustainability) into boardrooms that are different from those of male directors. Moreover, due to their different

[20] Over the estimation window, there is no reported new source reduction practice by either treated firm facilities or control firm facilities.
[21] Results remain similar if we exclude control firms' facilities located in California, suggesting that our results are not driven by other confounding regulatory changes in California.

values and perspectives, backgrounds, and expertise, some of which perhaps are hard to measure, female directors contribute to diversity of thought in the boardroom, which may help shape environmental-friendly corporate policies and practices. Finally, female directors are diligent monitors and their presence helps improve accountability and incentive alignment, resulting in better environmental performance. To explore these potential channels, we employ director- and board-level data primarily from BoardEx, supplemented by Refinitiv's ESG Board Member data set.

6.1. Director and board qualifications

Motivated by the literature on gender and director qualifications (e.g., Kim and Starks 2016; Adams, Akyol, and Verwijmeren 2018; Field, Souther, and Yore 2020), we first examine whether female directors differ significantly from their male counterparts in terms of biographic characteristics and professional qualifications. For this analysis, we employ a sample of firm-director-year observations derived from the firm sample in Table 3 and control for firm times year fixed effects. Table 8 presents the results.

Panel A presents the regression results comparing female and male directors in age, board tenure, and educational background, within a firm-year. We show that, female directors are significantly younger and have significantly shorter board tenures compared to their male counterparts. We further show that female directors are significantly less likely to have studied business or STEM compared to their male counterparts, but more likely to have arts and medical degrees. Also, female directors are significantly more likely to have studied in more fields and better educated (in terms of the highest degree achieved) compared to their male counterparts.

Panel B presents the regression results comparing female and male directors in skill sets, within a firm-year. We first show that, female directors are more likely than their male counterparts to have skills in academic, community, international, sustainability, government,

legal, risk management, and technology, consistent with the findings in Kim and Starks (2016). Within the business domain, female directors are more likely to have expertise in marketing, strategic planning, and HR, but are less likely to have traditional backgrounds valued by boards such as expertise in general management, entrepreneurship, and M&As. In general, female directors are more likely to possess E&S related expertise (e.g., community, sustainability) and have a significantly broader set of expertise than male directors.

We next explore the extent to which director/board qualifications account for the observed positive effect of female directors on firms' environmental performance. This positive effect could be driven by director gender itself, and/or it could be due to the addition of female directors with characteristics and qualifications that correlate positively with firms' commitment to environmental performance. Our rich set of director- and board-level attributes allows us to disentangle the two. If the influence of female directors on corporate environmental performance simply reflects certain qualifications specific to female directors (as uncovered in Panels A and B), when we run a horse race by adding board-level academic fields and skills to the baseline specification in Table 5 column (1), we would expect those field and skill variables to load significantly and/or even to supersede the share of female directors. Panel C presents the results.

We show that our main findings regarding the significant effect of *Female director ratio* on corporate environmental performance remain. In contrast, almost all female director-specific fields (e.g., arts, medicine) or expertise (e.g., government and policy, community, sustainability) do not exhibit any significant association with corporate environmental performance, suggesting a distinctive role of director gender beyond those individual, measurable director characteristics and qualifications.

6.2. Board diversity

While individual, measurable director qualification does not appear to explain away the effect of *Female director ratio* on corporate environmental performance, it could still be the case that the mixture of director skills drives the female director effect. To further explore how female directors help enhance corporate environmental performance, we examine whether and how firms consider board diversity when adding female directors and whether standard board diversity measures supersede *Female director ratio* in explaining firms' environmental performance.

Table 9 Panel A directly tests whether firms consider board diversity when hiring female directors, as suggested by the opening quotation. Following Bernile, Bhagwat, and Yonker (2018), we construct various Herfindahl-Hirschman (HHI) indices spanning: educational background, skill, sector experience, undergraduate college, and ethnicity. We then regress the year-to-year change in *Female director ratio* on lagged HHI measures. We show that firms do tend to increase the fraction of female directors on boards when they have less diversified boards, captured by high HHI values. In contrast, most of the firm financial characteristics do not predict the change in *Female director ratio*. Overall, it seems that companies indeed try to improve board diversity by adding female directors, potentially because of these directors' non-business backgrounds and expertise.

We next examine the extent to which board diversity measures account for the observed positive effect of female directors on firms' environmental performance. If the influence of female directors on corporate environmental performance simply reflects added diversity brought by those directors (as uncovered in Panel A), when we run a horse race by adding different board diversity measures one at a time to the baseline specification in Table 5 column (1), we would expect those board diversity measures to load significantly and/or even to supersede the share of female directors. Panel B presents the results.

We show that *Female director ratio* has a distinct and significant role rather than those HHI indices in corporate environmental performance. Together with the plausibly causal effect from *Female director ratio* established in Section 4, our cumulative evidence seems to point to the share of female directors as a holistic measure of some potentially unmeasurable values and perspectives that female directors bring to the table. Specifically, female directors with strong innate "other-regarding" preferences could contribute to diversity of thought in the boardroom, facilitate open discussions/decision-making on environmental issues, which helps improve their firms' environmental policies and practices.

6.3. Female directors as monitors

Next, we directly examine the governance role of female directors. Flammer, Hong, and Minor (2019) show that incentives are vital to improving corporate environmental performance. Adams and Ferreira (200), Field, Souther, and Yore (2020) point to gender differences in director monitoring. We thus expect that female directors are more likely to scrutinize and/or link executive compensation linked to corporate environmental performance. We obtain from the Refinitiv ESG data set, at the firm-year level, data on whether there is a ESG committee (either at the executive level or board level), and whether there is compensation policy linking ESG metrics to executive pay.[22] Table 10 presents the results.

Panel A presents the regression results comparing female and male directors in board leadership and committee roles, controlling for director characteristics such as education backgrounds and skills. We first show that female directors are significantly less likely to serve leadership roles on boards (as Chairman of the Board or lead director) compared to

[22] In untabulated analysis, we note that 28% of the firm-year observations have an ESG (executive) committee, and about a quarter of the firm-year observations have a compensation policy linking ESG metrics to executive pay.

their male counterparts, consistent with the findings in Field, Souther, and Yore (2020).[23] We further show that female directors are significantly more likely to serve on key committees on a board—audit, compensation, and nomination committees—compared to their male counterparts, consistent with the findings in Adams and Ferreira (2009). Importantly, we identify a positive and significant association between a director being a female and her likelihood to be on the CSR committee, possibility due to her pro-social preferences, backgrounds, or expertise.

Panel B presents the regression results using a similar specification as Equation (1), controlling for board-level academic fields and skills. We show a positive and significant association between a firm's *Female director ratio* and it having ESG (executive) committee or ESG-linked compensation policy for executives. This result also serves as a mechanism revealing how female directors exert their influence to improve corporate environmental performance.

We conclude that female directors with different values and perspectives, non-business backgrounds, and expertise (from those of male directors) contribute to diversity of thought in the boardroom and help improve corporate environmental performance, potentially through both their advising and monitoring roles.

7. Conclusions

Using firm- and facility-level measures of corporate environmental performance over the period 2002–2021, this paper establishes a robust and positive association between board gender diversity and corporate environmental performance. Based on identification strategies

[23] In these two specifications, we include industry times year and firm fixed effects, instead of firm times year fixed effects, because typically only one director per firm-year takes a leadership position.

using the instrumental variables approach and California's SB 826 in 2018, we conclude that this relation is likely to be causal.

Using granular director- and board-level data, we uncover a number of non-mutually exclusive channels for this causal relationship. We show that female directors with their "other-regarding" preferences, long-term orientations, and non-business backgrounds and expertise contribute to diverse perspectives in the boardroom. We further run horse races between the share of female directors and a large number of director/board qualification measures and standard board diversity measures in explaining corporate environmental performance. We show that none of those board qualification or diversity measures loads significantly nor do they supersede the role of female directors. These findings suggest that director gender is likely a holistic measure of potentially unmeasurable values and perspectives that female directors bring to the table, and that female directors contribute to diversity of thought and help improve corporate environmental performance. We further show that firms with female directors are more likely to have ESG (executive) committees and link executive compensation to ESG metrics.

We conclude that gender diversity on boards brings long-term benefits to society. Moreover, we highlight the important interactions among the three pillars of ESG in this paper: Policies targeting at *s*ocial issues (e.g., improving board diversity) could have spillover effects for corporate *e*nvironmental performance, possibly through *g*overnance channels. Exploring such interactions in future research will both guide how corporate ESG performance could be measured and inform government policies and corporate practices.

Appendix
Variable definitions

All continuous variables are winsorized at the 1st and 99th percentiles.

Variable	Definition	Source
Environmental performance measures		
E score	Average of emissions reduction score, resource use score, and innovation score.	Refinitiv ESG
Emissions reduction score	The emission reduction score measures a firm's commitment and effectiveness towards reducing environmental emissions in its production and operational processes.	Refinitiv ESG
Innovation score	The innovation score reflects a firm's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.	Refinitiv ESG
Resource use score	The resource use score reflects a firm's performance and capacity to reduce the use of materials, energy, or water and to find more eco-efficient solutions by improving supply chain management.	Refinitiv ESG
ln(#Source reduction practices by chemical + 1)	Natural logarithm of one plus the total number of a facility's source reduction activities (i.e., activities a facility implements to prevents pollution) applied to each different toxic chemical in a year. For example, if a facility implements two source reduction practices W1 and W2 in a year (both W1 and W2 are applied to toxic chemicals A and B, and W2 is applied to toxic chemical Z), then its *#Source reduction practices* by chemical is 5. The value is collected from TRI File Type 2A Form (more details are provided in the Internet Appendix).	EPA Pollution Prevention (P2)
ln(#Source reduction practices by facility + 1)	Natural logarithm of one plus the total number of a facility's unique source reduction activities (i.e., activities a facility implements to prevents pollution) applied to different toxic chemicals in a year. For example, if a facility implements two source reduction practices W1 and W2 in a year (both W1 and W2 are applied to toxic chemicals A and B, and W2 is applied to toxic chemical Z), then its *#Source reduction practices by facility* is 2. The value is collected from TRI File Type 2A Form (more details are provided in the Internet Appendix).	EPA Pollution Prevention (P2)
ln(Total production waste + 1)	Natural logarithm of one plus a facility's total quantity of toxic chemicals (in millions of pounds) produced in the production process in a year.	EPA TRI
Firm characteristics		

Female director ratio	Number of female directors scaled by board size.	BoardEx
ΔFemale director ratio	Change in female director ratio from the prior to the focal fiscal year	BoardEx
Board size	Number of directors on a board.	BoardEx
Board governance	Sum of three indicator variables: 1) Board size indicator takes the value of one if a firm's board size is not in the top quartile of BoardEx firms in a fiscal year, and zero otherwise; 2) Board independence indicator takes the value of one if a firm's board independence ratio is in the top quartile of BoardEx firms in a fiscal year, and zero otherwise; and 3) Board busyness indicator takes the value of one if a firm's board busyness measure is not in the top quartile of BoardEx firms in a fiscal year, and zero otherwise.	BoardEx
Female CEO	Indicator variable that takes the value of one if a firm has a female CEO, and zero otherwise.	BoardEx
Big3 institutions	Fraction of shares outstanding held by BlackRock, Vanguard, and State Street.	WRDS Thomson 13F
M/B	Market value of equity scaled by book value of equity.	Compustat
Firm size	Natural logarithm of total assets.	Compustat
ROA	Net income after subtracting expenses or losses, including extraordinary items scaled by total assets.	Compustat
Leverage	Sum of long-term debt and debt in current liabilities scaled by total assets.	Compustat
Cash holdings	Cash and short-term investments scaled by total assets.	Compustat
SG&A	Selling, general, and administrative expenses scaled by sales.	Compustat
Female director ratio quartile 1	Indicator variable that takes the value of one if a firm's female director ratio is in the bottom quartile, and zero otherwise.	BoardEx
Female director ratio quartile 2	Indicator variable that takes the value of one if a firm's female director ratio is in the second quartile, and zero otherwise.	BoardEx
Female director ratio quartile 3	Indicator variable that takes the value of one if a firm's female director ratio is in the third quartile, and zero otherwise.	BoardEx
Female director ratio quartile 4	Indicator variable that takes the value of one if a firm's female director ratio is in the top quartile, and zero otherwise.	BoardEx
Board IDV (UAI, PDI, MAS)	Average of the individualism (uncertainty avoidance, power distance, or masculinity) score of directors on a board in a year, based on a director's ancestral background inferred from her last name. See Pan, Wang, and Siegel (2017, 2020) for details.	Hofstede Culture Dimension website, Pan, Wang, and Siegel (2017, 2020)

Board Democratic share	Average of the Democratic share of each director on a board in a year. A director k's Democratic share is captured by her contribution amount to the Democratic ($D_{k,\to t}$) and Republican ($R_{k,\to t}$) parties up to year t as follows: $$Dem_{k,t} = \frac{D_{k,\to t}}{R_{k,\to t} + D_{k,\to t}}.$$	Federal Election Commission
Facility characteristics		
Credit score	The maximum Dun & Bradstreet PayDex Score, a 100-point indexing system that captures trade experiences reported to NETS, compares payment to terms of sale, and scores the overall manner of payment. The index is dollar-weighted by the amount of credit involved. A PayDex Score of 80 indicates that, on average, a business pays its bills in a "Prompt" manner.	NETS
ln(Sales)	Natural logarithm of estimated sales (in millions of dollars) of a facility in a year.	NETS
ln(#Employees)	Natural logarithm of reported number of employees working in a facility in a year.	NETS
Instrumental variable		
Gender Equality Index	Firm-year average of the Gender Equality Index (GEI) of the state where a director obtained her undergraduate degree. We first assign GEI to each director based on the state where she went to college. We then calculate the firm-year average GEI across all directors on a board in a year. The index includes state-level indicators of economic, political, and legal gender equality. It combines seven indicators of economic gender equality (such as labor market participation and labor income), four indicators of political gender equality (such as female representation in state house and as mayors), and thirteen indicators of legal gender equality (such as fair employment practices law and equal pay law), using data from the State and Regional Indicators Archive over the period 1977–1983.	Sugarman and Straus (1988)
Gender Egalitarian Index	The first principal component of two standardized variables measuring cultural attitudes toward women in a firm's headquarters county. The two variables are derived from the World Values Survey using questions about individual perceptions about women's role in society, and from the Hofstede (1980, 2001) survey for how much a society values traditional male and female roles. We first assign each 1900 U.S. Census respondent their country of origin's gender-egalitarianism index value, and then average these	McLean, Pirinsky, and Zhao (forthcoming)

	values across respondents within each county. The detailed variable construction is provided in the Appendix of McLean, Pirinsky, and Zhao (forthcoming).	
Civil Rights Act	Firm-year average of the Civil Rights Act indicator across all directors on a board in a year. The Civil Rights Act indicator takes the value of one if a director was 18 years old or younger in 1965 following passage of the Civil Rights Act of 1964, and zero otherwise. The Act makes it illegal for college admissions to discriminate on the basis of race or gender, providing more higher education opportunities and job mobility for minorities and women.	Field, Souther, and Yore (2020)
Channel variables		
Director-level		
Female	Indicator variable that takes the value of one if a director is a female, and zero otherwise.	BoardEx
Age	Director age.	BoardEx
Tenure	Director tenure.	BoardEx
Field_arts	Indicator variable that takes the value of one if a director has earned a degree in arts (e.g., BA, AB, MA, MPhil), and zero otherwise.	
Field_business	Indicator variable that takes the value of one if a director has earned a degree in economics or business (e.g., MBA, BBA, BCOM, DBA) or has professional designation as chartered accountant, or chartered financial analyst, and zero otherwise.	BoardEx
Field_law	Indicator variable that takes the value of one if a director has earned a degree in law (e.g., JD, LLB, LLM), and zero otherwise.	BoardEx
Field_medicine	Indicator variable that takes the value of one if a director has earned a degree in medicine (e.g., MD), and zero otherwise.	BoardEx
Field_STEM	Indicator variable that takes the value of one if a director has earned a degree in science (e.g., BS, BSc, Bachelor of Engineering, MSc), and zero otherwise.	BoardEx
#Fields	Sum of a director's fields of study.	BoardEx
Highest degree	Highest degree received by a director. It takes the value of 3 for PhD, 2 for MBA, JD, MD, or other master's degree, or 1 for bachelor's degree, and zero otherwise.	
Skill_academic	Indicator variable that takes the value of one if a director has worked at universities and her prior job roles contain any of the following key words—professor, lecturer, faculty, instructor, dean, director, chair, provost, chancellor, principal, or president, and zero otherwise.	BoardEx

Skill_government & policy	Indicator variable that takes the value of one if a director has worked at government agencies, or her prior job roles or descriptions contain any of the following key words—commissioner, council member, senior advisor, director, regulatory, policy, policies, government, public policy, ambassador, public sector, enforcement, or lobby, and zero otherwise.	BoardEx
Skill_risk management	Indicator variable that takes the value of one if a director has experience in risk management, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: risk, cyber, or information security.	BoardEx
Skill_scientific	Indicator variable that takes the value of one if a director has experience in scientific research or research and development, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: researcher, scientist, scientific, research & development, R&D, clinical research, research fellow, or research investigator.	BoardEx
Skill_technology	Indicator variable that takes the value of one if a director has experience in technology, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: technology, technologist, technologies, CIO, chief information officer, CTO, chief technology officer, innovation, IT, or information technology.	BoardEx
Skill_sustainability	Indicator variable that takes the value of one if a director has experience in environmental and/or sustainability issues, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: environment, safety, sustainability, sustainable, or ESG.	BoardEx
Skill_community	Indicator variable that takes the value of one if a director has worked at charities, or her prior job roles or job descriptions contain any of the following key words—community, non-profit, nonprofit, philanthropic, philanthropy, social, CSR, feminine care, family care, PR, public relation, public affair, charity, or charities, and zero otherwise.	BoardEx
Skill_finance accounting & econ	Indicator variable that takes the value of one if a director has experience in finance, accounting, or economics, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: financ, CFO, accountant, accounting, auditing, auditor, bank, investment, securities, economist, economic, banker, private bank, equity research, private equity, equity analyst, fixed income, bond, debt, loan, capital market, account manager, account management, accounts, trader, credit analyst, security analyst, credit officer, tax, underwriter, portfolio manager, treasury, treasurer, capital market, comptroller, controller, trading, trader, real	BoardEx

	estate, wealth, corporate accounts, enterprise account, asset management, holdings, lending, mortgage, high growth markets, quantitative analyst, CFA, or CPA.	
Skill_management	Indicator variable that takes the value of one if a director has management experience, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: executive officer, president, CEO, CFO, COO, CIO, CTO, CPO, CCO, managing, or management.	BoardEx
Skill_entrepreneurship	Indicator variable that takes the value of one if a director has experience in entrepreneurship, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: entrepreneur, evaluating business, innovative idea, start-up, startup, venture, founder, co founder, co-founder, founding, owner, or small business.	BoardEx
Skill_international	Indicator variable that takes the value of one if a director has international experience, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: global, international, multinational, worldwide, north america, latin america, europe, asia, asia pacific, americas, middle east, africa, australia, china, japan, india, canada, united kingdom, UK, great britain, france, germany, new zealand, foreign, korea, emerging markets, brazil, ireland, mexico, turkey, colombia, americas region, poland, malaysia, taiwan, italy, hong kong, or israel.	BoardEx
Skill_legal	Indicator variable that takes the value of one if a director has legal experience, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: attorney, lawyer, legal, litigation, law, intellectual property, general counsel, patent counsel, law clerk, senior counsel, or corporate counsel.	BoardEx
Skill_manufacturing	Indicator variable that takes the value of one if a director has experience in manufacturing, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: industrial, manufactured, manufacturing, production, process, or quality.	BoardEx
Skill_marketing	Indicator variable that takes the value of one if a director has marketing experience, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: marketing, mktg, market, CMO, advertising, brand, sales, salesman, merchandising, merchandise, retail, product strategy, consumer, customer, channel, communication, user experience, client, media, investor relation, investor service, or analyst relation.	BoardEx
Skill_strategic planning	Indicator variable that takes the value of one if a director has experience in strategic planning, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: business planning, business	BoardEx

	planner, business-planning, business solutions, decision making, decision-making, problem solving, problem-solving, strategic, strategies, strategy, strategist, business intelligence, business development, business affairs, business analyst, corporate development, planner, corporate affairs, organization development, organizational development, alliance, or change management.	
Skill_HR	Indicator variable that takes the value of one if a director has HR experience, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: human resource, HR, recruitment, recruiter, recruiting, talent, staffing, compensation, employee relation, labor, people operations, diversity, or DEI.	BoardEx
Skill_operations	Indicator variable that takes the value of one if a director has experience in operations, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: operations, COO, logistics, supply chain, supply-chain, business operations, supply, procurement, sourcing, buyer, commodity manager, distribution, project, quality assurance, global sourcing, product line manage, or OPS.	BoardEx
Skill_M&As	Indicator variable that takes the value of one if a director has experience in M&As, and zero otherwise. A director has such experience if her prior job roles or job descriptions contain any of the following key words: M&A, M & A, merger and acquisition, merger & acquisition, mergers and acquisitions, mergers & acquisitions, merger, or acquisition.	BoardEx
#Skills	Sum of a director's skills.	BoardEx
Chairman of the Board	Indicator variable that takes the value of one if a director is Chairman of the Board, and zero otherwise.	BoardEx
Lead director	Indicator variable that takes the value of one if a director's role contains any of the following key words—lead independent director, lead independent chairman, presiding lead independent director, lead independent corporate director, lead independent vice chairman, lead director, vice chairman (lead independent director), or lead independent outside director, and zero otherwise.	BoardEx
Audit committee	Indicator variable that takes the value of one if a director sits on audit committee in a year, and zero otherwise.	BoardEx
Compensation committee	Indicator variable that takes the value of one if a director sits on compensation committee in a year, and zero otherwise.	BoardEx

ESG committee	Indicator variable that takes the value of one if a director sits on ESG committee in a year, and zero otherwise. A board committee is responsible for ESG if its committee name contains any of the following key words: CSR, ESG, environ*, social, or sustain*.	BoardEx
Nomination committee	Indicator variable that takes the value of one if a director sits on nomination committee in a year, and zero otherwise.	BoardEx
Firm-level		
HHI field	Herfindahl-Hirschman (HHI) index of the number of directors with different academic fields. The filed categories include arts, business, STEM, law, and medicine.	BoardEx
HHI skill	HHI of the number of directors with different skills due to work experiences and job roles. The skill categories include academic, government, risk management, scientific, technology, sustainability, community, finance, accounting & economics, management, entrepreneurship, international, legal, manufacturing, marketing, strategic planning, HR, operations, and M&As.	BoardEx
HHI sector	HHI of the number of directors with different sector-specific experiences, as defined by BoardEx. For example, if a board has two directors in technology, three directors in finance, one director in non-for-profit, and the board size is five. HHI sector will be (2/5)^2 + (3/5)^2 + (1/5)^2 = 0.56.	BoardEx
HHI college	HHI of the number of directors attending different undergraduate colleges. For example, if a board has three directors who were Harvard graduates, and four directors who were Yale graduates, and the board size is seven. HHI college will be (3/7)^2 + (4/7)^2 = 0.51.	BoardEx
HHI ethnicity	HHI of the number of directors with different ethnicities, as defined by ISS. The ethnicity categories include Caucasian/white, Black/African American, Asian, Hispanic/Latin American, Middle-eastern/North African, Native American/Alaskan Native, Native Hawaiian/other Pacific Islander, and Other.	ISS
Female top executive ratio	Number of female top executives scaled by the number of (up to) top 5 executives.	ExecuComp
Mean age of directors	Average age of directors on a board.	BoardEx
Mean age of top executives	Average age of (up to) top 5 executives.	ExecuComp
SRI ownership	Fraction of shares outstanding held by socially responsible investment (SRI) funds.	Heath, Macciocchi, Michaely, and Ringgenberg (forthcoming)
ESG (executive) committee	Indicator variable that takes the value of one if a firm has an ESG committee at either the board level or at the senior management level, and zero otherwise. The data item from Refinitiv is as follows: “Does the company have a CSR committee or team, e.g., board	Refinitiv

	level or Senior management committee responsible for decision making on CSR strategy?"	
Compensation policy including ESG metric	Indicator variable that takes the value of one if a firm has an executive compensation policy that takes into account its ESG performance, and zero otherwise. The data item from Refinitiv is as follows: "Does the company have an extra-financial performance oriented compensation policy that includes remuneration for the CEO, executive directors, non-board executives, and other management bodies based on ESG or sustainability factors?"	Refinitiv

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Figure 1
The share of female directors over time

This figure plots the temporal trend in the share of female directors over time. The horizontal axis indicates the fiscal year. The vertical axis is the average *Female director ratio* across sample firms in a fiscal year. Our sample comprises 21,534 firm-year observations representing 3,174 firms over the period 2001–2020.

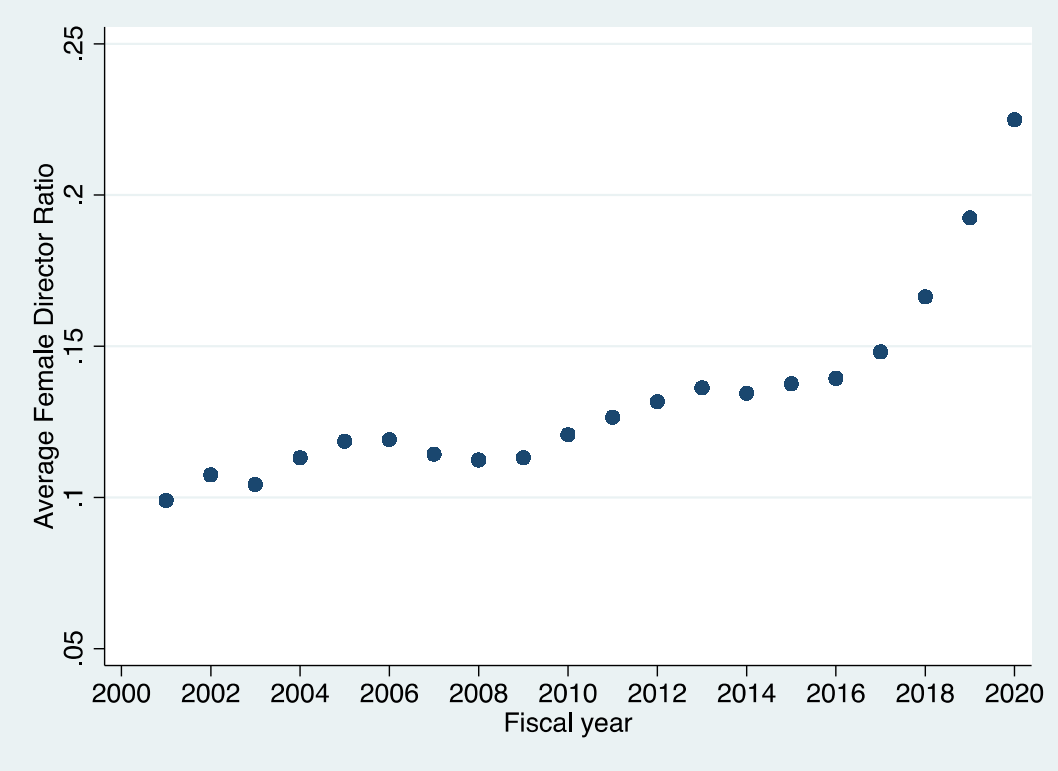


Table 1
Sample formation

This table lists the steps taken and filters applied to form the samples used in our analyses. Panel A reports the steps and filters applied to form our main sample of 21,534 firm-year observations for a sample of 3,174 firms over the period 2002–2021. Panel B reports the steps and filters applied to form our facility-level sample of 48,373 facility-year observations for a sample of 4,671 facilities associated with 618 firms over the same period.

Panel A: Firm sample formation

	#firm-year obs.	#firm-year obs. removed	#unique firms
WRDS Refinitiv ESG, 2002–2021	24,525		3,588
Remove observations with missing data from BoardEx	23,535	990	3,477
Remove observations with missing data form Compustat	22,933	602	3,343
Remove observations with missing data form WRDS Thomson 13F	22,869	64	3,338
Remove observations without Augmented 10-X Header Data	22,649	220	3,236
Remove observations due to fixed effects	21,534	1,115	3,174
Final sample	21,534		3,174

Panel B: Facility sample formation

	#facility-year obs.	#facility-year obs. removed	#unique facilities
TRI facility-year observations matched to GVKEY,1991–2021	166,453		14,008
Remove observations not covered by NETS	109,679	52,135	9,739
Remove observations not in our baseline firm sample	90,955	18,724	8,605
Remove observations with missing data used in regression analysis	49,835	41,120	5,259
Remove observations due to fixed effects	48,373	1,462	4,671
Final sample	48,373		4,671

Table 2
Summary statistics

This table provides the summary statistics for our firm and facility samples. Panel A presents the summary statistics for the firm-level variables of 21,534 firm-year observations for a sample of 3,174 firms over the period 2002–2021. Panel B presents the summary statistics for the director-level variables of 206,115 director-year observations for the firm sample. Panel C presents the summary statistics for the facility-level variables of 48,373 facility-year observations for the facility sample. Panel C presents the correlation matrix for key variables in the firm sample. Definitions of the variables are provided in the Appendix.

Panel A: Summary statistics for the firm sample

	Mean	SD	P5	Median	P95
	(1)	(2)	(3)	(4)	(5)
E score	0.212	0.254	0.000	0.098	0.739
Emissions reduction score	0.241	0.303	0.000	0.083	0.876
Innovation score	0.150	0.259	0.000	0.000	0.791
Resource use score	0.245	0.312	0.000	0.046	0.893
Female director ratio	0.151	0.107	0.000	0.143	0.333
Board size	10.975	3.724	6.000	10.000	17.000
Board governance	1.868	0.571	1.000	2.000	3.000
Female CEO	0.038	0.190	0.000	0.000	0.000
Big3 institutions	0.145	0.080	0.022	0.146	0.284
M/B	3.437	5.685	0.504	2.212	11.894
Firm size	8.184	1.885	5.014	8.175	11.293
ROA	0.003	0.172	-0.284	0.027	0.155
Leverage	0.272	0.220	0.000	0.242	0.691
Cash holdings	0.161	0.203	0.005	0.078	0.639
SG&A	0.277	0.659	0.000	0.161	0.689
HHI field	0.336	0.077	0.254	0.320	0.469
HHI skill	0.158	0.046	0.106	0.148	0.242
HHI sector	0.131	0.081	0.060	0.107	0.289
HHI college	0.152	0.079	0.083	0.136	0.278
HHI ethnicity	0.820	0.166	0.520	0.820	1.000
ESG (executive) committee	0.251	0.434	0.000	0.000	1.000
Compensation policy including ESG metric	0.280	0.449	0.000	0.000	1.000

Panel B: Summary statistics for the director sample

	Mean	SD	P5	Median	P95
	(1)	(2)	(3)	(4)	(5)
Female	0.179	0.383	0.000	0.000	1.000
Age	62.271	8.739	47.000	63.000	76.000
Tenure	7.950	7.379	0.600	5.700	22.700
Field_arts	0.389	0.487	0.000	0.000	1.000
Field_business	0.534	0.499	0.000	1.000	1.000
Field_STEM	0.451	0.498	0.000	0.000	1.000
Field_law	0.137	0.343	0.000	0.000	1.000
Field_medicine	0.030	0.171	0.000	0.000	0.000
# Fields	1.540	0.686	0.000	2.000	2.000
Highest degree	1.752	0.640	1.000	2.000	3.000
Skill_academic	0.129	0.335	0.000	0.000	1.000
Skill_government & policy	0.188	0.391	0.000	0.000	1.000

Skill_risk management	0.016	0.125	0.000	0.000	0.000
Skill_scientific	0.040	0.197	0.000	0.000	0.000
Skill_technology	0.083	0.276	0.000	0.000	1.000
Skill_sustainability	0.018	0.135	0.000	0.000	0.000
Skill_community	0.069	0.254	0.000	0.000	1.000
Skill_finance accounting & economics	0.464	0.499	0.000	0.000	1.000
Skill_management	0.861	0.346	0.000	1.000	1.000
Skill_entrepreneurship	0.299	0.458	0.000	0.000	1.000
Skill_international	0.261	0.439	0.000	0.000	1.000
Skill_legal	0.095	0.293	0.000	0.000	1.000
Skill_manufacturing	0.072	0.258	0.000	0.000	1.000
Skill_marketing	0.267	0.442	0.000	0.000	1.000
Skill_strategic planning	0.177	0.382	0.000	0.000	1.000
Skill_HR	0.044	0.205	0.000	0.000	0.000
Skill_operations	0.228	0.420	0.000	0.000	1.000
Skill_M&As	0.033	0.179	0.000	0.000	0.000
#Skills	3.345	1.735	1.000	3.000	6.000
Chairman of the Board	0.101	0.301	0.000	0.000	1.000
Lead director	0.046	0.209	0.000	0.000	0.000
Audit committee	0.438	0.496	0.000	0.000	1.000
Compensation committee	0.357	0.479	0.000	0.000	1.000
CSR committee	0.034	0.180	0.000	0.000	0.000
Nomination committee	0.276	0.447	0.000	0.000	1.000

Panel C: Summary statistics for the facility sample

	Mean	SD	P5	Median	P95
	(1)	(2)	(3)	(4)	(5)
#Source reduction practices by chemical	0.345	1.275	0.000	0.000	2.000
#Source reduction practices by facility	0.189	0.607	0.000	0.000	1.000
Total production waste (in millions of pounds)	1.270	3.882	0.000	0.045	8.045
ln(#Source reduction practices by chemical + 1)	0.142	0.431	0.000	0.000	1.099
ln(#Source reduction practices by facility + 1)	0.107	0.310	0.000	0.000	0.693
ln(Total production waste + 1)	0.371	0.711	0.000	0.044	2.202
Female director ratio	0.136	0.086	0.000	0.133	0.286
Board governance	1.661	0.743	0.000	2.000	3.000
Female CEO	0.029	0.168	0.000	0.000	0.000
Big3 institutions	0.124	0.077	0.009	0.129	0.247
M/B	2.996	4.299	0.874	2.272	7.840
Firm size	9.132	1.925	6.200	9.009	12.801
ROA	0.047	0.066	-0.043	0.047	0.136
Leverage	0.283	0.145	0.060	0.270	0.550
Cash holdings	0.087	0.079	0.006	0.067	0.234
SG&A	0.126	0.105	0.000	0.109	0.322
Sales (in millions of dollars)	149.940	299.141	2.250	53.304	648.751
#Employees	429.555	708.042	9.000	200.000	1618.000
ln(Sales +1)	17.640	1.664	14.627	17.792	20.291
ln(#Employees +1)	5.114	1.529	2.303	5.303	7.390
Credit score	73.741	5.526	64.000	75.000	80.000

Panel D: Correlation matrix of the firm sample

		1	2	3	4	5	6	7	8	9	10	11
1	E score	1.000										
2	Female director ratio	0.251***	1.000									
3	Board governance	-0.091***	0.031***	1.000								
4	Female CEO	0.035***	0.247***	0.025***	1.000							
5	Big3 institutions	0.280***	0.287***	0.145***	0.030***	1.000						
6	M/B	0.010	0.032***	0.008	0.017**	-0.008	1.000					
7	Firm size	0.501***	0.146***	-0.258***	-0.024***	0.151***	-0.126***	1.000				
8	ROA	0.184***	0.045***	-0.076***	-0.026***	0.140***	-0.034***	0.349***	1.000			
9	Leverage	0.104***	0.054***	0.060***	0.008	0.105***	-0.061***	0.106***	-0.042***	1.000		
10	Cash holdings	-0.179***	-0.037***	0.071***	0.031***	-0.124***	0.225***	-0.450***	-0.401***	-0.249***	1.000	
11	SG&A	-0.120***	-0.024***	0.028***	0.015**	-0.097***	0.091***	-0.254***	-0.351***	-0.085***	0.292***	1.000

Table 3
Female directors and corporate environmental performance

This table examines the relation between the share of female directors on a board and corporate environmental performance. The sample consists of 21,534 firm-year observations over the period 2002–2021. We use four different environmental scores as the dependent variables: *E score*, *Emissions reduction score*, *Innovation score*, and *Resource use score*. Our variable of interest is *Female director ratio*, the number of female directors scaled by board size. We include (three-digit SIC) industry times year fixed effects. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	E score	Emissions reduction score	Innovation score	Resource use score
	(1)	(2)	(3)	(4)
Female director ratio	0.232***	0.287***	0.116***	0.293***
	(0.029)	(0.035)	(0.032)	(0.036)
Board governance	-0.011**	-0.017***	-0.007	-0.010*
	(0.004)	(0.006)	(0.005)	(0.006)
Female CEO	-0.001	-0.007	0.002	0.001
	(0.015)	(0.018)	(0.019)	(0.018)
Big3 institutions	0.073	0.060	0.040	0.120**
	(0.045)	(0.055)	(0.050)	(0.054)
M/B	0.001***	0.002***	0.001*	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.093***	0.108***	0.060***	0.112***
	(0.003)	(0.003)	(0.004)	(0.003)
ROA	-0.054***	-0.049**	-0.051***	-0.064***
	(0.016)	(0.019)	(0.016)	(0.019)
Leverage	-0.068***	-0.074***	-0.055***	-0.077***
	(0.016)	(0.020)	(0.018)	(0.020)
Cash holdings	0.044**	0.055**	0.063***	0.014
	(0.020)	(0.026)	(0.023)	(0.024)
SG&A	0.004*	0.007**	0.001	0.004*
	(0.002)	(0.003)	(0.002)	(0.003)
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	21,534	21,534	21,534	21,534
Adj-R^2	0.532	0.490	0.362	0.487

Table 4
Female directors and corporate environmental performance: 2SLS

This table examines the relation between the share of female directors on a board and corporate environmental performance using 2SLS regressions. The sample consists of 18,365 firm-year observations with available data for the instrumental variables over the period 2002–2021. Column (1) reports the first-stage regression results, where *Gender Equality Index*, *Gender Egalitarian Index*, and *Civil Rights Act* are used as the instrumental variables. Column (2) reports the second-stage regression results. We use four different environmental scores as the dependent variables: *E score*, *Emissions reduction score*, *Innovation score*, and *Resource use score*. Our variable of interest is *Female director ratio*, the number of female directors scaled by board size. We include the same set of firm-level controls as in Table 3. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	Female director ratio	E score	Emission reduction score	Innovation score	Resource use score
	1st stage	2nd stage			
	(1)	(2)	(3)	(4)	(5)
Gender Equality Index	0.110***				
	(0.036)				
Gender Egalitarian Index	0.005***				
	(0.002)				
Civil Rights Act	0.072***				
	(0.008)				
Female director ratio		0.534**	0.454*	0.656**	0.494*
		(0.220)	(0.262)	(0.256)	(0.279)
Firm-level controls	Yes	Yes	Yes	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
F value	30.96				
Overidentificaiton test (Hansen's J statistic)		0.592	0.452	0.537	1.354
Obs.	18,365	18,365	18,365	18,365	18,365
Adj-R^2	0.261	0.315	0.293	-0.004	0.297

Table 5
Female directors and corporate environmental performance: firm fixed effects and nonlinearity

This table examines within-firm temporal variations in the share of female directors on a board in relation to within-firm temporal variations in corporate environmental performance and potential nonlinearity in the relation. The sample consists of 21,294 firm-year observations over the period 2002–2021. In column (1), we include firm fixed effects, and our variable of interest is *Female director ratio*, the number of female directors scaled by board size. In column (2), we include four indicator variables using the sample quartiles of *Female director ratio* as the cutoffs. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	E score	
	(1)	(2)
Female director ratio	0.072***	
	(0.023)	
Female director ratio quartile 1		-0.021
		(0.080)
Female director ratio quartile 2		0.066
		(0.114)
Female director ratio quartile 3		0.121*
		(0.066)
Female director ratio quartile 4		0.090**
		(0.044)
Board governance	0.004	0.004
	(0.003)	(0.003)
Female CEO	-0.002	-0.003
	(0.015)	(0.015)
Big3 institutions	-0.040	-0.037
	(0.037)	(0.037)
M/B	-0.000	-0.000
	(0.000)	(0.000)
Firm size	0.028***	0.029***
	(0.005)	(0.005)
ROA	-0.019**	-0.020**
	(0.010)	(0.010)
Leverage	-0.023*	-0.023*
	(0.014)	(0.014)
Cash holdings	0.033*	0.033*
	(0.018)	(0.018)
SG&A	-0.002	-0.002
	(0.002)	(0.002)
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Obs.	21,294	21,294
Adj-R^2	0.843	0.843

Table 6
Female directors and corporate environmental performance: California's SB 826

This table examines changes in both the share of female directors on a board and corporate environmental performance between the treated and control firms around passage of California's SB 826, which since 2018 has imposesd a female director quota on firms headquartered in California. The treated firms are public firms without a female director in 2018 and headquartered (and stayed) in California. We find the closest control firm for each treated firm by matching on (three-digit SIC) industry, firm size, and *E score*. Panel A presents the sanity check on the impact of the California law change on the share of female directors in the treated firms compared to that in the control firms. In column (1), we regress *Female director ratio* on *Treated* × *Post*, an interaction term between the indicator variable *Treated* and the indicator variable, *Post*, for the post-event window (2019 to 2021). Column (2) employs a dynamic DID specification by interacting *Treated* with the year indicators for each year within the event window examined. Panel B presents the DID analysis with the environmental score, *E score*, as the dependent variable. We include the same set of firm-level controls as in Table 3. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the state level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: CA law change and the share of female directors on a board

	Female director ratio	
	(1)	(2)
Treated × Post	0.068***	
	(0.013)	
Treated × Year 2015		-0.010
		(0.013)
Treated × Year 2016		-0.005
		(0.011)
Treated × Year 2017		-0.010
		(0.012)
Treated × Year 2019		0.045***
		(0.014)
Treated × Year 2020		0.066***
		(0.017)
Treated × Year 2021		0.084***
		(0.026)
Firm-level controls	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Obs.	533	533
Adj-R^2	0.751	0.751

Panel B: CA law change and corporate environmental performance

	E score	
	(1)	(2)
Treated × Post	0.038***	
	(0.011)	
Treated × Year 2015		-0.026
		(0.021)
Treated × Year 2016		-0.015
		(0.023)
Treated × Year 2017		-0.009
		(0.007)
Treated × Year 2019		0.025***
		(0.007)
Treated × Year 2020		0.037**
		(0.014)
Treated × Year 2021		0.034**
		(0.016)
Firm-level controls	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes

Obs.	428	428
Adj-R^2	0.647	0.642

Table 7
Female directors and facility-level environmental performance

This table examines the relation between the share of female directors on a board and facility-level environmental performance. The sample consists of 48,373 facility-year observations for a sample of 4,671 facilities associated with 618 firms over the period 2002–2021. Panels A and B present the results where the dependent variables are facility-level pollution prevention measures: *ln(#Source reduction practices by chemical + 1)* and *ln(#Source reduction practices by facility + 1)*, respectively. Panel C presents the results where the dependent variable is facility-level total quantity of production-related waste, *ln(Total production waste + 1)*. We include three facility-level controls, the same set of firm-level controls as in Table 3, as well as facility fixed effects, firm-level (three-digit SIC) industry times year fixed effects, facility-level (three-digit SIC) industry times year fixed effects, firm headquarters state times year fixed effects, and facility state times year fixed effects. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Female directors and facility-level pollution source reduction practices by chemical

	ln(#Source reduction practices by chemical + 1)			
	(1)	(2)	(3)	(4)
Female director ratio	0.206**	0.211**	0.208**	0.212**
	(0.088)	(0.088)	(0.088)	(0.088)
ln(Sales)			0.003	0.005
			(0.019)	(0.019)
ln(#Employees)			0.008	0.007
			(0.021)	(0.020)
Credit score			0.001	0.001
			(0.001)	(0.001)
Firm-level controls	No	Yes	No	Yes
Facility Fixed Effects	Yes	Yes	Yes	Yes
Firm industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Firm headquarters state × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility state × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	48,373	48,373	48,373	48,373
Adj-R^2	0.493	0.494	0.494	0.494

Panel B: Female directors and facility-level pollution source reduction practices by facility

	ln(#Source reduction practices by facility + 1)			
	(1)	(2)	(3)	(4)
Female director ratio	0.126**	0.125**	0.127**	0.125**
	(0.061)	(0.061)	(0.061)	(0.061)
ln(Sales)			-0.004	-0.004
			(0.014)	(0.014)
ln(#Employees)			0.010	0.010
			(0.015)	(0.015)
Credit score			0.001*	0.001*
			(0.000)	(0.000)
Firm-level controls	No	Yes	No	Yes
Facility Fixed Effects	Yes	Yes	Yes	Yes
Firm industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Firm headquarters state × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility state × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	48,373	48,373	48,373	48,373
Adj-R^2	0.465	0.466	0.466	0.466

Panel C: Female directors and facility-level total production waste

	ln(Total production waste + 1)			
	(1)	(2)	(3)	(4)
Female director ratio	-0.174***	-0.175***	-0.172***	-0.174***
	(0.063)	(0.063)	(0.062)	(0.062)
ln(Sales)			0.005	0.006
			(0.013)	(0.013)
ln(#Employees)			0.005	0.004
			(0.014)	(0.014)
Credit score			0.000	0.000
			(0.000)	(0.000)
Firm-level controls	No	Yes	No	Yes
Facility Fixed Effects	Yes	Yes	Yes	Yes
Firm industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Firm headquarters state × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility state × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	48,373	48,373	48,373	48,373
Adj-R^2	0.928	0.928	0.928	0.928

Table 8
Director and board qualifications and corporate environmental performance

This table examines gender differences in director qualifications, board qualifications, and corporate environmental performance. Panel A presents the regression results comparing female and male directors in age, board tenure, and educational background. Panel B presents the regression results comparing female and male directors in skill. Panel C presents the regression results examining the relation between the share of female directors on a board, board qualifications in terms of educational background and skill, and corporate environmental performance. Definitions of the variables are provided in the Appendix. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Gender differences in director age, tenure, and educational background

	Age	Tenure	Field_arts	Field_business	Field_STEM	Field_law	Field_medicine	# Fields	Highest degree
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Female	-3.361***	-2.318***	0.119***	-0.038***	-0.056***	0.008	0.010***	0.042***	0.086***
	(0.115)	(0.102)	(0.009)	(0.009)	(0.009)	(0.006)	(0.003)	(0.012)	(0.011)
Firm × Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	202,494	206,115	192,910	192,910	192,910	192,910	192,910	192,910	192,917
Adj-R^2	0.136	0.227	0.049	0.028	0.048	0.026	0.107	0.031	0.072

Panel B: Gender differences in director skill

	Female		Firm × Year Fixed effects	Intercept	Obs.	*Adj-R^2*
	(1)	(2)	(3)	(4)	(5)	(6)
Skill_academic	0.050***	(0.007)	Yes	Yes	206,115	0.033
Skill_government & policy	0.073***	(0.007)	Yes	Yes	206,115	0.064
Skill_risk management	0.013***	(0.002)	Yes	Yes	206,115	0.015
Skill_scientific	0.012***	(0.003)	Yes	Yes	206,115	0.123
Skill_technology	0.026***	(0.005)	Yes	Yes	206,115	0.051
Skill_sustainability	0.019***	(0.003)	Yes	Yes	206,115	0.015
Skill_community	0.072***	(0.006)	Yes	Yes	206,115	0.017
Skill_finance accounting & economics	0.001	(0.008)	Yes	Yes	206,115	0.031
Skill_management	-0.056***	(0.006)	Yes	Yes	206,115	0.028
Skill_entrepreneurship	-0.016**	(0.008)	Yes	Yes	206,115	0.067
Skill_international	0.060***	(0.008)	Yes	Yes	206,115	0.091
Skill_legal	0.033***	(0.005)	Yes	Yes	206,115	0.010
Skill_manufacturing	-0.006	(0.004)	Yes	Yes	206,115	0.046
Skill_marketing	0.089***	(0.008)	Yes	Yes	206,115	0.065
Skill_strategic planning	0.058***	(0.007)	Yes	Yes	206,115	0.056
Skill_HR	0.058***	(0.005)	Yes	Yes	206,115	0.016
Skill_operations	0.006	(0.007)	Yes	Yes	206,115	0.033
Skill_M&As	-0.010***	(0.003)	Yes	Yes	206,115	0.022
# Skills	0.481***	(0.030)	Yes	Yes	206,115	0.105

Panel C: Female directors, board qualifications, and corporate environmental performance

	E score		
	(1)	(2)	(3)
Female director ratio	0.073***	0.066***	0.069***
	(0.023)	(0.023)	(0.023)
Field_arts	-0.005		-0.010
	(0.023)		(0.022)
Field_business	-0.030*		-0.039**
	(0.018)		(0.019)
Field_law	0.017		0.022
	(0.027)		(0.039)
Field_STEM	0.011		0.001
	(0.021)		(0.021)
Field_medicine	0.048		0.073
	(0.053)		(0.056)
Skill_academic		-0.009	-0.016
		(0.029)	(0.030)
Skill_government & policy		0.010	0.006
		(0.025)	(0.025)
Skill_risk management		0.069	0.064
		(0.066)	(0.066)
Skill_scientific		-0.028	-0.044
		(0.046)	(0.047)
Skill_technology		0.003	0.004
		(0.037)	(0.037)
Skill_sustainability		-0.008	-0.010
		(0.069)	(0.069)
Skill_community		-0.029	-0.030
		(0.041)	(0.041)

Skill_finance accounting & economics		-0.003	0.009
		(0.018)	(0.019)
Skill_management		0.064**	0.068***
		(0.026)	(0.026)
Skill_entrepreneurship		0.009	0.009
		(0.020)	(0.020)
Skill_international		0.006	0.008
		(0.023)	(0.023)
Skill_legal		0.015	-0.004
		(0.034)	(0.048)
Skill_manufacturing		-0.019	-0.019
		(0.037)	(0.037)
Skill_marketing		-0.007	-0.004
		(0.024)	(0.024)
Skill_strategic planning		0.010	0.012
		(0.025)	(0.025)
Skill_HR		0.091*	0.089*
		(0.047)	(0.046)
Skill_operations		0.017	0.019
		(0.023)	(0.023)
Skill_M&As		-0.036	-0.035
		(0.047)	(0.047)
Board governance	0.004	0.004	0.004
	(0.003)	(0.003)	(0.003)
Female CEO	-0.002	-0.004	-0.004
	(0.015)	(0.014)	(0.014)
Big3 institutions	-0.040	-0.046	-0.046
	(0.037)	(0.036)	(0.036)
M/B	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Firm size	0.028***	0.028***	0.028***
	(0.005)	(0.005)	(0.005)
ROA	-0.019**	-0.020**	-0.020**
	(0.010)	(0.010)	(0.010)
Leverage	-0.022	-0.022*	-0.022
	(0.014)	(0.014)	(0.013)
Cash holdings	0.033*	0.033*	0.034*
	(0.018)	(0.018)	(0.018)
SG&A	-0.003	-0.002	-0.002
	(0.002)	(0.002)	(0.002)
Industry × Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Obs.	21,294	21,294	21,294
Adj-R^2	0.843	0.843	0.843

Table 9
Board diversity and corporate environmental performance

This table examines board diversity and corporate environmental performance. Panel A presents the regression results examining the relation between board diversity measures in terms of Herfindahl–Hirschman indices (HHI) in educational background, skill, sector experience, undergraduate college, and ethnicity, and changes in the share of female directors on a board. Panel B presents the regression results examining the relation between the share of female directors on a board, board diversity, and corporate environmental performance. Definitions of the variables are provided in the Appendix. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Board diversity and changes in the share of female directors on a board

	ΔFemale director ratio				
	(1)	(2)	(3)	(5)	(4)
HHI field	0.053***				
	(0.013)				
HHI skill		0.189***			
		(0.027)			
HHI sector			0.050**		
			(0.023)		
HHI college				0.097***	
				(0.019)	
HHI ethnicity					0.019**
					(0.008)
Board governance	0.000	-0.000	0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Female CEO	-0.033***	-0.032***	-0.033***	-0.033***	-0.029***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)
Big3 institutions	-0.007	-0.006	-0.008	-0.006	0.028
	(0.014)	(0.014)	(0.014)	(0.015)	(0.029)
M/B	0.000	0.000	0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.004***	0.004***	0.004**	0.004***	0.008***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
ROA	0.002	0.001	0.001	0.002	0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.010)
Leverage	-0.006	-0.007	-0.007	-0.007	-0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)
Cash holdings	-0.004	-0.003	-0.004	-0.004	0.013
	(0.008)	(0.008)	(0.008)	(0.008)	(0.011)
SG&A	0.002	0.002	0.002	0.002	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.007)
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Obs.	21,294	21,294	21,294	21,294	7,377
Adj-R^2	-0.020	-0.017	-0.021	-0.018	-0.056

Panel B: Female directors, board diversity, and corporate environmental performance

	E score					
	(1)	(2)	(3)	(4)	(5)	(6)
Female director ratio	0.072***	0.070***	0.078***	0.072***	0.071***	0.076*
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	-0.041
HHI field		-0.053				
		(0.041)				
HHI skill			0.127			
			(0.080)			
HHI sector				0.046		
				(0.048)		
HHI college					-0.015	
					(0.041)	
HHI ethnicity						0.048
						(0.034)
Board governance	0.004	0.004	0.004	0.004	0.004	0.012**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Female CEO	-0.002	-0.002	-0.002	-0.002	-0.002	-0.007
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.030)
Big3 institutions	-0.040	-0.040	-0.039	-0.040	-0.040	-0.156
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.106)
M/B	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.028***	0.028***	0.028***	0.028***	0.028***	0.031***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.011)
ROA	-0.019**	-0.019**	-0.020**	-0.020**	-0.019**	0.015
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.029)
Leverage	-0.023*	-0.023*	-0.023*	-0.023*	-0.023*	-0.004
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.035)
Cash holdings	0.033*	0.033*	0.033*	0.033*	0.033*	0.050
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.041)
SG&A	-0.002	-0.002	-0.002	-0.002	-0.002	-0.012
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.013)
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	21,294	21,294	21,294	21,294	21,294	7,377
Adj-R^2	0.843	0.843	0.843	0.843	0.843	0.837

Table 10
Female directors, committee roles, and governance roles

This table examines whether female directors are different from their male counterparts in terms of committee roles and governance roles. Panel A presents the regression results comparing female and male directors in board leadership and committee roles, controlling for directors' educational backgrounds and skills. Panel B presents the regression analysis examining the relation between the share of female directors on a board and a firm having ESG (executive) committee, ESG reporting, or ESG-linked compensation policy for executives, controlling for firm characteristics. Definitions of the variables are provided in the Appendix. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Female directors and board leadership and committee roles

	Chairman of the Board	Lead director	Audit committee	Compensation committee	CSR committee	Nomination committee
	(1)	(2)	(3)	(4)	(5)	(6)
Female	-0.082***	-0.019***	0.097***	0.031***	0.014***	0.060***
	(0.003)	(0.002)	(0.007)	(0.007)	(0.002)	(0.006)
Age	-0.003***	0.002***	0.011***	0.008***	0.000***	0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Tenure	0.012***	0.003***	-0.010***	-0.002***	-0.000**	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Field_arts	-0.002	0.007**	0.001	0.038***	-0.001	0.028***
	(0.005)	(0.003)	(0.007)	(0.007)	(0.002)	(0.006)
Field_business	-0.010**	0.010***	0.103***	0.006	-0.005***	-0.003
	(0.004)	(0.003)	(0.007)	(0.006)	(0.002)	(0.005)
Field_STEM	0.011**	0.005*	0.007	0.012*	-0.002	0.008
	(0.005)	(0.003)	(0.007)	(0.006)	(0.002)	(0.006)
Field_law	0.008	0.020***	-0.022*	-0.019	0.003	0.053***
	(0.009)	(0.006)	(0.013)	(0.012)	(0.004)	(0.011)
Field_medicine	-0.026***	-0.018***	-0.098***	-0.028	-0.001	0.030**
	(0.008)	(0.006)	(0.017)	(0.018)	(0.005)	(0.015)
Highest degree	-0.003	0.001	-0.027***	0.009*	0.003**	0.005
	(0.003)	(0.002)	(0.005)	(0.005)	(0.002)	(0.004)
Skill_academic	-0.035***	0.003	0.039***	-0.001	0.003	0.039***
	(0.005)	(0.004)	(0.009)	(0.009)	(0.002)	(0.007)
Skill_government & policy	0.004	0.004	-0.042***	-0.004	0.006***	0.031***
	(0.005)	(0.003)	(0.008)	(0.007)	(0.002)	(0.006)
Skill_risk management	-0.008	-0.021***	0.070***	-0.084***	0.001	-0.052***
	(0.012)	(0.006)	(0.021)	(0.017)	(0.005)	(0.015)
Skill_scientific	-0.002	-0.021***	-0.071***	-0.074***	0.007	-0.032**
	(0.009)	(0.005)	(0.016)	(0.015)	(0.006)	(0.013)
Skill_technology	-0.013**	-0.000	0.014	-0.011	0.007**	0.003
	(0.006)	(0.004)	(0.010)	(0.009)	(0.003)	(0.008)
Skill_sustainability	0.007	-0.014*	0.009	-0.013	0.019***	0.019
	(0.012)	(0.007)	(0.021)	(0.017)	(0.007)	(0.015)
Skill_community	-0.023***	0.002	-0.015	0.011	0.007**	0.020**
	(0.006)	(0.005)	(0.012)	(0.010)	(0.003)	(0.009)
Skill_finance accounting & econ	-0.011***	0.003	0.177***	-0.052***	-0.007***	-0.029***
	(0.004)	(0.003)	(0.006)	(0.006)	(0.002)	(0.005)
Skill_management	0.069***	0.002	-0.081***	-0.011	-0.000	-0.042***
	(0.004)	(0.004)	(0.009)	(0.008)	(0.002)	(0.007)
Skill_entrepreneurship	0.015***	0.003	-0.019***	0.020***	0.001	0.016***
	(0.004)	(0.003)	(0.006)	(0.006)	(0.001)	(0.005)
Skill_international	-0.003	0.000	-0.003	0.013**	0.001	0.017***
	(0.004)	(0.003)	(0.007)	(0.007)	(0.002)	(0.005)
Skill_legal	-0.015*	-0.014**	-0.005	0.014	-0.003	0.003
	(0.009)	(0.006)	(0.014)	(0.013)	(0.003)	(0.011)
Skill_manufacturing	0.015**	-0.000	-0.024**	0.010	-0.001	0.005
	(0.007)	(0.005)	(0.011)	(0.010)	(0.003)	(0.008)

Skill_marketing	0.008*	-0.000	-0.046***	0.033***	0.001	-0.000
	(0.004)	(0.003)	(0.007)	(0.006)	(0.002)	(0.005)
Skill_strategic planning	-0.009*	0.002	0.016**	-0.004	0.000	0.000
	(0.005)	(0.003)	(0.007)	(0.006)	(0.002)	(0.006)
Skill_HR	-0.010	0.004	-0.077***	0.100***	0.005	0.002
	(0.008)	(0.006)	(0.013)	(0.013)	(0.004)	(0.010)
Skill_operations	0.009**	-0.000	-0.025***	-0.012*	0.001	-0.020***
	(0.005)	(0.003)	(0.007)	(0.007)	(0.002)	(0.005)
Skill_M&As	-0.026***	-0.002	-0.021	0.004	-0.005	-0.002
	(0.010)	(0.006)	(0.015)	(0.013)	(0.005)	(0.012)
Firm × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	192,722	192,722	192,722	192,722	192,722	192,722
Adj-R^2	-0.011	-0.019	0.051	0.099	0.427	0.238

Panel B: Female directors and ESG (executive) committee and executive compensation

	ESG (executive) committee	Compensation policy including ESG metric
	(1)	(2)
Female director ratio	0.130**	0.141**
	(0.058)	(0.062)
Board governance	0.010	0.013*
	(0.007)	(0.007)
Female CEO	0.033	-0.003
	(0.042)	(0.037)
Big3 institutions	-0.018	0.019
	(0.084)	(0.099)
M/B	-0.000	-0.000
	(0.001)	(0.001)
Firm size	0.007	0.064***
	(0.012)	(0.012)
ROA	0.015	-0.031
	(0.024)	(0.024)
Leverage	0.013	-0.054*
	(0.037)	(0.032)
Cash holdings	0.005	0.110***
	(0.046)	(0.042)
SG&A	-0.001	-0.004
	(0.004)	(0.004)
Field_arts	-0.114**	-0.078
	(0.052)	(0.053)
Field_business	0.075	-0.101**
	(0.049)	(0.046)
Field_law	0.103	-0.041
	(0.100)	(0.091)
Field_STEM	-0.057	0.006
	(0.050)	(0.050)
Field_medicine	0.077	0.135
	(0.160)	(0.126)
Skill_academic	-0.042	-0.036
	(0.078)	(0.065)
Skill_government & policy	0.083	-0.048
	(0.061)	(0.056)
Skill_risk management	-0.129	0.102
	(0.192)	(0.170)
Skill_scientific	-0.037	0.137
	(0.139)	(0.117)
Skill_technology	0.031	-0.039
	(0.077)	(0.079)
Skill_sustainability	0.212	-0.038

	(0.201)	(0.165)
Skill_community	0.008	-0.186**
	(0.101)	(0.080)
Skill_finance accounting & economics	-0.040	-0.049
	(0.049)	(0.047)
Skill_management	-0.070	0.014
	(0.057)	(0.055)
Skill_entrepreneurship	-0.004	0.059
	(0.046)	(0.044)
Skill_international	0.048	0.077
	(0.052)	(0.050)
Skill_legal	0.075	0.110
	(0.111)	(0.100)
Skill_manufacturing	0.158	0.010
	(0.103)	(0.080)
Skill_marketing	-0.051	0.084*
	(0.052)	(0.050)
Skill_strategic planning	-0.005	0.020
	(0.056)	(0.054)
Skill_HR	0.017	0.212**
	(0.117)	(0.105)
Skill_operations	0.064	-0.030
	(0.060)	(0.048)
Skill_M&As	-0.016	0.124
	(0.111)	(0.108)
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Obs.	19,379	19,379
Adj-R^2	0.708	0.641

Internet Appendix for "The Eco Gender Gap in Boardrooms"

Table IA1
Female directors and corporate environmental performance: robustness checks

This table examines the relation between the share of female directors on a board and corporate environmental performance, controlling for additional executive and board characteristics. Panel A controls for the share of female top executives, the average ages of directors and executives, or ownership by SRI funds. Panel B controls for a board's national cultural values or its political leaning. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Controlling for the share of female top executives, average director/top executive age, or ownership by SRI funds

	E score				
	(1)	(2)	(3)	(4)	(5)
Female director ratio	0.232***	0.248***	0.226***	0.253***	0.227***
	(0.029)	(0.041)	(0.029)	(0.042)	(0.033)
Board governance	-0.011**	-0.007	-0.012***	-0.007	-0.013**
	(0.004)	(0.005)	(0.004)	(0.005)	(0.006)
Female CEO	-0.001		-0.001	-0.001	-0.005
	(0.015)		(0.015)	(0.021)	(0.018)
Big3 institutions	0.073	0.134**	0.086*	0.133**	
	(0.045)	(0.065)	(0.046)	(0.065)	
Female top executive ratio		0.009			
		(0.026)			
Mean age of directors			-0.001**		
			(0.001)		
Mean age of top executives				0.000	
				(0.001)	
SRI ownership					1.230**
					(0.551)
M/B	0.001***	0.002***	0.001***	0.002***	0.001*
	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Firm size	0.093***	0.113***	0.093***	0.113***	0.096***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ROA	-0.054***	0.063**	-0.052***	0.063**	-0.052***
	(0.016)	(0.029)	(0.016)	(0.029)	(0.016)
Leverage	-0.068***	-0.063***	-0.070***	-0.063***	-0.076***
	(0.016)	(0.023)	(0.016)	(0.023)	(0.018)
Cash holdings	0.044**	0.128***	0.039*	0.128***	0.065***
	(0.020)	(0.032)	(0.020)	(0.032)	(0.023)
SG&A	0.004*	-0.001	0.004*	-0.001	0.003
	(0.002)	(0.017)	(0.002)	(0.017)	(0.002)
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Obs.	21,534	15,269	21,534	15,269	12,822
Adj-R^2	0.532	0.546	0.533	0.546	0.530

Panel B: Controlling for a board's national cultural values or its political leaning

	E score			
	Sample with directors' ancestral data		Sample with directors' donation data	
	(1)	(2)	(3)	(4)
Female director ratio	0.232***	0.230***	0.238***	0.237***
	(0.031)	(0.031)	(0.037)	(0.038)
Board MAS		-0.006		
		(0.075)		
Board IDV		0.111		
		(0.082)		
Board UAI		-0.049		
		(0.062)		
Board PDI		0.244**		
		(0.095)		
Board Democratic share				0.003
				(0.016)
Board governance	-0.012***	-0.013***	-0.014***	-0.014***
	(0.005)	(0.005)	(0.005)	(0.005)
Female CEO	-0.002	-0.001	0.009	0.009
	(0.016)	(0.016)	(0.020)	(0.020)
Big3 institutions	0.055	0.052	0.064	0.065
	(0.048)	(0.048)	(0.060)	(0.060)
M/B	0.001***	0.001***	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.094***	0.094***	0.096***	0.096***
	(0.003)	(0.003)	(0.004)	(0.004)
ROA	-0.054***	-0.055***	-0.036*	-0.036*
	(0.017)	(0.017)	(0.019)	(0.019)
Leverage	-0.069***	-0.069***	-0.067***	-0.067***
	(0.017)	(0.017)	(0.020)	(0.020)
Cash holdings	0.056***	0.056***	0.090***	0.090***
	(0.021)	(0.022)	(0.025)	(0.025)
SG&A	0.004*	0.004*	0.003	0.003
	(0.002)	(0.002)	(0.003)	(0.003)
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	19,295	19,295	14,395	14,395
Adj-R^2	0.529	0.529	0.515	0.515

Table IA2
Female directors and corporate environmental performance: different fixed effects

This table examines the relation between the share of female directors on a board and corporate environmental performance using the same regression analysis as Table 3 and including different fixed effects. In addition to firm, year, and (three-digit SIC) industry times year fixed effects, we further include the following fixed effects: headquarters state times year fixed effects and incorporation state times year fixed effects. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	E score				
	(1)	(2)	(3)	(4)	(5)
Female director ratio	0.100***	0.096***	0.071***	0.068***	0.060**
	(0.025)	(0.025)	(0.026)	(0.023)	(0.025)
Board governance	0.002	0.000	0.003	0.003	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Female CEO	0.012	0.011	0.014	-0.007	-0.001
	(0.014)	(0.015)	(0.015)	(0.015)	(0.016)
Big3 institutions	0.028	0.045	-0.000	-0.030	-0.040
	(0.041)	(0.040)	(0.046)	(0.036)	(0.041)
M/B	0.000	-0.000	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.026***	0.026***	0.028***	0.027***	0.028***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
ROA	-0.014	-0.021**	0.001	-0.020**	-0.008
	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
Leverage	-0.036**	-0.044***	-0.031*	-0.019	-0.017
	(0.015)	(0.015)	(0.016)	(0.014)	(0.015)
Cash holdings	0.036**	0.038**	0.037*	0.031*	0.031
	(0.018)	(0.018)	(0.020)	(0.018)	(0.021)
SG&A	0.003	0.004	0.004	-0.002	-0.002
	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes				
Industry × Year Fixed Effects				Yes	Yes
Headquarters state × Year Fixed Effects		Yes		Yes	
Incorporation state × Year Fixed Effects			Yes		Yes
Obs.	21,297	21,160	18,963	21,144	18,927
Adj-R^2	0.821	0.827	0.824	0.852	0.844

Table IA3
Additional firm-level analysis related to California's SB 826

This table conducts additional firm-level analysis related to California's SB 826. Panel A compares the share of female directors on a board and corporate environmental performance between the treated and control firms before and after SB 826. The treated firms are public firms without a female director in 2018 and headquartered (and stayed) in California. We find the closest control firm for each treated firm by matching on (three-digit SIC) industry, firm size, and *E score*. Pre-event represents the pre-event window (2015 to 2017). Post-event represents the post-event window (2019 to 2021). Panel B repeats the DID analysis in Table 6, using 2016 as the pseudo event year. Panel C repeats the DID analysis in Table 6, using the same treated firms while the control firms are chosen from those headquartered in California with at least two female directors in 2018, in the same (three-digit SIC) industry, and closest in firm size and *E score* to the treated firms. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the state level in Panel B and at the treatment level in Panel C. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Comparing treated and control firms in female director share and E score

	Female director ratio			E score		
	Treated	Control	Treated – Control	Treated	Control	Treated – Control
	(1)	(2)	(3)	(4)	(5)	(6)
Pre-event	0.019	0.017	0.003	0.016	0.014	0.001
Post-event	0.209	0.130	0.078***	0.052	0.039	0.013*
Post – Pre			0.075***			0.012

Panel B: DID analysis using 2016 as the pseudo event year

	Female director ratio	E score
	(1)	(2)
Treated × Post	0.008	0.008
	(0.007)	(0.011)
Firm-level controls	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Obs.	476	282
Adj-R^2	0.602	0.679

Panel C: DID analysis using control firms headquartered in California with at least two female directors in 2018

	Female director ratio	E score
	(1)	(2)
Treated × Post	0.137***	0.028**
	(0.027)	(0.009)
Firm-level controls	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Obs.	317	275
Adj-R^2	0.798	0.857

Table IA4
Female directors and facility-level environmental performance: Poisson regressions

This table examines the relation between the share of female directors on a board and facility-level environmental performance using Poisson regressions. The dependent variables are *#Source reduction practices by chemical* and *#Source reduction practices by facility.* The sample consists of 48,373 facility-year observations for a sample of 4,671 facilities associated with 618 firms over the period 2002–2021. The sample size drops to 15,103 facility-year observations when running Poisson regressions. We include the same set of firm-level controls as in Table 3. Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the firm level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Female directors and facility-level pollution source reduction practices by chemical

	#Source reduction practices by chemical			
	(1)	(2)	(3)	(4)
Female director ratio	2.222***	2.205***	2.192***	2.176***
	(0.838)	(0.822)	(0.839)	(0.822)
ln(Sales)			0.016	0.012
			(0.174)	(0.173)
ln(#Employees)			-0.018	-0.011
			(0.199)	(0.199)
Credit score			0.007	0.007
			(0.005)	(0.005)
Firm-level controls	No	Yes	No	Yes
Facility Fixed Effects	Yes	Yes	Yes	Yes
Firm industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Firm headquarters state × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility state × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	15,103	15,103	15,103	15,103

Panel B: Female directors and facility-level pollution source reduction practices by facility

	#Source reduction practices by facility			
	(1)	(2)	(3)	(4)
Female director ratio	2.183***	2.096***	2.166***	2.084***
	(0.772)	(0.754)	(0.774)	(0.756)
ln(Sales)			-0.018	-0.036
			(0.141)	(0.139)
ln(#Employees)			0.056	0.074
			(0.158)	(0.157)
Credit score			0.007	0.007
			(0.005)	(0.005)
Firm-level controls	No	Yes	No	Yes
Facility Fixed Effects	Yes	Yes	Yes	Yes
Firm industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Firm headquarters state × Year Fixed Effects	Yes	Yes	Yes	Yes
Facility state × Year Fixed Effects	Yes	Yes	Yes	Yes
Obs.	15,103	15,103	15,103	15,103

Table IA5
Facility-level analysis related to California's SB 826

This table conducts facility-level analysis related to California's SB 826. Panel A compares total production waste between the treated and control firms before and after SB 826. The treated firms are public firms without a female director in 2018 and headquartered (and stayed) in California. We find the closest control firm for each treated firm by matching on (three-digit SIC) industry, firm size, and *E score*. Pre-event represents the pre-event window (2015 to 2017). Post-event represents the post-event window (2019 to 2021). Panel B repeats the DID analysis with facility fixed effects (column (2)). Definitions of the variables are provided in the Appendix. Standard errors (in parentheses) are clustered at the state level. ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

Panel A: Comparing treated and control firms in total production waste

	ln(Total production waste + 1)		
	Treated	Control	Treated – Control
	(1)	(2)	(3)
Pre-event	0.073	0.006	0.067***
Post-event	0.057	0.008	0.049*
Post – Pre			-0.018**

Panel B: DID analysis with controls

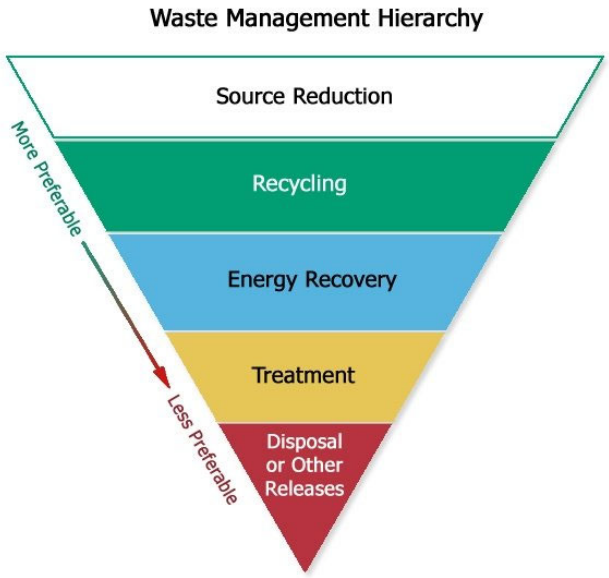
	ln(Total production waste + 1)	
	(1)	(2)
Treated × Post	-0.018**	-0.010**
	(0.005)	(0.002)
Treated	0.067***	
	(0.007)	
Post	0.002	-0.002
	(0.005)	(0.002)
Facility Fixed Effects		Yes
Obs.	50	49
Adj-R^2	0.201	0.965

Appendix IA1
Introduction to the EPA's TRI database

A. The Pollution Prevention (P2) database

The Pollution Prevention Act (P2 Act), approved by Congress in 1990, authorized the EPA to gather and disseminate information on pollution prevention activities (also known as source reduction activities). Such actions are compiled under the TRI database (in File Type 2A: https://www.epa.gov/toxics-release-inventory-tri-program/tri-basic-plus-data-files-calendar-years-1987-present). Facilities satisfying the following criteria are required to report to the TRI database: (1) in the mining, utility, manufacturing, publishing, hazardous waste, or federal industry; (2) manufacturing, processing, or otherwise using a TRI-listed chemical in quantities above certain threshold levels set by the EPA in a given year; and (3) having ten or more full-time equivalent employees.

Facilities are required to disclose any source reduction practices implemented at their facilities to reduce production waste in the reporting year. Source reduction practices denote the first layer of the waste management hierarchy (see the figure below): Once potential production waste is reduced, firms do not need to recycle, recover, treat, and release it.

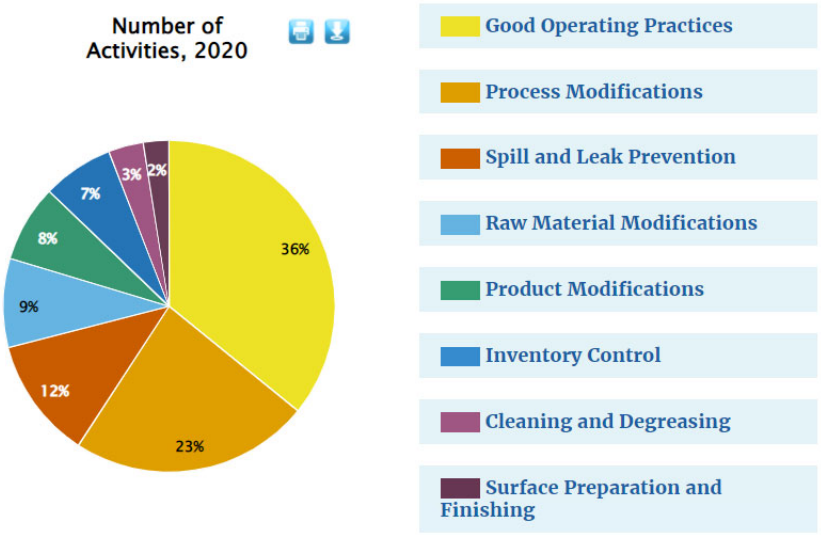


Source: https://www.epa.gov/trinationalanalysis/pollution-prevention-and-waste-management

Facilities report these newly implemented source reduction practices by selecting one or more predefined codes (W-codes) that describe specific practices within the eight categories: raw material modifications, product modifications, cleaning and degreasing, surface preparation and finishing, process modifications, spill and leak prevention, inventory control, and good operating practices (detailed definitions are provided at https://www.epa.gov/toxics-release-inventory-tri-program/pollution-prevention-p2-and-tri). Note that, since 2021, the classification of reduction practices has been changed to a system of S-codes, as seen in Appendix D of the following document: https://www.epa.gov/system/files/documents/2021-08/file_type_2a_0.pdf

The following pie chart illustrates the frequencies of eight categories of source reduction practices:

For 2020, a total of 1,188 facilities (6% of all TRI facilities) reported initiating 2,779 new source reduction activities. Good operating practices, process modifications, and spill and leak prevention were the activities reported most frequently. Click on the legend or graph to see examples of source reduction activities; reported codes are included in parentheses.



Source: https://www.epa.gov/toxics-release-inventory-tri-program/pollution-prevention-p2-and-tri

B. The Toxics Release Inventory (TRI) database

The TRI program was established by the EPA due to the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. The TRI reporting started with the 1987 reporting year (first TRI reports due July 1st, 1988) and has continued to the present. In terms of coverage, we find more comprehensive coverage since 1991. By August 2022, the TRI toxic chemical list contains 775 individually listed chemicals and 33 chemical categories.

Each TRI-reporting facility reports the production and ultimate outlets of each chemicals (see: https://www.epa.gov/toxics-release-inventory-tri-program/common-tri-terms). "Production waste" denotes the amount of all chemicals produced along with the production process. The outlets of those waste include recycling, energy recovery, treatment, and releases (definitions are provided in the above link).
The releases include air releases, water release, and land release (also defined in the above link).

After collecting all facility-level releases data from the EPA website (https://www.epa.gov/toxics-release-inventory-tri-program), we use the link between facility id (TRIFD) and Compustat GVKEY, established by Chen, Hiseh, Hsu, and Ross (2022) based on matching facility names and parent company names.

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