Director appointments, boardroom networks, and firm environmental performance[*]

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Abstract

Using BoardEx (2000–2017), we create a dynamic network connecting firms and board directors in the United States. We use the Environmental Protection Agency's Toxics Release Inventory to measure environmental performance at the director and firm-level. We first examine how candidates' environmental performance and networks affect their probability to be appointed to the board. We find that firms are likely to appoint influential directors with good environmental records and similar characteristics. We then show that directors' past environmental records affect their current firm's chemical releases. We address endogeneity concerns related to directors' appointments and firms' environmental performance by modeling directors' network formation.

Keywords: Network Formation, Firm Organization, Toxic Release, Board of directors
JEL Classification: D85, L21, Q5,

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[*] We like to thank George Deltas, Dietrich Earnhart, seminar audience from Pennsylvania State University, Monash University, Maastricht University, University of Oklahoma, and University of Liege, and participants at the 20th Annual International Industrial Organization Conference, the 29th Annual European Association of Environmental and Resource Economists Conference and the 50th annual Conference of EARIE for their helpful comments. We also thank the editor and two anonymous referees for helpful comments that significantly improved the paper. The authors declare that they have no relevant material or financial interests that relate to the research described in this paper.

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1 Introduction

Over the last two decades, firms have faced increasing regulatory and investor pressure regarding their environmental impacts. Legislative initiatives such as the United Kingdom's Companies Act 2006 and recent U.S. climate disclosure laws have expanded directors' fiduciary duties to include environmental considerations, while the rapid growth of sustainable investment has increased scrutiny of firms' environmental performance. Yet firms respond unevenly to these external pressures. A growing body of evidence suggests that such heterogeneity reflects differences in internal governance structures. Corporate boards play a central role in translating regulatory requirements and investor scrutiny into firm policies and outcomes, as directors' oversight, expertise, and network connections shape how environmental information and norms diffuse across firms (Kassinis and Vafeas, 2002; Berrone and Gomez-Mejia, 2009; Walls et al., 2012; Omer et al., 2020).

Because board composition changes over time through director appointments, these appointments represent a potentially important channel through which environmental expertise, practices, and norms enter firms. Studying appointments is therefore essential for understanding how firms incorporate environmental considerations into governance and how directors transmit practices across firms through their multiple directorships.

Against this backdrop, we examine whether directors' past environmental records (captured by the pollution performance of the firms and facilities they previously oversaw) influence their appointment to new boards, and whether these records subsequently affect firms' environmental performance. Unlike the prior literature, we explicitly model the formation of the director–firm network, allowing us to account for endogenous link formation and examine how directors' environmental expertise diffuses across firms. Our results indicate that firms are more likely to appoint directors with stronger environmental track records and that boards with such directors oversee facilities with lower levels of pollution.

Our analysis proceeds in two steps. First, we model the director appointment process using tools from network theory and data from BoardEx North America, which allow us to construct a dynamic firm–director network. We then merge these data with facility-level pollution information from the U.S. Environmental Protection Agency's Toxics Release Inventory (TRI). We measure facility environmental performance using total toxic releases to air, water, and land, and define a director's environmental record as the share of TRI-reporting facilities under her/his oversight that released toxic chemicals in the previous period. Because TRI emissions are publicly disclosed, and economically salient, they provide a visible signal of directors' environmental exposure. There is also evidence that the amount of legally emitted toxic chemicals negatively affects companies' market value (Khanna et al., 1998; Konar and Cohen, 2001).

We examine director network formation, using a Bayesian model approach similar to Christakis et al. (2020) and De Silva et al. (2022). In addition to a director's environmental record, we control for a range of other director characteristics (e.g. experience as a CEO, years of experience as a director, homophily measures between the candidate and the appointing firm) that are likely to affect hiring decisions.

We then turn to the second dimension of our analysis, i.e., the influence of directors on their firm's environmental performance. As firms often own more than one facility in the US, we examine facility-level outcomes and exploit the panel structure of our data. We estimate how a board's environmental record (measured by the average of all existing directors' environmental records) influences a facility's probability of reporting a toxic release using a probit model. We also estimate the impact on facility-level releases of production-related chemical waste using simple linear regression techniques. We control for location-specific demographic (and geographic) characteristics that may affect a facility's location and pollution decisions using US Census data.

Our baseline results show that firms tend to appoint directors with stronger environmental records, especially when candidates share similarities with existing board members or are more central in the network. We also find that boards with higher average environmental records oversee facilities with fewer toxic releases and a greater share of production-related waste managed through recycling, energy recovery, and treatment (RRT). These findings are robust to a wide range of specifications, including the addition of financial controls from Compustat, controls for institutional ownership, adjustments for serial correlation in facility-level toxic releases, and the use of censored regressions to account for the non-negativity of release measures.

A natural concern is reverse causality: firms with stronger environmental performance may be more likely to attract directors with better environmental records, rather than directors driving subsequent improvements. We address this concern using two complementary approaches. First, we exploit our network formation model to construct probability-weighted measures of expected board composition, thereby relying on ex ante network-implied exposure to environmentally experienced directors rather than realized appointments. Second, we implement a restricted-sample approach that holds board composition and firms' own past environmental performance fixed, so that remaining variation in board environmental records arises from changes elsewhere in the director network. Together, these approaches substantially mitigate concerns that our results are driven by endogenous matching rather than director influence.

The restricted-sample approach also allows us to isolate the mechanism through which board composition matters. Focusing on firms with unchanged board membership and stable own past environmental performance, we exploit changes arising from directors' external network connections. Across these restricted samples, facilities overseen by boards connected to environmentally stronger firms exhibit lower toxic releases and higher shares of waste managed through recycling, energy recovery, and treatment. These results highlight the role of board networks in transmitting environmental practices across firms.

We contribute to the literature in several ways. First, we complement the literature on director selection. Studies have emphasized the role of firm performance (Brickley et al., 1999; Ferris et al., 2003), financial fraud (Fich and Shivdasani, 2007), and directors' specific skills

(Becher et al., 2017) in influencing the likelihood that a director is appointed to the board of another firm. Recent papers have examined how CEOs' and directors' social networks (Kramarz and Thesmar, 2013) and professional networks (Cashman et al., 2013; Cai et al., 2022) affect board composition and firm performance. Our research adds to this literature by documenting the role of directors' environmental performance and influence within the broader firm-director network.

Second, we extend the environmental economics literature (Gray and Shadbegian, 2003; List et al., 2003; Earnhart, 2004; Lim, 2016; De Silva et al., 2016; Wang et al., 2021) on firm heterogeneity in pollution behavior. We show that beyond external factors such as regulatory stringency or community pressure, internal corporate governance structure also plays an important role in shaping environmental performance.

In that respect, our research is closely connected to the literature linking directors' characteristics to firms' environmental performance. Previous studies have shown that directors' legal expertise (De Villiers et al., 2011; McKendall et al., 1999) and specific environmental expertise based on their roles, education, or presence on environmental subcommittees (Homroy and Slechten, 2019; Walls et al., 2012) are associated with better firm environmental performance. Our point of departure is that we are interested in the impact of directors' past environmental record, which is not based on educational background or participation in specific committees, but rather on the actual environmental performance of the companies they oversaw in the previous period.

Finally, we contribute more broadly to the literature on board connectedness and access to information (Cohen et al., 2008; Omer et al., 2020) by examining whether directors' connections to firms with strong environmental performance (holding the focal firm's board composition constant) help them leverage information or knowledge to improve their firm's environmental performance.

The paper is organized as follows. In the next section, we describe the three main data sources used in the paper. Section 3 presents the network formation analysis. Section 4 investigates whether directors' environmental records affect firm environmental performance. The final Section concludes and discusses the implications of our findings.

2 Data

We compile a comprehensive director-firm level dataset on environmental performance and board characteristics and networks by combining three main sources of data for the period 2000 to 2017. Facility-level pollution data are taken from the Toxics Release Inventory (TRI) Program. The director-firm-level data for US companies are gathered from BoardEx. Census tract-level data are collected from the US Census Bureau.[1]

2.1 TRI Data

The TRI Program was established by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986. It is administered by the EPA and is a resource where local communities, companies, or government agencies can learn about toxic chemical releases and pollution prevention activities reported by private and federal facilities. The TRI Program covers hundreds of individual chemicals that typically have significant adverse effects on human health and the environment. A facility has to report to the TRI Program in a given year if it meets three criteria. First, the facility must belong to an industry sector that is covered by the TRI Program. Second, it should employ 10 or more full-time equivalent employees. Third, the plant should manufacture, process, or otherwise use a TRI-listed chemical in the quantities above the threshold levels each year.

Every year, facilities meeting these three criteria have to prepare and submit a TRI reporting form that includes information on how they manage their production-related chemical waste.

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[1] Note that, while TRI and Census data are publicly available, this is not the case for BoardEx data. We are able to access BoardEx data under the terms of a non-disclosure agreement, and interested researchers can access or purchase these data from BoardEx: https://corp.BoardEx.com/client-segments/academics-and-non-profit

Waste management consists of waste handled through energy recovery, recycling, treatment, or release (to air, water, or land).[2] Energy recovery, recycling, and treatment (RRT) are waste management practices that are socially preferable to releasing waste into the environment. For each plant, the EPA provides the amount of production-related waste (released or managed through RRT) in pounds (expressed as toxicity, regardless of the chemical) to facilitate comparisons between different chemicals. Further, the TRI data provide information about a facility's geocoded address, the name of the parent firm (if applicable), and the industry sector.

Tables OA.1-OA.2 (Online Appendix) present the summary statistics for all facilities that submitted a report on their chemical waste management practices to the TRI Program between 2000 and 2017 (denoted *TRI-reporting facilities*). This corresponds to $41,904$ unique facilities from $19,787$ firms in 30 industry sectors. The yearly breakdown of the unique number of facilities and firms, along with the production-related chemical waste that is released into the environment (*toxic releases*) or managed through energy recovery, recycling, and treatment (*RRT*) is shown in Table OA.1. On average, there are about $23,000$ facilities per year. The total amounts of toxic releases and RRT per facility are obtained by summing these amounts over all pollutants reported by a facility in a given year. The average toxic releases per facility vary between 157,000 and 282,300 pounds per year, while the average RRT varies between 779,000 and 1,283,700 pounds.

Table OA.2 presents summary statistics by sector. The metal mining industry is the most polluting sector, while the publishing industry is the cleanest sector among the sectors reporting to the TRI Program. Taken together, the chemical and fabricated metals sectors account for 27% of the total number of facilities covered by the TRI Program. Average toxic releases vary substantially across sectors. However, variation within sectors is also substantial.

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[2] The definition of these terms is given on the EPA website: `https://www.epa.gov/toxics-release-inventory-tri-program/common-tri-terms`

2.2 BoardEx

We use data provided by BoardEx, a global data management firm, to identify the relationships between directors and firms.[3] BoardEx includes details about company board structures along with current, upcoming and historic executives, directors' start and end dates, and industry sectors. BoardEx North America covers most publicly listed companies and major private companies in the US.

Table OA.3 presents summary statistics for firms and directors in BoardEx North America between 2000 and 2017. We observe $119,607$ unique directors in $157,997$ unique firms. On average, a firm has about 2.5 directors. This low average is due to the fact that our sample includes both listed and non-listed companies. If we restrict our sample to listed companies only, the average number of directors on the board is 9.128 (which is very close to the average board size obtained in Coles et al. 2008, for example). On average, directors sit on two company boards per year. Directors' market exposure (i.e. the number of years they appear in BoardEx) is about 10.6 years while their term in a firm is about 5.6 years. The dummy variable *Director is a CEO* indicates whether a director in year t was a CEO in year $t-1$ (in the same firm or in another company). In our sample, around 11% of directors were CEOs in the previous year.

In Table OA.4, we report the unique number of firms and directors by year. Using the information from BoardEx, we build a firm-director network for each year of our sample period. Directors and firms are nodes, and a link between a director and a firm means that the director is serving on the board of this firm. The appointment of a board member represents the formation of a link between this director and the firm.[4]

The director and firm centrality within the network are measured using eigenvector centrality. Eigenvector centrality is a measure that takes into account the centrality of a node's

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[3] BoardEx specializes in relationship mapping and intelligence. BoardEx data contain more than 2 million profiles of public, private, and not-for-profit organizations and more than 1.5 million people around the globe. See https://www.boardex.com/.

[4] Even though we focus on BoardEx North America, we capture part of the international director network, as some multinational firms conduct business activities in North America.

first-degree connections. It is, therefore, based on the pattern of the entire network. A high eigenvector score means that a node is connected to to nodes that themselves have high scores. Eigenvector centrality captures director- and firm-level network influence. A value of one for the eigenvector centrality measure represents the most influential director (or firm) in the entire network at a given time. Those directors and firms with scores of zero are isolated nodes—not connected to any other firm or director.

2.3 US Census Tracts

There is evidence that a facility's propensity to release toxic chemicals depends on the demographic and geographic characteristics of the area in which it is located (De Silva et al., 2016, 2021). We collect US Census tract information published by the U.S. Census Bureau to control for plant locations' demographic characteristics. Census tracts are relatively small and permanent statistical subdivisions of a county during census years. The minimum population of a tract is $1,200$ and the maximum is $8,000$. Given that our data span two census periods, we consider 2010 locations as fixed geographic locations. From the Census data, we gather information regarding tract-level population density, minority ratio (i.e., proportion of non-white population), proportion of residents with a college degree, and median household income for all available years.[5] There are $73,082$ US tracts, including tracts with military installations, that do not report demographic information. We denote these tracts as *special tracts*.

Prior to 2007, Census data did not report estimates by year. As in De Silva et al. (2016) and De Silva et al. (2021), we linearly impute and estimate the missing data to estimate the population density, minority ratio, proportion of individuals with a college degree, and median household income from 2000 to 2008.

We report summary statistics for all tracts in Table OA.5. On average, a tract has a population of 4,133 and a population density of 5,165 per square mile. Each tract has about

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[5] Note that to obtain population density, we use the total population in a tract from the US Census data, and the tract area from the Social Vulnerability Index (provided by the Agency for Toxic Substances and Disease Registry).

1,040 households and the median household income is about \$64,000. For a given tract, the minority ratio is about 24% while the college-educated ratio is about 26%. Additionally, we identify tracts that are located along the Canadian and Mexican borders and tracts that are located in a Metropolitan Statistical Area (MSA), in urban counties, rural counties, and coastal counties.[6]

2.4 Matching TRI, BoardEx, and Census Data

We match the TRI and BoardEx datasets in two steps. We first match the TRI facilities (for which we have the name of the parent company) with BoardEx firms based on similarities in firm names. This procedure allows us to match only a small proportion of the TRI facilities to a firm in BoardEx because the two datasets are created separately and firms can be recorded under different names.

There are also three major challenges that need to be tackled. First, firms can change names. For example, 3M Co. was Minnesota Mining & Manufacturing Co. prior to 2002. Second, there were changes in the ownership of some of the TRI facilities (mergers and acquisitions) and these changes were not always recorded accurately in the TRI or BoardEx datasets. For example, Forest River Inc. was acquired by Berkshire Hathaway in 2005 and some of its facilities were still reporting their parent company as Forest River Inc. in the TRI data after 2005, instead of Berkshire Hathaway. Finally, we have to match subsidiaries with their parent firms. For example, Volkswagen AG and Volkswagen Group of America are recorded in the TRI dataset as two different parent companies, but Volkswagen Group of America is controlled by Volkswagen AG. Therefore, in our analysis, we consider the facilities from Volkswagen Group of America as being part of Volkswagen AG.

We obtain additional information on companies' previous names, addresses, contact details,

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[6] To define MSA, urban and rural counties, we use the 2013 rural-urban continuum codes provided by the US Department of Agriculture's Economic Research Service. Counties are divided as either MSA or non-MSA counties (2013 Office of Management and Budget). MSA counties are then distinguished by the population size of their metropolitan area, and non-MSA counties by their degree of urbanization and adjacency to an MSA area.

and board structure from manual internet searches (companies' websites, newspapers...) or companies' reports to the Securities and Exchange Commission (for publicly-listed companies). In some cases, we are able to use additional information provided by BoardEx. For example, BoardEx has public listing information including IPO dates and/or delisting dates.

It might be the case that, for a given year, a firm appears in one dataset but not in the other.[7] The next step consists in filling in the missing years based on a firm's (or director's) first and last appearance in both datasets. This step is based on the rationale that, if a firm exists in one dataset for a given year, this firm should also exist in the other for that same year. Finally, we use the facilities' geocodes to find their location in a tract and obtain their local demographic information.

Using this method, we are able to match $2,877$ TRI-reporting firms with at least one board director recorded in BoardEx from 2000 to 2017 (see Table 1, Column 2). These firms are responsible for the daily operations of 18,941 different TRI-reporting facilities. This represents 45.2% of the total number of reporting facilities in the TRI dataset, or around 63% of the total aggregate toxic releases over the period 2000-2017. This constitutes our sample of TRI-reporting facilities/firms going forward.

Each firm matched with a company in BoardEx has about 6.7 facilities. We also observe 16,910 firms without board information reported in BoardEx that have 22,963 facilities. Firms without board information have about 1.4 facilities. This indicates that firms with board members are larger firms with five times more facilities per firm compared to the other TRI-reporting firms. It is, however, interesting to note that the probability of polluting (i.e. the probability that a TRI-reporting facility releases toxic chemicals in the environment) is very similar for facilities overseen by a firm in BoardEx and facilities without board information.

Among all the directors recorded in BoardEx, 17,224 unique directors are sitting on the

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[7] For example, companies' board information might be missing for some private firms as they are not required to disclose their board structure. Missing data are also common in BoardEx data in early years where they report only the board members' start and end years. Submitting a TRI report is a federal requirement for firms meeting the reporting criteria. However, it might be the case that for some period of time a firm does not meet all these requirements and does not need to report (for example, if it has less than 10 full-time employees).

board of at least one TRI-reporting firm. About 16% of those directors serve on the board of at least two TRI-reporting firms per year. On average, a director oversees 14 facilities per year. Directors are not confined to one particular TRI sector as, on average, a director is supervising facilities from 3 different sectors in a given year (see Table OA.2 for the list of TRI sectors).

3 Firm-Director Network Analysis

In the first part of our analysis, we study the firm-director network formation through the board appointment process. In particular, we investigate whether TRI-reporting firms value directors' past environmental record when determining their suitability for the board.

3.1 Empirical Framework

3.1.1 Board Appointments as Link Formation

In each period, a TRI-reporting firm j has to choose to form (or continue) a link with a director d. A link is created when a firm appoints a new director to its board, or maintained when it renews an existing director's mandate. Directors may hold multiple board positions simultaneously, and firms can appoint several directors at once. These hiring decisions are assumed to be independent of one another and are made simultaneously for a given year.[8]

We follow the standard assumption that directors act as passive agents in this setting, exerting no decision-making power in the link formation process. Firms (or their nomination committees) are instead the active decision-makers, choosing the set of directors that maximizes expected firm value.[9] While firms are assumed to observe the current structure of the

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[8] This implies that the utility of a link does not depend on the decisions of the other pairs of agents (Jackson, 2010; Christakis et al., 2020)

[9] One point needs to be made. Our analysis is based on the premises that directors represent shareholders and the board's objective is to maximize the value of the company. Shareholders typically do not nominate the directors who represent them. In most legal systems, the incumbent board nominates candidates, who are voted upon by the shareholders in a general meeting. There is evidence that shareholder votes have little impact on board elections (Bebchuk, 2003; Cai et al., 2009). However, Cai et al. (2009) also document that, even in uncontested elections, lower levels of director votes affect some corporate outcomes (e.g., lower "abnormal" compensation and higher levels of CEO turnover). Moreover, in recent years, activist shareholders have become increasingly successful in obtaining board seats in proxy contests (Zhang, 2021).

director–firm network, they have no knowledge of how the network will evolve in the future.

Formally, the probability of a link $l_{d,j,t}$ being established by firm j to director d at time t is denoted as:

$$Pr(l_{d,j,t}|R_{d,t-1}, N_{d,j,t-1}, g(N_{d,j,t-1}), D_{d,t-1}; \theta_t)$$

where θ_t is a vector of unknown parameters. R denotes directors' environmental attributes, N captures the network position of directors and firms, $g(N)$ reflects similarities between candidates and firms, and D includes other director-specific characteristics.

Although we assume that hiring decisions are conditionally independent across firm–director pairs within a year, this does not imply that the network is modeled as independent. Interdependence arises because the probability of appointment depends on existing network features (such as prior ties, shared connections, and homophily), which themselves evolve over time. Conditional on these observable network characteristics, we assume that unobserved factors affecting each potential match are independent across pairs. In this way, the model captures endogenous sorting through the structure of the board network, while abstracting from explicit coordination across firms in the same year. This assumption allows us to estimate link probabilities in a transparent and computationally feasible manner.

3.1.2 Key Determinants of Link Formation

The board of directors is a key element in corporate governance and has a fiduciary duty to protect shareholders' interests through their monitoring and advising roles (Adams et al., 2010). The probability of forming a link between a director and a firm will therefore depend on the director's ability to make strategic decisions that increase firm value. However, the existing structure of the network (current board composition, other directors' connections...) and the specific needs of the hiring firm are likely to affect the ability of a director to improve firm value, and thus her/his probability of being appointed.

The theoretical and empirical literature on director selection provides some indication about the way candidates' skills and attributes and firms' needs and specificities influence the director appointment process.

Directors' Environmental Characteristics (R)

Our main variable of interest is the director's environmental record at the time of appointment. We define this record as the ratio of polluting facilities overseen by a director, i.e., the proportion of TRI-reporting facilities under their supervision that released toxic chemicals in a given year. We refer to this measure as the *director pollution ratio*.

Importantly, this measure is not intended to capture technological efficiency or abatement intensity per se. Rather, it reflects a publicly observable signal of environmental exposure and track record that is visible to firms and nomination committees at the time of board appointments. TRI participation and release status are standardized, highly visible, and publicly disclosed, and they are frequently used by investors, regulators, NGOs, and the media to characterize firms' environmental profiles. As a result, directors associated with firms overseeing fewer TRI-reporting facilities appear to have "cleaner" environmental records in the director labor market, regardless of the specific mechanisms driving those outcomes. In this sense, the director pollution ratio captures environmental exposure and reputation, rather than a structural measure of abatement effort. In Section 4, we examine whether this reputational signal is subsequently associated with realized environmental outcomes at the facilities directors oversee.

The director pollution ratio measure matters because prior evidence shows that both catastrophic accidents (e.g., explosions at chemical plants) and the amount of legally emitted toxic chemicals negatively affect firm market value (Khanna et al., 1998; Konar and Cohen, 2001; Capelle-Blancard and Laguna, 2010). Moreover, sustainability is increasingly central to corporate strategy, ranking just behind financial performance on many board agendas (Mazars and Board Agenda, 2018). Our conjecture is therefore that directors with stronger environmental records are more likely to be appointed to new boards, while directors associated with poorer records face lower chances of appointment.

Beyond past environmental performance, firms may value directors with specific expertise in sustainability and environmental oversight. To capture this, we use information on board committee memberships from BoardEx. Because environmental responsibilities are frequently embedded in broader sustainability or ESG committees, we adopt a broad definition consistent with the literature (Homroy and Slechten, 2019; Walls et al., 2012). Committees are classified as environmental if their titles contain keywords such as "environment", "sustain", "responsibility," or "social".[10] We then identify directors who serve on such committees and construct a measure of *experience in environmental committees*, defined as the number of environment-related committee positions held by a director in the previous year.

Network Position and Influence (N)

The probability of a director's appointment also depends on the position of both firms and directors within the wider firm–director network. We measure influence using eigenvector centrality, which captures not only the direct connections of a director/firm but also the centrality of their connections. Other aspects of the network that might affect a firm–director match are board size or the number of seats already held by a candidate.[11] Given the way eigenvector centrality is computed, these aspects are, however, already captured by our centrality measure.

Since central directors are more visible and often more desirable, we also test whether the importance of a candidate's environmental record varies with their network position. Specifically, we include an interaction between a director's pollution ratio and their eigenvector centrality.

Other Director Characteristics (D)

Several individual-level characteristics may further influence appointment decisions. First, we measure *market exposure* as the number of years since a director's first appearance in BoardEx, which serves as a proxy for experience and reputation. Second, we include a dummy equal to

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[10] A narrower definition, where committees are classified as environmental if their titles contain only "environment", is examined in Table OC.1 in the Online Appendix.

[11] For example, Cashman et al. (2013) shows that well-connected candidates are significantly more likely to be appointed.

one if the director served as a *CEO* in the previous year. CEOs are often sought-after directors because of their managerial expertise and ability to provide strategic advice (Brickley et al., 1999).

Firm–Director Similarities ($g(N)$)

Finally, we account for homophily, i.e. the tendency for firms to appoint directors with similar attributes. Two types of similarity are particularly relevant in our context.

We first control for centrality similarity: firms with high centrality are more likely to attract directors who are themselves highly connected. Formally, it is measured as the absolute difference in a director's influence and the firm's influence (eigenvector centrality).

Second, firms may prefer directors whose environmental track record aligns with their own (environmental similarity). We capture this through two measures: (1) the difference between a director's pollution ratio and the firm's pollution ratio (proportion of the firm's facilities releasing toxic chemicals); (2) the difference between a director's relative pollution degree centrality and the average relative pollution degree centrality of the appointing firm's board members.

The relative pollution degree centrality of a director is defined as the share of their connections to polluting firms (firms that had at least one toxic-releasing facility in the previous year) relative to all their connections to TRI-reporting firms. This metric provides a broader measure of a director's environmental exposure within the network.[12] Figure 1 illustrates how we compute our environmental performance measure using degree centrality.[13]

Importantly, environmental similarity may also reflect industry-specific expertise. Directors serving in highly polluting sectors (e.g., chemicals) will inevitably have higher pollution ratios than those from cleaner sectors (e.g., publishing). Yet such directors may be attractive to firms within the same industry because they bring sector-specific knowledge of managing waste and

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[12] Note that to compute our director-level environmental performance measures, we only consider firms with facilities reporting to the TRI Program, and not all the firms in BoardEx. This is because we want to exclude sectors (banking, insurance...) that could never "pollute" (according to the criteria of the TRI).

[13] Figure 1 only shows nodes that are no further than two edges from the most influential directors (red nodes). When allowing more distanced nodes in the graph, the size increases exponentially. Figure 2 (in the Appendix) includes all nodes that are within a distance of four from any of the two most influential directors. The number of nodes increases by 1,316, and the number of edges increases by 1,815 compared to Figure 1.

pollution.

3.1.3 Empirical Specification

We model the probability of a link $l_{d,j,t}$ established by firm j to director d at time t as a function of the unknown vector of parameters θ_t using the following specification:

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\begin{aligned}
&ln\left(\frac{Pr(l_{d,j,t}|N_{d,j,t-1},R_{d,t-1},D_{d,t-1},g(N_{d,j,t-1});\theta_t)}{1-Pr(l_{d,j,t}|N_{d,j,t-1},R_{d,t-1},D_{d,t-1},g(N_{d,j,t-1};\theta_t)}\right)\\
&=\gamma+N^{'}_{d,j,t-1}\beta+R^{'}_{d,t-1}\rho+D^{'}_{d,t-1}\delta+(g(N_{d,t-1}-N_{j,t-1})'\Psi(g(N_{d,t-1}-N_{j,t-1})))+\tau_t+\epsilon_{d,j,t}
\end{aligned}
\tag{1}
$$

where the term $(g(N_{d,t-1}-N_{j,t-1})'\Psi(g(N_{d,t-1}-N_{j,t-1})))$ is the disutility (cost) of having a difference in homophily between potential director candidates relative to firm j in period $t-1$ (see Christakis et al. (2020) for a similar measure of homophily). Ψ is a diagonal matrix. The function g is a measure of homophily that is expressed as the absolute value of the difference in environmental performance and influence between candidates and firms. All our explanatory variables are lagged by one year. We assume that the $\epsilon_{d,j,t}$ are independent across all j and d at a given time, t, and that they follow a logistic distribution.

Following Christakis et al. (2020) and De Silva et al. (2022), we use a Bayesian approach to estimate equation (1) and obtain posterior distributions for each parameter of the model based on prior information on link-formation choices. We use observed data of the structure of the network, N, directors' environmental characteristics, R, other individual characteristics, D, and the homophily measures, $g(N)$, and we postulate a prior distribution for θ. Based on this information, we derive the posterior distribution for θ_t and calculate the probability of link formation for different values of $N_{d,j,t-1}$, $R_{d,t-1}$, $D_{d,t-1}$ and $g(N_{d,j,t-1})$.

We generate network-related posterior distributions using Markov Chain Monte Carlo (MCMC) methods. Specifically, we use a Bayesian MCMC technique based on a hybrid Metropolis-Hastings algorithm with Gibbs sampling updates to estimate posterior means and posterior standard deviations of the model parameters. This procedure searches over the parameter space to generate simulated network distributions that are consistent with key features of the observed firm–director network.[14] We estimate the model using the full set of eligible firm–director pairs rather than relying on random subsamples.[15] We use uniform priors for the regression coefficients and an inverse-gamma prior with shape and scale parameters of 0.1 for the error variance. In all Bayesian estimations, we run 10,000 MCMC iterations and discard the first 2,500 draws as burn-in.

The Bayesian MCMC framework is particularly well suited to our setting for three reasons. First, director appointments reflect endogenous link formation in a highly interdependent network, rather than independent binary outcomes. The probability that a firm appoints a given director depends not only on observable firm and director characteristics, but also on existing board composition, similarity to incumbent directors, and the evolving structure of the firm–director network. Standard parametric logit models treat firm–director pairs as conditionally independent and therefore do not naturally accommodate this dependence structure.

Second, our objective is not merely to estimate correlates of board appointments, but to recover firm–director–year–specific probabilities of link formation, which are subsequently used to construct expected board composition and to address endogenous matching between directors and firms in the facility-level analysis. The Bayesian framework delivers posterior distributions of these link probabilities, from which we use posterior means to construct probability-weighted board measures in the second stage. This approach avoids reliance on single-equation point estimates in a setting with endogenous network formation and complex dependence across links.

Third, the structure of the data makes simpler parametric approaches fragile. The network formation sample consists of a very large number of potential firm–director pairs and a highly

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[14] Gelman (2004) provides a detailed description of the Bayesian methods used in this paper.

[15] Estimation is computationally demanding and is implemented using high-performance computing resources.

unbalanced outcome, with approximately 2% of pairs corresponding to realized links. In such sparse settings, standard logit models are prone to rare-event bias, separation, and instability, particularly in the presence of high-dimensional interactions such as homophily measures (Albert and Anderson, 1984; King and Zeng, 2001; Li and Zheng, 2009). Bayesian estimation allows regularization through priors and yields stable estimates without imposing restrictive functional-form assumptions.

3.1.4 Pool of Candidates

It is not realistic to assume that all directors in BoardEx are potential candidates for all TRI-reporting firms. Potential candidates have to be in the reach of this firm, which is determined by their position in the network. To identify potential pools of candidates, we take the following steps. First, for each TRI-reporting firm, we construct the maximum difference in the relative pollution degree centrality a director has had with its board from 2000 to 2017. Similarly, we measure the maximum difference between all the appointed directors' pollution ratios and the firm's pollution ratio during the sample period. Then, we consider all candidates that fall within either of these two maximum values as a potential candidate for a given board. Based on these cut-offs, we identify a possible 8,487,170 director-firm pairs for all TRI-reporting firms with directors for all years. On average, this corresponds to about 300 potential candidates per TRI-reporting firm in a given year. We use this sample in our network formation analysis.

3.2 Network Formation Results

Baseline results

Table 2 reports summary statistics for the link-formation sample. The unconditional probability that a candidate director is appointed to a given TRI-reporting firm in a given year is 1.9%, highlighting the sparsity of realized links relative to the pool of potential matches. On average, 45% of the facilities overseen by candidate directors released toxic chemicals in the previous year, indicating substantial variation in environmental exposure across candidates.

Table 3 presents posterior means and 95% credible intervals for the parameters of equation (1), estimated for all TRI-reporting firms (Column 1) and for listed firms only (Column 2).

The posterior mean associated with the director's past pollution ratio is negative, and its credible interval lies strictly below zero in the baseline specification. This indicates that firms systematically penalize candidates with poorer environmental records. Although the coefficient is small in absolute magnitude relative to network centrality (approximately -0.01 compared to 0.10 for centrality), the two variables are measured on very different scales.

To compare magnitudes across covariates measured on different scales, we evaluate economically meaningful changes using the coefficients reported in Column 1 of Table 3. A one–standard-deviation increase in a candidate's past pollution ratio (SD = 0.384) reduces the probability of appointment by approximately 0.04 percentage points, a modest but statistically robust effect. By contrast, a one-standard-deviation increase in candidate influence (SD = 0.014) increases appointment probability by roughly 0.15 percentage points, indicating that network centrality plays a substantially larger quantitative role in driving appointments. Homophily effects are even stronger: a one-standard-deviation increase in the difference between the candidate's and the firm's pollution ratio lowers appointment probability by about 1.44 percentage points, and a comparable increase in the difference in relative pollution degree reduces it by approximately 0.82 percentage points. These effects are economically meaningful relative to the unconditional appointment probability of 1.9%.

For other characteristics, moving from 0 to 1 provides the appropriate benchmark. Becoming a CEO increases appointment probability by about 0.12 percentage points, while holding one additional environmental committee position increases it by roughly 0.62 percentage points.

The interaction between the pollution ratio and influence must be interpreted jointly with the main effect of influence. For a director with a clean environmental record (pollution ratio = 0), a one–standard-deviation increase in influence raises appointment probability by approximately

0.15 percentage points. For a director with the average pollution ratio (0.45), the corresponding increase falls to about 0.11 percentage points, implying that the benefit of network centrality is reduced by roughly 25% when the candidate has an average environmental record. This pattern indicates that while firms value influential directors, they discount that influence when it is coupled with a poor environmental track record.

Taken together, these magnitudes suggest a hierarchy in appointment determinants. Network position and environmental alignment (homophily) are quantitatively the dominant forces, formal environmental committee experience also plays a meaningful role, and the direct level effect of the pollution ratio is smaller but systematically negative. One implication is that the pollution ratio may function less as a primary screening device and more as a secondary or tie-breaking criterion, particularly when candidates are otherwise comparable in terms of experience, influence, and network position. Importantly, environmental reputation matters more for highly influential directors, as reflected in the economically significant interaction effect.

Table OB.1 in the Online Appendix reports robustness checks using an alternative intensity-based measure of environmental performance, defined as the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution. In the full sample, the coefficient on the alternative pollution measure remains negative, but the credible interval overlaps zero. The interaction with influence, however, remains negative and statistically credible. For listed firms, both the level effect and the interaction are statistically significant and are qualitatively similar to the baseline results. This pattern reinforces the interpretation that the baseline pollution ratio works as a salient and publicly observable signal. The alternative measure may be less transparent to hiring committees, particularly in private firms, which could explain the weaker results outside the listed subsample.

Two robustness checks

A director's prior experience within the focal firm could also influence the likelihood that the firm maintains a board link with that director. Because this variable is highly correlated with market exposure, we excluded it from the main specification. As a robustness check, however, we re-estimate the model including an indicator for whether the director served in the focal firm in the previous year. The results (in Table A.1, panel A) are qualitatively unchanged: even after controlling for this indicator, a director's past pollution ratio continues to have a significant negative effect on the probability of appointment.

In an alternative specification, we proxy a candidate's environmental record by the change in their past pollution ratios over the previous two years, calculated as $\Delta Pollution\ ratio_{d,t-1} = Pollution\ ratio_{d,t-1}$ - $Pollution\ ratio_{d,t-2}$. Focusing on changes rather than levels mitigates concerns that our baseline measure captures persistent cross-industry differences in waste management practices or variation in industrial expertise. We re-estimate equation (1) using this alternative measure. The results (Table A.1, Panel B) are qualitatively unchanged: the posterior mean of the change in past pollution ratios is negative, and the 95% credible interval lies entirely below zero. The sample size is smaller in this specification because it is limited to director-year observations with consecutive pollution ratio data and excludes cases where the change is equal to zero.

4 Director Influence on Environmental Performance

We now turn to the second dimension of our analysis and examine the relationship between directors' environmental records and their facilities' environmental performance.

Facilities' environmental performance is not solely determined by external regulation or local pressure; it is also shaped by corporate governance, and in particular by the board of directors. Although directors do not manage facilities directly, they play a central role in setting corporate strategy, allocating resources, and shaping managerial incentives. A board's collective environmental record reflects the past environmental exposure of the firms its members have overseen, which may influence current facility-level outcomes through several channels, including the diffusion of abatement practices, compliance strategies, and reputational norms.

That said, the relationship may also operate in the opposite direction. Firms with cleaner facilities may be more likely to attract directors who already have strong environmental profiles, while more polluting firms may be linked to directors with weaker records. In the empirical analysis that follows, we address these concerns by exploiting the estimated network formation model and by focusing on specifications designed to limit the role of endogenous matching.

Throughout Section 4, we treat the director pollution ratio as a publicly observable measure of directors' prior environmental exposure and reputation, and examine whether this signal is systematically associated with subsequent facility-level environmental outcomes.

4.1 Empirical Specification

We model the relationship between facilities' environmental performance and boardroom characteristics using the following regression equation:

$$y_{f,j,i,l,t} = B'_{j,t-1}\beta + C'_{j,t-1}\gamma + F^{'}_{f,t-1}\delta + \eta M_{i,t} + L^{'}_{l,t}\phi + \alpha_f + \tau_t + \mu_{f,j,i,l,t} \tag{2}$$

where facility f belongs to firm j from industry i, in location l at time t. α_f is the industry-, facility- or firm-fixed effects or random effects (depending on the specification) that control for time-invariant unobservable heterogeneity. τ_t is the time effect that controls for common time-varying effects (e.g. changes in regulation, public pressure). We adjust standard errors for heteroscedasticity and clustering at the firm-level.

$y_{f,j,i,l,t}$ is our measure of a facility's environmental performance. We first use a dummy variable, *probability of polluting*, which takes the value 1 in a given year if the facility releases toxic chemicals in the environment. Second, we use the facility-level *total amount of toxic releases* in a given year. We then examine a potential channel through which companies can reduce their facilities' chemical releases: we estimate equation (2) using the proportion of production-related chemical waste that is managed through RRT.

Board-level environmental characteristics (B). Our main variable of interest is the board's average pollution ratio. It is defined as the average past pollution ratio of the directors serving on the board overseeing the TRI-reporting facility f.[16] The variable *proportion of directors in environmental committees* captures directors' expertise in environmental issues. It is defined as the proportion of board directors of firm j serving on at least one environmental board committee (either in firm j or any other firm) in the last period.[17]

We also take into account diversity in terms of environmental records among the directors. To this end, we use directors' relative pollution degree centrality and define diversity in terms of environmental records as the board range (i.e. the difference between the maximum and minimum of the directors' relative pollution degree centrality). A range different from zero implies that some of the board members hold multiple directorships. The larger the range, the more heterogeneous (in terms of environmental performance) are the companies overseen by these board members. As directors acquire information through their multiple directorships, a firm's environmental performance could be positively associated with the range of pollution degree centrality. At the same time, a more diverse board may result in lower environmental performance if this diversity reflects different opinions regarding environmental issues and increases the chance of conflicts among board members.

Firm-level control variables (C). Firm size is proxied by the number of TRI-reporting plants owned by a company in a given year. We control for a firm's influence in the market using the firm's eigenvector centrality, which captures the size of its board and the influence of its board members within the network.

Facility-level control variables (F). At the facility-level, we include a listed firm dummy, which is equal to 1 if facility f belongs to a listed firm. This dummy captures the fact that

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[16] Note that our main results remain qualitatively the same if we use our other measure of director's environmental performance, i.e. the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution (Tables OB.2-OB.4 in the Online Appendix).

[17] As for the network formation analysis, we use the broad definition of environmental committees in our main specifications, but report the results for the narrower definition in Tables OC.2-OC.4 in the Online Appendix.

publicly traded companies might be more responsive to the increasing pressure to become environmentally responsible.

Local and Sectoral controls (L and M). The tract-level demographic characteristics (denoted by L) that could affect a facility's decisions regarding waste management practices, include median household income, minority ratio, college-education ratio, population density, and an indicator for facilities sited in a special tract (defined as a tract that does not have any demographic information disclosed by the US Census). Regarding the geographical characteristics, we control for tracts that are part of an MSA, urban county, rural county, and coastal county, as well as for tracts belonging to counties located along the border with Canada and Mexico. In addition, we aggregate facility-level toxic releases within each TRI industry to construct annual industry-level average emissions. We include this measure (M) to control for time-varying industry-specific pollution intensity.

4.2 Summary Statistics

Our analysis is conducted on the matched sample of facilities belonging to firms observed in both the TRI and BoardEx datasets. This sample contains 288,277 facility–year observations.[18] Table 4 presents summary statistics for this regression sample. In our empirical analysis, all explanatory variables are lagged by one year, which implies that our sample period starts in 2001, and we lose all facilities that are observed only once during the sample period. Facilities have a probability of reporting toxic releases of about 53%. They release, on average, 152,000 toxic pounds, and the proportion of total toxic waste managed through RRT is around 55%.

Given that a substantial share of facilities do not report toxic releases in every year, we assess whether reporting thresholds generate spurious variation in our director-level pollution measure by examining switching behavior at the facility level (Table A.2 in the Appendix). Of

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[18] In Online Appendix D, we report the results using the full TRI sample (582,722 facility–year observations) to show that unmatched facilities are not fundamentally different from matched facilities in terms of pollution outcomes.

the 18,927 facilities in our sample, approximately 40% either always report or never report toxic releases over the period they are observed in the sample. Among facilities that switch between reporting and non-reporting, most do so infrequently: roughly half switch only once or twice, while repeated toggling is rare. Fewer than 1,000 facilities (about 5% of the sample) switch four or more times over the sample period. This pattern suggests that threshold-driven noise is unlikely to be a dominant source of variation in the director pollution ratio.

On average, boards have a pollution ratio of about 30%. That is, slightly less than one-third of all the facilities supervised by the average board are releasing toxic chemicals. The proportion of directors serving on an environmental committee in a given year is 5.4%. 37% of the facilities belong to a listed firm.

4.3 Endogenous link formation and expected board composition

A key concern in assessing the relationship between board environmental characteristics and firm environmental performance is endogeneity arising from non-random director selection. Firms with cleaner facilities may attract directors with stronger environmental records, while more polluting firms may be less likely to do so. In that case, observed board composition would partly reflect firms' prior environmental orientation rather than directors exerting an independent influence on subsequent outcomes.

To mitigate this concern, we exploit the director–firm network formation model developed in Section 3 to construct a measure of expected, rather than realized, board environmental composition. The core idea is to shift identification away from ex post matches (which may respond to firm-level environmental performance) toward ex ante exposure to environmentally experienced directors implied by the firm's position in the director–firm network.

Specifically, Section 3 estimates, for each firm–director–year triple, the probability that a given director is appointed to a given firm as a function of observable characteristics, including directors' past environmental records, network centrality, experience, and homophily. These predicted probabilities summarize the systematic, network-driven component of director appointments, independent of realized board composition in a given firm-year.

We then construct a probability-weighted measure of board environmental performance by weighting each director's environmental record by their predicted probability of sitting on the board, rather than conditioning on realized membership. This replaces the observed board with its expected composition given the network structure, so that variation in board environmental characteristics reflects differences in firms' network-implied exposure to environmentally experienced directors rather than endogenous appointment decisions.

The identifying assumption is that short-run, firm-specific shocks to environmental performance that directly affect facility-level pollution outcomes do not simultaneously affect the broader director–firm network structure captured by the formation model. Under this assumption, the probability-weighted board measure is less sensitive to reverse causality than specifications based solely on realized board composition. We do not claim that this approach gives a strict causal identification, but it provides a transparent and data-driven way to attenuate bias from endogenous matching.

Section 4.6 implements a complementary strategy to provide additional evidence on the direction of causality. There, we restrict attention to firms whose board composition, directors' network connections, and own environmental performance have remained unchanged over the previous two years. Under these restrictions, changes in the board's environmental record can only arise from changes in the environmental performance of other firms connected to the board members, rather than from endogenous director selection or firm-level environmental improvements. While this approach also does not fully eliminate endogeneity, it substantially limits reverse causality concerns and provides converging evidence that directors' environmental exposure through the network influences firm environmental performance.

4.4 Baseline Results

4.4.1 Facility-level Probability of Pollution

We first investigate whether board characteristics affect the probability that a facility reports a release to the TRI Program. Our dependent variable in equation (2) is $y_{f,j,i,l,t} = pollute_{f,i,j,l,t}$, which takes the value 1 if facility f, belonging to firm j in sector i and located in tract l, releases any toxic chemical at time t. We estimate equation (2) using a probit model with time and industry fixed effects.

Table 5 presents the marginal effects at the mean associated with the probit estimation (Columns 1 and 2). We also estimate equation (2) with facility-level random effects (Columns 3 and 4). In Columns 1 and 3, we use the actual values of our environmental performance measures to compute the board's pollution ratio and range of the board's relative pollution degree centrality. In Columns 2 and 4, we use their expected values obtained using the posterior estimates of our network formation analysis (Column 1 of Table 3).

Results in Columns 1 and 2 indicate that when a facility belongs to a company whose board has a poor environmental record, this facility has a significantly higher probability of future toxic releases. While the magnitude of the estimated marginal effects decreases when we allow for facility-level random effects (Columns 3 and 4), the qualitative findings do not change.

Given a standard deviation of 0.348 (Table 4) and a marginal effect of 0.490 (Column 1, Table 5), a one–standard-deviation increase in the board pollution ratio increases the probability that a facility reports toxic releases by approximately 17 percentage points. Relative to the unconditional probability of polluting in our sample (about 53%), this represents a substantial shift in the likelihood of reporting toxic releases. The magnitude suggests that differences in boards' prior environmental exposure are economically meaningful determinants of facilities' extensive-margin pollution decisions.

Such effects are consistent with the binary nature of TRI reporting and with prior work documenting sizeable probability shifts in firms' environmental behavior. In particular, research on EPA's 33/50 voluntary pollution reduction program models firms' participation as a binary regulatory decision and shows that firm and governance characteristics generate economically meaningful differences in participation likelihood (e.g., Arora and Cason, 1996; Khanna and Damon, 1999). Likewise, governance studies report sizeable probability effects of board characteristics on rare "binary" environmental outcomes such as environmental lawsuits or convictions (Kassinis and Vafeas, 2002; Tauringana et al., 2017).

Directors' expertise in environmental issues (proxied by their participation in environmental board committees) is negatively associated with the probability of polluting at the facility-level. If the facility belongs to an industry reporting large amounts of toxic releases, then the facility has a higher probability of releasing toxic chemicals in any given year. Listed firms have a lower probability of polluting compared to non-listed firms.

4.4.2 Facility-level Toxic Releases

In a second specification, we use total toxic waste released at the facility level as our dependent variable and estimate equation (2) using a linear regression model. Because total releases are highly skewed (with a mean of approximately 151,600 pounds but a standard deviation exceeding 2.2 million pounds) we model release intensity using ln(1+releases). In Columns 1 and 3 of Table 6, we include firm-level fixed effects while, in Columns 2 and 4, we control for facility-level unobservable heterogeneity by including facility-level fixed effects. Further, Columns 3 and 4 are estimated using the posterior estimates of the network formation analysis.

Facilities overseen by boards with higher average pollution ratios tend to release significantly larger amounts of toxic chemicals. Using the coefficient of 1.709 reported in Column 2 of Table 6 a one–standard-deviation increase in the board pollution ratio raises the log of total releases by approximately 0.595 log points. This corresponds to an increase in releases of roughly 81%. While sizeable, this magnitude must be interpreted in light of the fact that total releases are extremely dispersed, with a small fraction of facilities accounting for very large emissions. In such a skewed distribution, economically meaningful shifts in firm characteristics can be associated with large proportional changes in expected emissions. In addition, once we implement the approaches to mitigate endogenous matching, the estimated increase in releases falls to 25% (Column 4) or 33% (Section 4.6, Table 8, Panel C).

The listed-firm indicator and the proportion of directors serving on environmental committees enter with the expected signs. However, once we replace realized board characteristics with the probability-weighted measures derived from the network formation model, these coefficients are no longer statistically significant at conventional levels.

4.4.3 Facility-level Toxic Waste Recovered, Recycled, and Treated

If a facility does not release toxic chemicals in the environment, it might be because it successfully manages their chemical waste through other waste management practices (RRT). To investigate the role played by the board of directors in the choice of waste management activities, we estimate the impact of the board's past environmental record on the proportion of total production-related waste managed through RRT.

Our dependent variable is the log difference between the total production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility. We estimate a linear regression model similar to equation (2). In Columns 1 and 3 of Table 7, we include firm-level fixed effects while, in Columns 2 and 4, we allow for facility-level fixed effects. As before, Columns 3 and 4 are estimated using the posterior estimates of the network formation analysis for all firms in our sample.

In line with our previous results, when the board's average pollution ratio is high (poor environmental record), the facilities overseen by this board tend to manage a lower proportion of their production-related waste through RRT. This suggests that reductions in total toxic releases are not entirely driven by reductions in production. Firms also seem to change their waste management practices.

4.5 Robustness Checks

4.5.1 Serial Correlation of Environmental Performance

One potential concern is that a facility's environmental performance (total releases or RRT) might be serially correlated. This could pose a problem because the board's average pollution ratio is derived from the past environmental performance of facilities overseen by that board. If serial correlation exists, our results could be biased.

Our facility-level panel is unbalanced because facilities are observed for different time spans. Some are present throughout the sample period, while others enter later or exit earlier. In addition, some facilities do not report releases in every year, generating reporting gaps. As a result, the effective time interval between observations can differ across facilities.

Standard panel data methods that model serial correlation often assume equally spaced observations and identical time intervals across units. When panels are unbalanced, applying these methods without adjustment can lead to misspecified error structures and inefficient inference. For this reason, we use Baltagi and Wu (1999)'s approach to account for the potential serial correlation of environmental performance. The coefficients associated with the board's average pollution ratio reported in Table A.3 are qualitatively similar to what we observe in Tables 6-7.

The key intuition of Baltagi and Wu (1999) is that in an AR(1) process, the correlation between errors depends on the length of time between observations, not merely on their ordering. Baltagi and Wu (1999) explicitly account for unequal time gaps by modifying the AR(1) transformation to reflect the actual spacing between observations for each unit. This allows error correlation to decay appropriately as the time interval increases. The resulting feasible GLS estimator accommodates unbalanced panels, permits individual-specific effects, and produces consistent estimates of the serial correlation parameter and variance components.

4.5.2 Censored Regressions

In our dataset, many firms are not reporting any toxic releases in a given year. As a robustness check, we estimate our empirical models using censored regression techniques. We present these results in Table A.4. As a reference point, in Columns 1 and 4, we report linear regression results with industry fixed effects (and no facility-level effects). In Columns 2 and 5, we report the censored regression results. In Columns 3 and 6, we present another set of censored regression results with facility-level random effects, controlling for facility-level unobservable heterogeneity. The censored regression results for the board's average pollution ratio show even larger effects than the linear specification. This is expected. When a non-trivial share of observations is censored at zero, OLS on ln(1+releases) attenuates estimated coefficients. Tobit-type models jointly estimate the probability of positive releases and the expected level of releases under parametric assumptions about the error distribution. When a regressor affects both the extensive margin (whether releases occur) and the intensive margin (how much is released), censored models typically attribute a larger overall marginal effect to that regressor than linear models estimated on transformed outcomes.

4.5.3 Environmental Performance and Institutional Ownership

Recent evidence suggests that hedge funds or other institutional investors can affect environmental performance, through investor activism (Naaraayanan et al., 2021; Liang et al., 2022). To examine whether institutional ownership might drive our results, we obtain companies' shareholding information via Refinitiv Eikon and merge this information with our dataset using companies' tickers provided by BoardEx (listed companies only).[19] We re-estimate equation (2), while controlling for the percentage of shares held by institutional investors (*Holdings by institutions*) and by strategic entities (*Holdings by Strategic Entities*).[20] Table A.5 reports the

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[19] In Refinitiv Eikon, there are quarterly records for each company's ownership information in the database. We take the average values for each given year.

[20] Strategic entities can be companies, government agencies, individual investors, or insider investors. They do not buy shares for investment management purposes, but rather for strategic stakes (concentrated stock position

results for the log of total toxic releases (Columns 1 and 2) or the log difference between the total production-related waste recovered, recycled, and treated, and the total production-related waste managed (Columns 3 and 4). Results remain qualitatively the same. The shareholding variables are not statistically significant at conventional levels.

4.5.4 Other Firm-level Control Variables

Using the company ticker from BoardEx, we obtain additional firm-level control variables from Compustat. Data on Compustat cover only listed firms. The sample size is therefore reduced to 84,548 facility-year observations. In Table A.6, we present the results of the estimation of equation (2) with the log of total assets as an additional control variable for firm size (see Berrone and Gomez-Mejia 2009). The main results remain qualitatively unchanged.

4.5.5 Environmental Performance and ESG Scores

The TRI data provide an objective and quantitative measure of realized environmental performance at the facility level. However, TRI releases capture only one dimension of environmental outcomes (toxic chemical waste). By contrast, most publicly listed firms are now evaluated by third-party providers on broader environmental, social, and governance (ESG) dimensions. ESG scores aggregate information from corporate social responsibility (CSR) reports, sustainability disclosures, annual reports, and other public sources, and typically combine environmental indicators with social and governance components. As a result, ESG ratings capture a wider and partially disclosure-based concept of performance that may differ from realized operational pollution outcomes.

To examine whether our results extend to broader sustainability measures, we re-estimate equation (2) using ESG scores as dependent variables. We obtain Thomson Reuters ESG data from Refinitiv Eikon, available from 2002 onwards. Our ESG sample includes 385 unique

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or substantial equity position for enhancing acquisition, hedge, yield enhancement). The category *Holdings by institutions* includes, among others, bank and trust, hedge fund, investment advisor, insurance company, pension fund, private equity, venture capital.

listed firms over the period 2002–2017 (for which Compustat and ownership information is also available). We consider the overall ESG score as well as its Environmental, Social, and Governance pillar scores. In addition, we include the "Resource Use" score, a subcomponent of the Environmental pillar measuring firms' ability to reduce material use and improve supply-chain efficiency (Refinitiv (2022), p. 25).

Importantly, our measure of board environmental performance remains unchanged in these specifications. The board pollution ratio continues to be defined as the share of TRI-reporting facilities overseen by directors that released toxic chemicals in the previous period. Thus, even when ESG is the dependent variable, the key explanatory variable reflects directors' past exposure to operational toxic releases rather than broader ESG engagement, disclosure practices, or sustainability governance structures. In this sense, we are testing whether directors' TRI-based environmental exposure predicts variation in composite ESG ratings that incorporate many dimensions unrelated to toxic emissions.

Before turning to the regression results, it is useful to assess the relationship between TRI releases and ESG scores. The two measures are only weakly correlated. The correlation between the total ESG score and total toxic releases is 0.035, and the correlation with the Environmental Pillar score is -0.02. This suggests that TRI emissions and ESG ratings capture distinct dimensions of firm environmental performance.

Table A.7 reports the estimation results. As a reference, Column 1 presents facility-level toxic releases estimated on the exact subsample of firms for which ESG data are available. The board pollution ratio remains positive and statistically significant, confirming that our baseline TRI results are not driven by differences in sample composition. Columns 2-6 replace toxic releases with the total ESG score and its components. In these specifications, neither the board pollution ratio nor the proportion of directors serving on environmental committees is statistically significant.

ESG ratings aggregate multiple dimensions, including social performance, governance structures, and disclosure policies, that may evolve slowly and reflect longer-term strategic positioning rather than short-run operational pollution decisions. Directors' exposure to firms with lower TRI-reported emissions may therefore influence facility-level environmental practices without necessarily translating into measurable changes in composite ESG scores.[21]

4.6 Understanding the Impact of the Board's Environmental Record

Changes in the board pollution ratio can occur through four main channels: (1) the appointment of new directors, (2) changes in the environmental performance of the firm itself, (3) changes in the environmental performance of other firms connected to the board members, or (4) directors of the focal firm joining or leaving other boards, or changes in the composition of those boards.

To disentangle these various channels and isolate the sources of variation in the board's average pollution ratio, we implement a series of sample restrictions. Specifically, we analyze changes in total toxic releases for a subset of firms where board composition, directors' first-degree connections, and the firms' past environmental performance remained unchanged for at least two consecutive years (e.g., $t-1$, $t-2$, etc.). For these subsets of firms, we estimate the effect of changes in the board's average pollution ratio between two consecutive years (Δ*Board's average pollution ratio*) using a linear model with facility- or firm-level fixed effects. The dependent variable is either the log of toxic waste released or the log difference between the total production-related waste managed through RRT and the total production-related waste from a facility f in year t. This approach is conceptually similar to strategies used in the board networks literature (Omer et al., 2020), which examine changes in network-based measures while holding board composition fixed, so that remaining variation reflects developments external to the focal firm.

This approach serves two additional purposes. First, it helps address concerns about reverse

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[21] The absence of significant results for ESG scores could also stem from the fact that these scores exhibit substantially lower within-firm variation over time than TRI releases. The mean within-firm standard deviation of ESG scores is 0.26, compared to 1.27 for log toxic releases. Once fixed effects are included, most of the cross-sectional variation in ESG ratings is absorbed, leaving limited time-series variation to be explained by changes in board characteristics.

causality, specifically the possibility that firms with better environmental performance attract directors with stronger environmental profiles. By focusing on this restricted sample, we mitigate concerns about endogenous director selection, as changes in the board pollution ratio are driven by decisions made by other firms rather than by the focal firm.

Second, the restricted sample allows us to control for other board characteristics that could influence a firm's environmental performance but remain constant within the sample (e.g., board size, gender composition, directors' educational backgrounds). By narrowing the analysis to firms with unchanged board composition, we ensure that changes in a facility's environmental performance are not attributable to these board-level characteristics.

The results for the various sample restrictions are presented in Table 8. First, in Panel A of Table 8, we restrict the sample to firms with unchanged board composition. Under this restriction, any changes in the board's average pollution ratio must stem either from the firm's own past environmental performance or from external changes in the performance of other companies where board members hold directorships.

In Panel B of Table 8, we further refine the sample by including only firms whose past pollution ratio (defined as the number of polluting facilities owned by the firm divided by the total number of facilities owned by the firm) remains unchanged for at least two consecutive years ($t-1$, $t-2$...). By holding both the board composition and the firm's past environmental performance constant, any changes in the board's average pollution ratio must come from external factors, such as the appointment or removal of directors from other boards or changes in the environmental performance of facilities overseen by these directors in other firms.

Finally, in Panel C of Table 8, we apply an even stricter restriction, considering only firms with unchanged board composition, firm-level environmental performance, and first-degree connections of their directors. Under this final restriction, the only channel through which the board's average pollution ratio can be affected is a change in the environmental performance of other firms. This is because the directors of the focal firm neither join nor leave any boards, and all their existing boards remain unchanged.

Across all subsamples, the analysis shows a significant (at the 1% level) positive association between changes in the board's average pollution ratio and subsequent facility-level toxic releases. This finding is consistent with the hypothesis that board connectedness improves environmental performance when board members are linked to firms with strong environmental practices.

One possible interpretation of these results is that well-connected directors have better access to information. By serving on a greater number of boards with good environmental performance, directors from firm j are exposed to good environmental practices, which they may then implement in firm j to improve the environmental performance of its facilities. These findings highlight the interconnected nature of board networks and the role of external environmental practices in shaping firm behavior.

With this specification, we are not able to test whether the appointment of a new director with a good environmental record also influences its facilities' environmental performance. In Online Appendix E, we examine the evolution of a firm's environmental performance around the appointment of a new clean director (an event study-type analysis) up to four years after their appointment. Our results show that the magnitude of the effect of appointing a clean director (compared to a director with a poor environmental record) on toxic chemicals released and managed through RRT is the largest one year after the appointment. However, these results have to be interpreted with caution as this approach does not control for the endogenous selection of directors.

5 Conclusion

This paper links corporate governance to a concrete, regulatory measure of environmental performance. Combining BoardEx with the EPA's Toxics Release Inventory, we construct director- and board-level measures of past environmental track records and relate them to facility-level toxic releases and waste management. The central takeaway is that who sits on the board, and the environmental track record embodied in those appointments, are related to subsequent environmental outcomes, even after accounting for several controls and multiple robustness checks.

Our results address two closely related aspects of the governance–environment relationship. First, in the director labor market, firms are more likely to appoint directors with stronger prior environmental records, and this pattern is shaped by network position and similarity between candidates and firms. Second, in the facility-level outcome analysis, boards with weaker environmental track records are associated with higher future toxic releases and a lower share of waste managed through recycling, energy recovery, or treatment. To mitigate concerns that boards simply mirror firms' pre-existing environmental orientation, we exploit the estimated network formation model to construct expected board characteristics and implement a set of sample restrictions designed to limit reverse causality. Across these exercises, the qualitative relationship between board environmental track records and facility outcomes remains.

These findings suggest that board composition and boardroom connections are empirically relevant for understanding firm-level environmental performance. While the paper does not directly observe the internal processes through which directors influence environmental decisions, the consistent association between directors' past environmental records and future facility outcomes, especially in specifications that hold board composition and firm-level performance constant, points to an important network-mediated governance channel linking firms. This interpretation is necessarily cautious: the results are consistent with the transmission of environmentally relevant experience across boards, but the analysis does not attempt to isolate the specific mechanisms involved.

From a broader perspective, the analysis highlights how governance structures can shape firms' responses to environmental regulation and public disclosure. In settings like the TRI, where environmental performance is observable and subject to scrutiny, boards appear to be one margin along which firms differ in their capacity to manage pollution and waste. This suggests that environmental outcomes may depend not only on regulatory design and local pressures, but also on how firms organize oversight and draw on external experience through their directors.

Several avenues for future research follow naturally from these results. First, establishing the mechanisms underlying the observed patterns would require data on internal policies, managerial practices, or technology adoption. Second, quantifying the relative importance of boards compared to other sources of influence, such as investors, regulators, or industry peers, would help clarify the scope of governance effects. Finally, research designs exploiting exogenous shocks to board composition or director mobility could further strengthen causal interpretation. Together, these extensions would improve our understanding of how corporate governance interacts with environmental regulation to shape environmental outcomes.

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Figure 1: Directors' subnetwork with a distance of 2

This graph shows a sub-network of the two most influential directors (determined by their eigenvector centrality measures) among all directors who are connected to at least one firm in the TRI dataset (green and brown nodes) in 2017. We are representing all the nodes that are at a distance of at most two (two edges) from the two most influential directors (red nodes). Brown nodes represent firms that have reported at least one toxic release in the previous year, while green nodes represent TRI-reporting firms without any toxic releases. Blue nodes represent the other directors. This sub-network includes nine firms–three polluting firms and six clean firms–with 69 directors. In our setting, directors' environmental performance will be a function of the past environmental performance of their connected firms. In this example, both directors have two 'pollution links' as they are connected to two polluting firms. However, one director serves on the board of three firms, while the other is connected to seven firms. The director serving on the board of seven firms will be considered as having a better environmental record in terms of relative degree centrality.

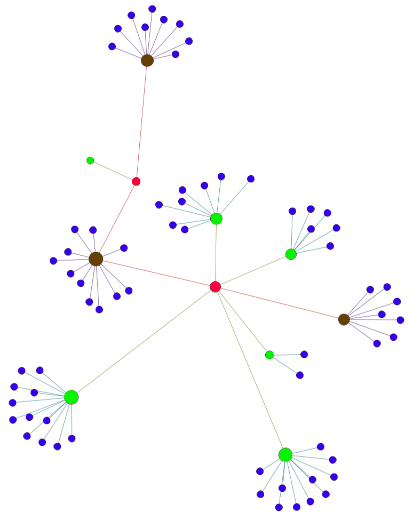

Table 1: Summary statistics for all TRI facilities and matched TRI facilities

Column 1 reports summary statistics for all the facilities reporting to the TRI Program between 2000 and 2017. Column 2 and Column 3 show the information on facilities belonging to a firm recorded in BoardEx (i.e. our matched sample) and facilities that don't have board information, respectively. Panel A contains sample counts. Panels B and C contain sample means. Total RRT represents the total amount of production-related waste managed through energy recovery, recycling and treatment.

Variables	All	With directors	Without directors
Panel A: Sample Counts			
Number of unique firms	19,787	2,877	16,910
Number of unique facilities	41,904	18,941	22,963
Number of unique directors	17,224	17,224	0
Number of unique tracts (with at least one facility)	18,423	11,178	12,882
Panel B: Facility-level Statistics			
Probability of polluting	0.532	0.530	0.535
	(0.499)	(0.499)	(0.499)
Total toxic releases by facility (in thousands of pounds)	125.372	159.636	91.952
	(4,215.965)	(2,464.392)	(5,402.327)
Total RRT by facility (in thousands of pounds)	620.002	799.859	444.573
	(13,135.137)	(9,650.520)	(15,808.669)
Panel C: Firm-level Statistics			
Number of facilities per firm	2.24	6.706	1.358
	(7.546)	(17.26)	(2.151)
Proportion of polluting facilities per firm	0.517	0.534	0.514
	(0.477)	(0.409)	(0.490)

Standard deviations are in parentheses.

Table 2: Summary statistics of variables used in the network formation analysis

This table reports summary statistics for the variables used in the network formation analysis. We create a pool of candidates based on homophily measures and identify a possible 8,487,170 director-firm pairs for all TRI-reporting firms with directors for all years. On average, this corresponds to about 300 potential candidates per firm in a given. Column 1 presents summary statistics for all TRI-reporting firms, while Column 2 provides summary statistics for listed firms.

Variable	Mean	
	All firms	Listed firms
	(1)	(2)
Probability of creating a link	0.019	0.026
	(0.137)	(0.160)
Candidate's past pollution ratio	0.450	0.491
	(0.384)	(0.365)
Candidate's influence	0.0002	0.0002
	(0.014)	(0.014)
Candidate's past pollution ratio × influence	0.0001	0.0001
	(0.009)	(0.009)
Candidate is a CEO	0.092	0.089
	(0.289)	(0.285)
Candidate's past experience in environmental committees	0.090	0.091
	(0.326)	(0.326)
Market exposure in years (number of years in BoardEx)	5.545	5.935
	(4.506)	(4.578)
Firm's influence	0.0001	0.00003
	(0.0021)	(0.0014)
Difference in candidate's relative pollution degree centrality and other board members average relative pollution degree centrality[a]	0.324	0.338
	(0.299)	(0.249)
Difference in candidate's pollution ratio and firm's pollution ratio[a]	0.345	0.332
	(0.320)	(0.285)
Difference in candidate's influence and firm's influence[a]	0.0003	0.0003
	(0.014)	(0.015)

[a] The homophily measures are given in absolute values. Standard deviations are in parentheses.

Table 3: Bayesian estimates of network formation parameters

The table displays the means of the posterior distributions for each network parameter affecting the probability of forming a link between directors and firms at time t. The dependent variable is equal to 1 if a director, in year t, becomes a member of the board. The independent variables used are lagged by one year. The model was estimated using Bayesian MCMC technique based on a hybrid Metropolis-Hastings algorithm with Gibbs sampling based on Equation (1). We use uniform priors for the regression coefficients and an inverse gamma prior with shape and scale parameters of 0.1 and 0.1 for the error variance. In all our Bayesian estimates, we use 10,000 iterations and omit the first 2,500 to mitigate possible start-up effects. Column 1 reports the regression results for all firms in our sample, and Column 2 reports the regression results for listed firms only.

Variable	Mean of the posterior distribution	
	All firms	Listed firms
	(1)	(2)
Candidate's past pollution ratio$_{t-1}$	-0.0010	-0.0146
	[-0.0013, -0.0008]	[-0.0151, -0.0141]
Candidate's influence$_{t-1}$	0.1045	0.1124
	[0.1004, 0.1081]	[0.0981, 0.1221]
Candidate's pollution ratio$_{t-1}\times$ influence$_{t-1}$	-0.0577	-0.0766
	[-0.0586, -0.0568]	[-0.0851, -0.0650]
Candidate is a CEO$_{t-1}$	0.0012	0.0017
	[0.0009, 0.0015]	[0.0011, 0.0023]
Candidate's past experience in environmental committees$_{t-1}$	0.0062	0.0106
	[0.0060, 0.0065]	[0.0101, 0.0111]
Firm's influence$_{t-1}$	0.1119	0.3645
	[0.1101, 0.1134]	[0.3575, 0.3707]
Difference in candidate's relative pollution degree centrality and other board members average relative pollution degree centrality$^{a}_{t-1}$	-0.0274	-0.0435
	[-0.0277, -0.0271]	[-0.0442, -0.0427]
Difference in candidate's pollution ratio and firm's pollution ratio $^{a}_{t-1}$	-0.0451	-0.0723
	[-0.0454, -0.0448]	[-0.0729, -0.0717]
Difference in candidate's influence and firm's influence$_{t-1}$	-0.0703	-0.0736
	[-0.0724, -0.0683]	[-0.0760, -0.0705]
Log(Market exposure in years)	0.0020	0.0027
	[0.0018, 0.0021]	[0.0024, 0.0029]
Trend	Yes	Yes
Number of obs	8,487,170	3,173,029
Log marginal likelihood	4,919,252	1,351,488

[a] The homophily measures are given in absolute values. 95% Credible intervals are in parentheses.

Table 4: Summary statistics for regression sample: 2001-2017

The regression sample includes all TRI facilities that could be matched to a firm in BoardEx. For panels A, D and E, the unit of observation is facility-year. The total number of observations is 288,777. For panels B and C, the unit of observation is firm-year. The total number of observations is 42,861.

Variables	Mean	Standard Deviation
Panel A: Dependent variables		
Probability of polluting	0.530	0.499
Total toxic releases by facility (in thousands of pounds)	151.602	2,212.775
Total RRT by facility (in thousands of pounds)	793.167	9,492.628
Proportion of waste managed through RRT	0.556	0.438
Panel B: Board-level characteristics		
Board's average pollution ratio	0.296	0.348
Range of the board's relative pollution degree centrality	0.260	0.367
Proportion of directors in environmental committees	0.054	0.165
Panel C: Other Firm-level Statistics		
Firm's influence (10^{-4})	0.306	13.014
Number of plants	6.726	17.273
Firm has an environmental committee	0.058	0.233
Panel D: Facility-level Statistics		
Facility belongs to a listed firm	0.370	0.483
Panel E: Facility-level Demographic and Geographic Characteristics		
Median household income	56,559.55	23,293.22
Minority ratio	0.232	0.238
College ratio	0.195	0.175
Population density	1,225.626	2,156.295
Probability of locating in a special tract	0.016	0.127
Probability of a plant located in an MSA County	0.751	0.432
Probability of a plant located in an urban County	0.231	0.421
Probability of a plant located in a coastal County	0.175	0.380
Probability of being located in a Mexico border County	0.010	0.099
Probability of being located in a Canada border County	0.038	0.191

Table 5: Pollution probabilities

This table presents the marginal effects associated with the probit estimation of Equation (2). All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. Columns 1 and 2 report the results without facility-level random effects, and Columns 3 and 4 report the results with facility-level random effects. In Columns 2 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Probability of polluting$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	0.490***		0.284***	
	(0.004)		(0.004)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.164***		-0.036***	
	(0.003)		(0.003)	
E[Board's average pollution ratio]$_{j,t-1}$		0.398***		0.176***
		(0.008)		(0.007)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		-0.298***		-0.120***
		(0.011)		(0.010)
Firm's influence$_{j,t-1}$	-0.263	0.543	0.415	1.165
	(1.467)	(1.509)	(1.470)	(1.428)
Log of avg. industrial releases$_{i,t}$	0.102***	0.111***	0.091***	0.091***
	(0.006)	(0.005)	(0.003)	(0.003)
Proportion of directors in environmental committees$_{j,t-1}$	-0.130***	-0.049***	-0.091***	-0.041***
	(0.005)	(0.005)	(0.006)	(0.006)
Facility belongs to a listed firm$_{f,t}$	-0.030***	0.006***	-0.031***	-0.007*
	(0.002)	(0.002)	(0.004)	(0.004)
Located in a special tract	Yes	Yes	Yes	Yes
MSA, Urban, and Coastal County effects	Yes	Yes	Yes	Yes
Located in a county that border Mexico or Canada	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Facility random effects			Yes	Yes
Observations	288,277	288,277	288,277	288,277
Wald χ^2	27,940	17,522	8,714	3,689
Log likelihood	-184,049	-190,004	-115,339	-118,099

Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6: Regression results for total toxic releases

This table reports the OLS regression results of Equation (2). The dependent variable is the facility-level log of total toxic chemical releases in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. Further, in Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Log of toxic releases$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	1.503***	1.709***		
	(0.138)	(0.125)		
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.072	-0.051		
	(0.082)	(0.076)		
E[Board's average pollution ratio]$_{j,t-1}$			0.448**	0.649***
			(0.189)	(0.151)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			-0.282	-0.400*
			(0.222)	(0.214)
Firm's influence$_{j,t-1}$	25.608	24.254	29.541	28.730
	(33.074)	(33.829)	(34.324)	(35.246)
Log of avg. industrial releases$_{i,t}$	0.676***	1.191***	0.678***	1.245***
	(0.064)	(0.199)	(0.064)	(0.199)
Proportion of directors in environmental committees$_{j,t-1}$	-0.438**	-0.421*	-0.191	-0.152
	(0.212)	(0.216)	(0.186)	(0.186)
Facility belongs to a listed firm$_{f,t}$	-0.255*	-0.247*	-0.137	-0.111
	(0.134)	(0.131)	(0.142)	(0.144)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.364	0.762	0.361	0.759

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 7: Regression results for toxic waste managed through RRT

This table reports the OLS regression results of Equation (2). The dependent variable is the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. In Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Log(RRT_{ft}/total toxic waste_{ft})			
	(1)	(2)	(3)	(4)
Board's average pollution $\text{ratio}_{j,t-1}$	-0.539***	-0.577***		
	(0.070)	(0.072)		
Range of the board's relative pollution degree $\text{centrality}_{j,t-1}$	0.026	0.027		
	(0.042)	(0.041)		
E[Board's average pollution ratio]$_{j,t-1}$			-0.227**	-0.274**
			(0.099)	(0.106)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			0.079	0.125
			(0.121)	(0.120)
Firm's $\text{influence}_{j,t-1}$	-11.525	-10.752	-12.912	-12.215
	(14.796)	(15.076)	(15.124)	(15.420)
Log of avg. industrial $\text{releases}_{i,t}$	-0.157***	-0.597***	-0.157***	-0.614***
	(0.040)	(0.155)	(0.040)	(0.154)
Proportion of directors in environmental $\text{committees}_{j,t-1}$	0.104	0.102	0.021	0.016
	(0.106)	(0.107)	(0.100)	(0.099)
Facility belongs to a listed $\text{firm}_{f,t}$	0.128*	0.121*	0.086	0.077
	(0.076)	(0.073)	(0.077)	(0.075)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.244	0.611	0.243	0.610

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Regression results - understanding the sources of variation in the board's average pollution ratio

This table reports the OLS regression results of Equation (2) for facilities that belong to a firm in BoardEx where the board composition did not change for at least two consecutive years (panel A), or where the board composition and the firm pollution ratio did not change for at least two consecutive years (panel B), or where the board composition, the firm pollution ratio, and the directors' first degree connections did not change for at least two consecutive years (panel C). The dependent variable is the facility-level log of total toxic chemical releases in a given year (columns 1 and 2) or the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year (columns 3 and 4). All regressions include log of avg. industrial releases, listed firm indicator, proportion of directors in environmental committees, firm influence, log number of plants per firm, log of median household income, minority ratio, college ratio, log of population density, time effects. In Columns 1 and 3, we include firm-level fixed effects along with indicators for special tract, tracts belonging to MSA counties, urban counties, coastal counties, and tracts located in counties that border Mexico and Canad ; while, in Columns 2 and 4, we allow for facility-level fixed effects.

Variable	Log of toxic releases$_{ft}$		Log$\left(\frac{RRT_{ft}}{total\ toxic\ waste_{ft}}\right)$	
	Firm FE	Facility FE	Firm FE	Facility FE
	(1)	(2)	(3)	(4)
Panel A: Same board composition				
ΔBoard's average pollution ratio$_{j,t-1}$	1.339***	1.338***	-0.546***	-0.540***
	(0.090)	(0.099)	(0.058)	(0.063)
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.689***	0.689***	-0.183***	-0.176**
	(0.122)	(0.133)	(0.069)	(0.075)
Observations	90,207	90,207	90,207	90,207
R^2	0.385	0.820	0.261	0.697
Panel B: Same board composition and same firm environmental performance				
ΔBoard's average pollution ratio$_{j,t-1}$	0.951***	0.954***	-0.420***	-0.427***
	(0.154)	(0.178)	(0.104)	(0.119)
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.932***	0.932***	-0.220**	-0.215**
	(0.158)	(0.183)	(0.094)	(0.108)
Observations	38,849	38,849	38,849	38,849
R^2	0.481	0.867	0.385	0.781
Panel C: Same board composition, same firm environmental performance, and same first-degree connections				
ΔBoard's average pollution ratio$_{j,t-1}$	0.818***	0.821***	-0.297***	-0.305**
	(0.154)	(0.178)	(0.103)	(0.119)
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.974***	0.978***	-0.208*	-0.203
	(0.179)	(0.207)	(0.108)	(0.125)
Observations	30,070	30,070	30,070	30,070
R^2	0.505	0.869	0.409	0.783

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix

Figure 2: Directors' sub-network with a distance of 4

Figure 2 presents the sub-network of the two most influential directors (same directors as in Figure 1) among all TRI-related directors (represented by the red nodes) for the year 2017. Nodes' color notations are the same as in Figure 1. Compared to Figure 1, we expand the sub-network to include all the nodes at a distance of at most four from the two most influential directors. With this increase in distance, the number of nodes increases by 1,316, and the number of edges increases by 1,815. The comparison of Figures 1 and 2 provides some insight into the complexity and size of the network.

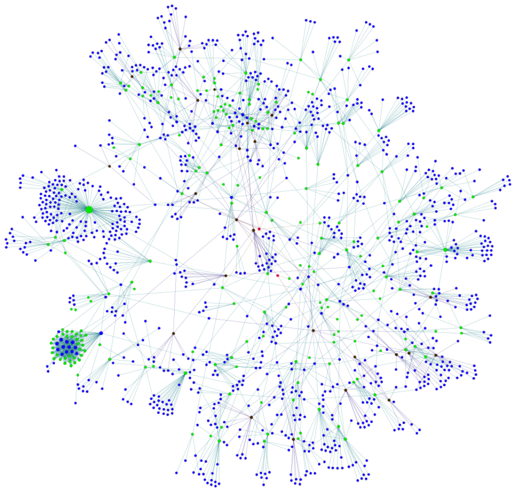

Table A.1: Bayesian estimates of network formation parameters - Robustness Checks

The table displays the means of the posterior distributions for each network parameter affecting the probability of forming a link between directors and firms at time t. The dependent variable is equal to 1 if a director, in year t, becomes a member of the board. The independent variables used are lagged by one year. Column 1 reports the regression results for all firms in our sample, and Column 2 reports the regression results for listed firms only. In both Columns, we control for Candidate's influence, CEO experience, Firm's influence, market exposure, trend, and homophily measures.

Variable	Mean of the posterior distribution	
	All firms	Listed firms
	(1)	(2)
Panel A: Director's prior experience in the focal firm		
Candidate's past pollution ratio$_{t-1}$	-0.0010	-0.0032
	[-0.0113, -0.0009]	[-0.0034, -0.0030]
Candidate's pollution ratio$_{t-1}\times$ influence$_{t-1}$	0.0809	0.0950
	[0.0804, 0.0813]	[0.0948, 0.0983]
Candidate's past experience in environmental committees$_{t-1}$	0.0006	0.0007
	[0.0005, 0.0007]	[0.00056, 0.0009]
Candidate was a board member$_{t-1}$	0.9933	0.9928
	[0.9930, 0.9936]	[0.9924, 0.9932]
Number of obs	8,487,170	3,173,029
Log marginal likelihood	12,788,515	4,535,020
Panel B: Change in past pollution ratio		
Change in candidate's past pollution ratio$_{t-1}$	-0.0042	-0.0087
	[-0.0045 , -0.0039]	[-0.0094 , -0.0079]
Candidate's past experience in environmental committees$_{t-1}$	0.0073	0.0113
	[0.0069 , 0.0076]	[0.0106 , 0.0120]
Number of obs	3,795,558	1,497,743
Log marginal likelihood	2,417,129	715,817

95% Credible intervals are in parentheses.

Table A.2: Switching behavior of TRI-reporting facilities (2000–2017)

Number of switches	Number of facilities	Share (%)
0 (always release)	4,529	23.9
0 (never release)	3,125	16.5
1	6,598	34.9
2	2,615	13.8
3	1,072	5.7
≥ 4	988	5.2
Total	18,927	100.0

Table A.3: GLS regression with AR(1) disturbances

This table reports regression results that account for serial correlation in facility-level environmental performance using the Baltagi and Wu (1999) estimator for unequally spaced panel data. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In all Columns we control for facility-level unobservable heterogeneity by including facility-level fixed effects.

Variable	Log of toxic releases$_{ft}$	Log$\left(\frac{RRT_{ft}}{total\ toxic\ waste_{ft}}\right)$
	(1)	(2)
Board's average pollution ratio$_{j,t-1}$	0.360***	-0.172***
	(0.025)	(0.020)
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.034*	0.035**
	(0.018)	(0.015)
Firm's influence$_{j,t-1}$	4.242	3.555
	(12.640)	(9.752)
Log of avg. industrial releases$_{i,t}$	0.640***	-0.222***
	(0.015)	(0.009)
Proportion of directors in environmental committees$_{j,t-1}$	-0.103**	0.110***
	(0.045)	(0.035)
Facility belongs to a listed firm$_{f,t}$	0.087***	0.006
	(0.030)	(0.022)
Facility effects	Yes	Yes
Year effects	Yes	Yes
Observations	288,277	288,277
χ^2	4368	1588
ρ_{AR}	0.701	0.610
ρ fraction of variance due tou_i	0.789	0.612
σ_e	1.829	1.512
σ_u	3.533	1.898
$\tau_{\max}$	0.651	0.585

Standard errors are in parentheses. *** p <0.01, ** p<0.05, * p<0.1

Table A.4: Censored linear regression results for total releases

This table reports censored linear regression results for total releases. We have left-censored the data for toxic releases per facility per year and estimated our empirical models using censored regression techniques. Columns 1 and 4 report linear regression results (as a benchmark). Columns 2 and 5 report results from censored regression. Columns 3 and 6 report censored regression results with facility-level random effects controlling for facility-level unobservable heterogeneity. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density in addition to indicators for facilities siting in a special tract, MSA, Urban, and Coastal Counties, located in a county that border Mexico or Canada, industry effects, and time effects.

Variable	Log of toxic releases$_{ft}$					
	OLS	Censored		OLS	Censored	
	(1)	(2)	(3)	(4)	(5)	(6)
Board's average pollution ratio$_{j,t-1}$	3.572***	3.952***	3.145***			
	(0.200)	(0.034)	(0.044)			
Range of the board's relative pollution degree centrality$_{j,t-1}$	-1.121***	-1.303***	-0.307***			
	(0.194)	(0.029)	(0.042)			
E[Board's average pollution ratio]$_{j,t-1}$				2.854***	3.162***	1.594***
				(0.359)	(0.064)	(0.078)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$				-2.597***	-2.873***	-1.158***
				(0.672)	(0.102)	(0.137)
Firm's influence$_{j,t-1}$	-21.182	-10.368	33.493*	-15.599	-6.094	40.770**
	(22.800)	(12.227)	(19.497)	(24.315)	(12.439)	(19.658)
Log of avg. industrial releases$_{i,t}$	1.147***	1.119***	2.085***	1.247***	1.238***	2.138***
	(0.192)	(0.049)	(0.039)	(0.192)	(0.049)	(0.039)
Proportion of directors in environmental committees$_{j,t-1}$	-0.752**	-0.995***	-1.321***	-0.122	-0.263***	-0.600***
	(0.298)	(0.045)	(0.078)	(0.366)	(0.045)	(0.079)
Facility belongs to a listed firm$_{f,t}$	-0.118	-0.179***	-0.445***	0.196	0.172***	-0.117**
	(0.135)	(0.022)	(0.050)	(0.164)	(0.021)	(0.049)
Facility level random effects			Yes			Yes
Observations	288,277	288,277	288,277	288,277	288,277	288,277
R^2	0.162			0.135		
Log likelihood		-617,019	-506,099		-622,434	-508,422
Uncensored observations		152,861	152,861		152,861	152,861

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.5: Regression results for total releases and RRT (ownership information)

This table reports the OLS regression results for facilities belonging to firms for which we have ownership information. The dependent variables are the facility-level log of total toxic chemical releases in a given year (Columns 1 and 2), and the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year (Columns 3 and 4). All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In all Columns, we allow for facility-level fixed effects. In columns 2 and 4, we estimate our model with expected values of the board's past environmental performance variables (using the probability of being a board member in a given firm at a given time obtained from Column 1 of Table 3).

Variable	Log of toxic releases$_{ft}$		$\text{Log}\left(\frac{RRT_{ft}}{total\ toxic\ waste_{ft}}\right)$	
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	3.551***		-1.216***	
	(0.476)		(0.280)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.114		-0.034	
	(0.212)		(0.130)	
E[Board's average pollution ratio]$_{j,t-1}$		2.941***		-1.151***
		(0.638)		(0.386)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		-1.452***		0.377
		(0.495)		(0.233)
Firm's influence$_{j,t-1}$	-26.154***	-10.625***	19.844	14.604
	(3.407)	(3.277)	(13.677)	(12.822)
Log of avg. industrial releases$_{i,t}$	0.997***	1.098***	-0.345***	-0.379***
	(0.171)	(0.198)	(0.101)	(0.111)
Proportion of directors in environmental committees$_{j,t-1}$	-0.584	-0.430	0.566**	0.537**
	(0.461)	(0.457)	(0.260)	(0.258)
Holdings by institutions$_{j,t}$	0.005	0.006	0.001	0.001
	(0.004)	(0.004)	(0.002)	(0.002)
Holdings by strategic entities$_{j,t}$	0.002	-0.000	-0.005	-0.004
	(0.003)	(0.004)	(0.003)	(0.003)
Facility effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Observations	85,772	85,772	85,772	85,772
R^2	0.784	0.776	0.613	0.611

Robust standard errors clustered by firms are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A.6: Regression results for total releases and RRT (Compustat information)

This table reports the OLS regression results for facilities belonging to firms for which we have firm-level data in Compustat. The dependent variables are the facility-level log of total toxic chemical releases in a given year (Columns 1 and 2), and the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year (Columns 3 and 4). All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In all Columns, we allow for facility-level fixed effects. In columns 2 and 4, we estimate our model with expected values of the board's past environmental performance variables (using the probability of being a board member in a given firm at a given time obtained from Column 1 of Table 3).

Variable	Log of toxic releases$_{ft}$		$\text{Log}\left(\frac{RRT_{ft}}{total\ toxic\ waste_{ft}}\right)$	
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	3.286***		-1.155***	
	(0.469)		(0.289)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.077		-0.011	
	(0.206)		(0.131)	
E[Board's average pollution ratio]$_{j,t-1}$		2.370***		-1.126***
		(0.637)		(0.413)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		-1.056**		0.356
		(0.502)		(0.254)
Firm's influence$_{j,t-1}$	-28.319***	-15.447***	20.843	16.492
	(3.274)	(2.880)	(14.031)	(13.391)
Log of avg. industrial releases$_{i,t}$	0.987***	1.094***	-0.316***	-0.354***
	(0.173)	(0.190)	(0.101)	(0.107)
Proportion of directors in environmental committees$_{j,t-1}$	-0.479	-0.453	0.368	0.364
	(0.431)	(0.442)	(0.280)	(0.293)
Log of total assets$_{j,t}$	0.434***	0.744***	-0.155**	-0.260***
	(0.093)	(0.111)	(0.074)	(0.070)
Facility effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Observations	84,548	84,548	84,548	84,548
R^2	0.788	0.782	0.614	0.612

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.7: Regression results for ESG scores

This table reports the OLS regression results for facilities belonging to firms that report ESG scores. The dependent variables are the log of total ESG score (Column 2), and the log of Environment score, Social score, Resource use score and Governance score of the ESG index (Columns 3,4, 5 and 6, respectively). As a reference, Column 1 presents facility-level toxic releases estimated on the exact subsample of firms for which ESG data are available. All regressions include log of avg. industrial releases, log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In all Columns, we control firms' ownership variables and log of total assets, and allow for facility-level fixed effects. Panel A presents the results of the estimation of Equation (2) with actual board's past environmental performance variables, while Panel B shows the results of the estimation of Equation (2) with expected values of the board's past environmental performance variables (using the probability of being a board member in a given firm at a given time obtained from Column 1 of Table 3).

Variable	Log of toxic releases	Log of ESG Score				
		Total	Environmental	Social	Resource use	Governance
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Without expected values						
Board's average pollution ratio$_{j,t-1}$	2.554***	-0.038	-0.077	-0.129	0.035	-0.014
	(0.658)	(0.117)	(0.426)	(0.096)	(0.498)	(0.127)
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.122	-0.007	0.108	-0.011	0.186	-0.105
	(0.281)	(0.049)	(0.164)	(0.053)	(0.220)	(0.086)
Firm's influence$_{j,t-1}$	-23.310***	1.659	38.546*	4.507	11.864	-13.124
	(7.050)	(8.382)	(23.187)	(9.514)	(19.565)	(12.092)
Proportion of directors in environmental committees$_{j,t-1}$	-0.448	-0.075	-0.346	0.060	0.327	-0.072
	(0.555)	(0.204)	(0.673)	(0.207)	(0.748)	(0.285)
Holdings shares	Yes	Yes	Yes	Yes	Yes	Yes
Facility effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,323	51,323	51,323	51,323	51,323	51,323
R^2	0.821	0.762	0.711	0.748	0.718	0.564
Panel B: With expected values						
E[Board's average pollution ratio]$_{j,t-1}$	1.587***	-0.173	-0.403	-0.130	-0.157	-0.070
	(0.608)	(0.238)	(0.975)	(0.134)	(1.043)	(0.207)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$	-0.721	-0.163	-0.768	-0.063	-1.002*	-0.074
	(0.523)	(0.127)	(0.521)	(0.129)	(0.531)	(0.174)
Firm's influence$_{j,t-1}$	-16.739**	1.651	39.278	4.205	13.238	-13.599
	(7.449)	(8.375)	(23.939)	(9.502)	(18.783)	(12.594)
Proportion of directors in environmental committees$_{j,t-1}$	-0.773	-0.043	-0.262	0.091	0.392	-0.032
	(0.579)	(0.192)	(0.630)	(0.196)	(0.724)	(0.285)
Holdings shares	Yes	Yes	Yes	Yes	Yes	Yes
Facility effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	51,323	51,323	51,323	51,323	51,323	51,323
R^2	0.818	0.764	0.714	0.748	0.721	0.563

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Online Appendix

Online Appendix A: Description of the main datasets

Table OA.1: TRI data summary statistics by year

This table shows the number of facilities (and associated firms) reporting their waste management practices to the TRI Program from 2000 to 2017. RRT refers to toxic waste managed through energy recovery, recycling, and treatment.

Year	Unique number of		Toxic releases per facility[a]	RRT per facility[a]
	Facilities	Firms		
2000	23,994	12,586	282.343	1,126.545
2001	25,678	13,183	222.780	838.897
2002	25,037	12,745	194.726	851.353
2003	24,500	12,383	186.458	844.766
2004	24,290	12,104	177.860	880.376
2005	24,123	11,827	184.781	840.414
2006	23,687	11,438	187.750	830.937
2007	23,182	10,881	183.103	847.880
2008	22,616	10,365	175.561	841.865
2009	21,756	9,859	157.602	778.810
2010	21,646	9,842	177.515	813.938
2011	21,758	9,836	190.378	847.769
2012	21,953	9,791	167.431	918.041
2013	22,108	9,800	189.234	930.146
2014	22,147	9,784	180.418	1,085.799
2015	22,067	9,690	156.956	1,080.828
2016	21,747	9,580	161.421	1,110.932
2017	21,297	9,396	186.713	1,283.696

[a] In thousands of pounds.

Table OA.2: Summary statistics by TRI industry sector

This table reports summary statistics about the number of facilities and toxic releases by industrial sectors in the TRI dataset over the period 2000-2017. We use the 30 industrial sectors defined by the TRI program.

Industry Sector	Unique number of Facilities	Toxic releases per facility[a]			
		Mean	SD	Min	Max
Apparel	20	9.689	17.019	0	92.463
Beverages	160	61.915	268.921	0	2,914.838
Chemical Wholesalers	815	3.358	18.361	0	695.850
Chemicals	5,892	144.078	1,023.976	0	35,701.312
Coal Mining	179	197.644	545.715	0	3,880.100
Computers and Electronic Products	2,197	8.029	69.126	0	2,817.507
Electric Utilities	890	1,308.804	2,467.118	0	34,769.833
Electrical Equipment	1,148	14.161	63.524	0	3,082.636
Fabricated Metals	5,515	17.769	69.121	0	2,483.430
Food	2,761	85.394	356.428	0	7,889.364
Furniture	643	34.038	62.139	0	1,132.100
Hazardous Waste	360	880.853	3,718.392	0	65,707.598
Leather	92	45.395	128.347	0	1,898.222
Machinery	2,120	8.058	41.297	0	2,630.909
Metal Mining	128	18,889.789	82,389.215	0	1,105,032.500
Miscellaneous Manufacturing	841	17.119	76.997	0	2,699.973
Nonmetallic Mineral Product	3,844	24.159	164.564	0	5,776.669
Other	1,127	82.270	611.116	0	14,313.505
Paper	757	437.120	868.500	0	8,866.349
Petroleum	1,171	113.717	395.587	0	8,604.379
Petroleum Bulk Terminals	1,026	6.015	52.529	0	4,290.924
Plastics and Rubber	2,646	38.195	161.238	0	5,236.246
Primary Metals	2,644	273.988	1,797.547	0	54,246.440
Printing	378	68.417	345.463	0	15,579.996
Publishing	18	3.131	8.494	0	52.960
Textile Product	115	10.619	25.768	0	324.912
Textiles	328	28.477	89.945	0	1,411.768
Tobacco	55	74.384	184.476	0	1,522.734
Transportation Equipment	2,673	36.824	125.268	0	3,360.853
Wood Products	1,361	21.194	72.660	0	1,801.539

[a] In thousands of pounds.

Table OA.3: BoardEx summary statistics

This table reports summary statistics for the BoardEx dataset. Between 2000 and 2017, there are 157,997 unique firms and 119,607 unique directors recorded in BoardEx North America.

Variable	Mean
Average number of directors per firm	2.518
	(3.012)
Average number of firms per director	2.064
	(1.913)
Director is a CEO	0.113
	(0.316)
Director's average existing period in BoardEx (year)	10.624
	(5.684)
Average term of a director in a firm (year)	5.560
	(4.668)

Standard deviations are in parentheses.

Table OA.4: BoardEx data summary statistics by year

This table reports yearly summary statistics for the BoardEx data from 2000 to 2017.

Year	Number of unique firms	Number of unique directors
2000	46,239	52,367
2001	47,375	55,567
2002	47,894	57,855
2003	48,939	60,594
2004	50,881	63,765
2005	53,005	66,266
2006	54,905	68,805
2007	57,184	70,961
2008	58,180	72,171
2009	59,135	72,740
2010	60,921	73,799
2011	61,992	74,990
2012	63,259	76,454
2013	64,395	78,193
2014	65,146	79,719
2015	65,356	80,759
2016	64,503	80,969
2017	88,851	84,686

Table OA.5: U. S. Census tract summary statistics

This table reports summary statistics for the US Census data set provided by the United States Census Bureau. We also obtain population density information created by the Agency for Toxic Substances and Disease Registry. Given that our data spans two census periods, we use 2010 locations as fixed geographic locations. As in De Silva et al. (2016, 2021), we linearly impute and estimate the missing data to estimate the population density, minority ratio, the proportion of individuals with a college degree, and median household income from 2000 to 2008.

Variable	Mean or count
Number of unique tracts (based on 2010 Census data)	73,082
Total population	4,133.523
	(1,878.227)
Population density (per square mile)	5,165.112
	(11,482.190)
Number of households	1,039.065
	(507.029)
Median household income	64,271.900
	(29,285.710)
College ratio	0.256
	(0.215)
Minority ratio	0.244
	(0.249)
Number of special tracts	961
Number of tracts located in a Mexico border County	1,521
Number of tracts located in a Canada border County	2,933
Number of tracts located in an MSA County	60,909
Number of tracts located in an urban County	10,569
Number of tracts located in a rural County	1,604
Number of tracts located in a coastal County	20,628

Standard deviations are in parentheses.

Online Appendix B: intensity-based measure of director environmental performance

Table OB.1: Bayesian estimates of network formation parameters - Alternate measure of director environmental performance

The table displays the means of the posterior distributions for each network parameter affecting the probability of forming a link between directors and firms at time t. The dependent variable is equal to 1 if a director, in year t, becomes a member of the board. The independent variables used are lagged by one year. The candidate's past pollution ratio is defined as the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution. Column 1 reports the regression results for all firms in our sample, and Column 2 reports the regression results for listed firms only.

Variable	Mean of the posterior distribution	
	All firms	Listed firms
	(1)	(2)
Candidate's past pollution ratio$_{t-1}$	-0.0001	-0.0120
	[-0.0003, 0.0002]	[-0.0125, -0.0115]
Candidate's influence$_{t-1}$	0.1004	0.0919
	[0.0993, 0.1015]	[0.0865, 0.0972]
Candidate's pollution ratio$_{t-1}\times$ influence$_{t-1}$	-0.0582	-0.0573
	[-0.0591, -0.0571]	[-0.0642, -0.0519]
Candidate is a CEO$_{t-1}$	0.0011	0.0017
	[0.0008, 0.0015]	[0.0010, 0.0023]
Candidate's past experience in environmental committees$_{t-1}$	0.0063	0.0103
	[0.0060, 0.0066]	[0.0098, 0.0109]
Firm's influence$_{t-1}$	0.1098	0.3299
	[0.1091, 0.1105]	[0.3260, 0.3330]
Difference in candidate's relative pollution degree centrality and other board members average relative pollution degree centrality$^{a}_{t-1}$	-0.0276	-0.0428
	[-0.0279, -0.0273]	[-0.0435, -0.0420]
Difference in candidate's pollution ratio and firm's pollution ratio $^{a}_{t-1}$	-0.0449	-0.0717
	[-0.0451, -0.0446]	[-0.0724, -0.0711]
Difference in candidate's influence and firm's influence$_{t-1}$	-0.0710	-0.0700
	[-0.0721, -0.0698]	[-0.0729, -0.0667]
Log(Market exposure in years)	0.0019	0.0023
	[0.0017, 0.0020]	[0.0020, 0.0025]
Trend	Yes	Yes
Number of obs	8,487,170	3,173,029
Log marginal likelihood	4,919,220	1,350,930

[a] The homophily measures are given in absolute values. 95% Credible intervals are in parentheses.

Table OB.2: Pollution probabilities - Alternate measure of director environmental performance

This table presents the marginal effects associated with the probit estimation of Equation (2). The main variable of interest is the board's average pollution ratio, where a director pollution ratio is defined as the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. Columns 1 and 2 report the results without facility-level random effects, and Columns 3 and 4 report the results with facility-level random effects. In Columns 2 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	Probability of polluting$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	0.529***		0.285***	
	(0.004)		(0.004)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.156***		-0.028***	
	(0.003)		(0.003)	
E[Board's average pollution ratio]$_{j,t-1}$		0.443***		0.177***
		(0.009)		(0.007)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		-0.288***		-0.108***
		(0.011)		(0.010)
Firm's influence$_{j,t-1}$	0.325	0.576	1.086	1.188
	(1.419)	(1.504)	(1.446)	(1.429)
Log of avg. industrial releases$_{i,t}$	0.113***	0.113***	0.100***	0.092***
	(0.006)	(0.005)	(0.003)	(0.003)
Proportion of directors in environmental committees$_{j,t-1}$	-0.130***	-0.051***	-0.086***	-0.040***
	(0.005)	(0.005)	(0.006)	(0.006)
Facility belongs to a listed firm$_{f,t}$	-0.032***	0.006**	-0.032***	-0.008**
	(0.002)	(0.002)	(0.004)	(0.004)
Located in a special tract	Yes	Yes	Yes	Yes
MSA, Urban, and Coastal County effects	Yes	Yes	Yes	Yes
Located in a county that border Mexico or Canada	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Facility random effects			Yes	Yes
Observations	288,277	288,277	288,277	288,277
Wald χ^2	28,262	17,731	7,896	3,602
Log likelihood	-183,754	-189,883	-115,816	-118,148

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table OB.3: Regression results for total toxic releases - Alternate measure of director environmental performance

This table reports the OLS regression results of Equation (2). The dependent variable is the facility-level log of total toxic chemical releases in a given year. The main variable of interest is the board's average pollution ratio, where a director pollution ratio is defined as the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. Further, in Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	Log of toxic releases$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	1.583***	1.823***		
	(0.151)	(0.136)		
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.055	-0.035		
	(0.082)	(0.076)		
E[Board's average pollution ratio]$_{j,t-1}$			0.485**	0.726***
			(0.210)	(0.171)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			-0.270	-0.395*
			(0.221)	(0.212)
Firm's influence$_{j,t-1}$	29.116	28.195	29.615	28.832
	(34.319)	(35.242)	(34.327)	(35.249)
Log of avg. industrial releases$_{i,t}$	0.677***	1.231***	0.678***	1.249***
	(0.064)	(0.199)	(0.064)	(0.199)
Proportion of directors in environmental committees$_{j,t-1}$	-0.424**	-0.408*	-0.190	-0.152
	(0.214)	(0.220)	(0.186)	(0.187)
Facility belongs to a listed firm$_{f,t}$	-0.271**	-0.265**	-0.139	-0.113
	(0.134)	(0.131)	(0.142)	(0.144)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.363	0.762	0.361	0.759

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table OB.4: Regression results for toxic waste managed through RRT - Alternate measure of director environmental performance

This table reports the OLS regression results of Equation (2). The dependent variable is the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year. The main variable of interest is the board's average pollution ratio, where a director pollution ratio is defined as the share of facilities overseen by a director whose emissions exceed the median of their sector-year distribution. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. In Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	$\text{Log}(\text{RRT}_{ft}/\text{total toxic waste}_{ft})$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	-0.559***	-0.612***		
	(0.076)	(0.077)		
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.019	0.021		
	(0.043)	(0.041)		
E[Board's average pollution ratio]$_{j,t-1}$			-0.237**	-0.303***
			(0.109)	(0.117)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			0.070	0.121
			(0.120)	(0.119)
Firm's influence$_{j,t-1}$	-12.784	-12.083	-12.950	-12.258
	(15.157)	(15.458)	(15.124)	(15.419)
Log of avg. industrial releases$_{i,t}$	-0.157***	-0.610***	-0.157***	-0.615***
	(0.040)	(0.155)	(0.040)	(0.154)
Proportion of directors in environmental committees$_{j,t-1}$	0.098	0.097	0.020	0.016
	(0.107)	(0.108)	(0.100)	(0.099)
Facility belongs to a listed firm$_{f,t}$	0.133*	0.127*	0.086	0.078
	(0.076)	(0.073)	(0.077)	(0.075)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.244	0.611	0.243	0.610

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Online Appendix C: Narrower definition of environmental committees

The results reported in this section use our narrower definition of environmental committees. Committees are classified as "environmental committees" if their titles contain "environment". We then identify directors who serve on such committees and construct a measure of *experience in environmental committees*, defined as the number of environment-related committee positions held by a director in the previous year.

Table OC.1: Bayesian estimates of network formation parameters - Alternate Definition of Environmental Committees

The table displays the means of the posterior distributions for each network parameter affecting the probability of forming a link between directors and firms at time t. The dependent variable is equal to 1 if a director, in year t, becomes a member of the board. The independent variables used are lagged by one year. Column 1 reports the regression results for all firms in our sample, and Column 2 reports the regression results for listed firms only.

Variable	Mean of the posterior distribution	
	All firms	Listed firms
	(1)	(2)
Candidate's past pollution ratio$_{t-1}$	-0.0012	-0.0145
	[-0.0014, -0.0009]	[-0.0149, -0.0140]
Candidate's influence$_{t-1}$	0.1058	0.1110
	[0.1045, 0.1071]	[0.1066, 0.1149]
Candidate's pollution ratio$_{t-1}\times$ influence$_{t-1}$	-0.0592	-0.0808
	[-0.0619, -0.0569]	[-0.0857, -0.0763]
Candidate is a CEO$_{t-1}$	0.0011	0.0016
	[0.0008, 0.0014]	[0.0010, 0.0023]
Candidate's past experience in environmental committees$_{t-1}$	0.0061	0.0075
	[0.0057, 0.0065]	[0.0068, 0.0082]
Firm's influence$_{t-1}$	0.1139	0.3758
	[0.1130, 0.1149]	[0.3720, 0.3794]
Difference in candidate's relative pollution degree centrality and other board members average relative pollution degree centrality[a]$_{t-1}$	-0.0275	-0.0436
	[-0.0277, -0.0272]	[-0.0443, -0.0429]
Difference in candidate's pollution ratio and firm's pollution ratio [a]$_{t-1}$	-0.0451	-0.0723
	[-0.0453, -0.0448]	[-0.0729, -0.0717]
Difference in candidate's influence and firm's influence$_{t-1}$	-0.0710	-0.0716
	[-0.0719, -0.0699]	[-0.0795, -0.0638]
Log(Market exposure in years)	0.0021	0.0029
	[0.0020, 0.0022]	[0.0027, 0.0032]
Trend	Yes	Yes
Number of obs	8,487,170	3,173,029
Log marginal likelihood	4,918,776	1,350,941

[a] The homophily measures are given in absolute values. 95% Credible intervals are in parentheses.

Table OC.2: Pollution probabilities - Alternate Definition of Environmental Committees

This table presents the marginal effects associated with the probit estimation of Equation (2). All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. Columns 1 and 2 report the results without facility-level random effects, and Columns 3 and 4 report the results with facility-level random effects. In Columns 2 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	Probability of polluting$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	0.484***		0.281***	
	(0.004)		(0.004)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.166***		-0.037***	
	(0.003)		(0.003)	
E[Board's average pollution ratio]$_{j,t-1}$		0.396***		0.174***
		(0.008)		(0.007)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		-0.304***		-0.127***
		(0.011)		(0.010)
Firm's influence$_{j,t-1}$	-0.384	0.455	0.448	1.153
	(1.456)	(1.505)	(1.476)	(1.432)
Log of avg. industrial releases$_{i,t}$	0.102***	0.111***	0.091***	0.091***
	(0.006)	(0.005)	(0.003)	(0.003)
Proportion of directors in environmental committees$_{j,t-1}$	-0.131***	-0.044***	-0.057***	0.009
	(0.006)	(0.007)	(0.008)	(0.008)
Facility belongs to a listed firm$_{f,t}$	-0.032***	0.005**	-0.031***	-0.008**
	(0.002)	(0.002)	(0.004)	(0.004)
Located in a special tract	Yes	Yes	Yes	Yes
MSA, Urban, and Coastal County effects	Yes	Yes	Yes	Yes
Located in a county that border Mexico or Canada	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Facility random effects			Yes	Yes
Observations	288,277	288,277	288,277	288,277
Wald χ^2	27,717	17,475	8,566	3,647
Log likelihood	-184,190	-190,032	-115,427	-118,122

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table OC.3: Regression results for total toxic releases - Alternate Definition of Environmental Committees

This table reports the OLS regression results of Equation (2). The dependent variable is the facility-level log of total toxic chemical releases in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. Further, in Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	Log of toxic releases$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	1.487***	1.693***		
	(0.137)	(0.124)		
Range of the board's relative pollution	-0.070	-0.048		
degree centrality$_{j,t-1}$	(0.082)	(0.076)		
E[Board's average pollution ratio]$_{j,t-1}$			0.436**	0.638***
			(0.187)	(0.149)
E[Range of the board's relative pollution			-0.302	-0.422**
degree centrality]$_{j,t-1}$			(0.221)	(0.212)
Firm's influence$_{j,t-1}$	25.914	24.537	29.579	28.725
	(32.857)	(33.611)	(34.163)	(35.092)
Log of avg. industrial releases$_{i,t}$	0.676***	1.191***	0.678***	1.244***
	(0.064)	(0.199)	(0.064)	(0.199)
Proportion of directors in environmental	-0.325	-0.285	0.029	0.103
committees$_{j,t-1}$	(0.259)	(0.245)	(0.271)	(0.258)
Facility belongs to a listed firm$_{f,t}$	-0.250*	-0.242*	-0.139	-0.114
	(0.132)	(0.130)	(0.139)	(0.142)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.363	0.762	0.361	0.759

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table OC.4: Regression results for toxic waste managed through RRT - Alternate Definition of Environmental Committees

This table reports the OLS regression results of Equation (2). The dependent variable is the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. In Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time to compute expected values of the board's past environmental performance.

Variable	Log(RRT_{ft}/total toxic waste_{ft})			
	(1)	(2)	(3)	(4)
Board's average pollution $\text{ratio}_{j,t-1}$	-0.542***	-0.579***		
	(0.070)	(0.072)		
Range of the board's relative pollution degree $\text{centrality}_{j,t-1}$	0.027	0.028		
	(0.042)	(0.041)		
E[Board's average pollution $\text{ratio}]_{j,t-1}$			-0.228**	-0.275***
			(0.099)	(0.106)
E[Range of the board's relative pollution degree $\text{centrality}]_{j,t-1}$			0.075	0.121
			(0.123)	(0.121)
Firm's $\text{influence}_{j,t-1}$	-11.646	-10.867	-12.957	-12.248
	(14.791)	(15.067)	(15.135)	(15.427)
Log of avg. industrial $\text{releases}_{i,t}$	-0.157***	-0.597***	-0.157***	-0.614***
	(0.040)	(0.155)	(0.040)	(0.154)
Proportion of directors in environmental $\text{committees}_{j,t-1}$	0.201	0.187	0.081	0.062
	(0.166)	(0.154)	(0.167)	(0.154)
Facility belongs to a listed $\text{firm}_{f,t}$	0.124	0.118	0.084	0.076
	(0.076)	(0.073)	(0.077)	(0.075)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	288,277	288,277	288,277	288,277
R^2	0.244	0.611	0.243	0.610

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Online Appendix D: regression results for all facilities

We report the estimation results of equation (2) for our main dependent variables using all the facilities reporting to the TRI Program. Our objective is to control that the effect of a board's average pollution ratio on the firm's environmental performance is not entirely driven by the fact that TRI-reporting firms in BoardEx are different from TRI-reporting firms without board information. We define a BoardEx dummy, which is equal to 1 if the facility belongs to a firm present in the BoardEx data (i.e., a firm with a board of directors).

Table OD.1: Pollution probabilities - All facilities

This table presents the marginal effects associated with the probit estimation of Equation (2) for all TRI facilities. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. Columns 1 and 2 report the results without facility-level random effects, and Columns 3 and 4 report the results with facility-level random effects. In Columns 2 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Probability of polluting$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	0.488***		0.286***	
	(0.004)		(0.004)	
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.190***		-0.048***	
	(0.003)		(0.003)	
E[Board's average pollution ratio]$_{j,t-1}$		0.301***		0.141***
		(0.005)		(0.005)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$		0.072***		0.116***
		(0.013)		(0.011)
Firm's influence$_{j,t-1}$	0.890	1.769	0.542	1.201
	(1.479)	(1.491)	(1.527)	(1.487)
Log of avg. industrial releases$_{i,t}$	0.090***	0.095***	0.095***	0.096***
	(0.004)	(0.004)	(0.002)	(0.002)
Facility belongs to a BoardEx firm$_{i,t}$	-0.111***	-0.067***	-0.099***	-0.066***
	(0.002)	(0.002)	(0.005)	(0.005)
Proportion of directors in environmental committees$_{j,t-1}$	-0.135***	-0.079***	-0.101***	-0.058***
	(0.005)	(0.005)	(0.006)	(0.006)
Facility belongs to a listed firm$_{f,t}$	-0.035***	-0.011***	-0.033***	-0.010***
	(0.002)	(0.002)	(0.004)	(0.004)
Located in a special tract	Yes	Yes	Yes	Yes
MSA, Urban, and Coastal County effects	Yes	Yes	Yes	Yes
Located in a county that border Mexico or Canada	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Facility random effects			Yes	Yes
Observations	582,722	582,722	582,722	582,722
Wald χ^2	36,139	25,133	11,808	6,971
Log likelihood	-383,393	-389,569	-247,325	-249,980

Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table OD.2: Regression results for total toxic releases - All facilities

This table reports the OLS regression results of Equation (2) for all TRI facilities. The dependent variable is the facility-level log of total toxic chemical releases in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. Further, in Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Log of toxic releases$_{ft}$			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	1.315***	1.537***		
	(0.141)	(0.125)		
Range of the board's relative pollution degree centrality$_{j,t-1}$	-0.156*	-0.124		
	(0.086)	(0.081)		
E[Board's average pollution ratio]$_{j,t-1}$			0.303	0.520***
			(0.186)	(0.151)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			-0.309	-0.415*
			(0.230)	(0.225)
Firm's influence$_{j,t-1}$	25.705	24.302	28.874	28.121
	(33.077)	(33.423)	(34.078)	(34.595)
Log of avg. industrial releases$_{i,t}$	0.653***	1.109***	0.655***	1.137***
	(0.056)	(0.119)	(0.056)	(0.120)
Proportion of directors in environmental committees$_{j,t-1}$	-0.460**	-0.432**	-0.214	-0.161
	(0.217)	(0.219)	(0.193)	(0.190)
Facility belongs to a listed firm$_{f,t}$	-0.221*	-0.205	-0.121	-0.083
	(0.128)	(0.127)	(0.135)	(0.138)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	582,722	582,722	582,722	582,722
R^2	0.463	0.726	0.462	0.724

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table OD.3: Regression results for toxic waste managed through RRT - All facilities

This table reports the OLS regression results of Equation (2) for all TRI facilities. The dependent variable is the log difference between the production-related waste recovered, recycled, and treated (RRT), and the total production-related waste managed by a facility in a given year. All regressions include log number of plants per firm, log of median household income, minority ratio, college ratio, and log of population density. In Columns 1 and 3, we include firm-level fixed effects; while, in Columns 2 and 4, we allow for facility-level fixed effects. In Columns 3 and 4, we weigh each director's environmental performance (pollution ratio and relative pollution degree centrality) by their calculated probability of being a board member in a given firm at a given time (from Column 1 of Table 3) to compute expected values of the board's past environmental performance.

Variable	Log(RRT$_{ft}$/total toxic waste$_{ft}$)			
	(1)	(2)	(3)	(4)
Board's average pollution ratio$_{j,t-1}$	-0.445***	-0.490***		
	(0.070)	(0.070)		
Range of the board's relative pollution degree centrality$_{j,t-1}$	0.066	0.062		
	(0.044)	(0.042)		
E[Board's average pollution ratio]$_{j,t-1}$			-0.144	-0.196*
			(0.096)	(0.102)
E[Range of the board's relative pollution degree centrality]$_{j,t-1}$			0.090	0.129
			(0.126)	(0.124)
Firm's influence$_{j,t-1}$	-11.410	-10.718	-12.427	-11.852
	(14.794)	(14.921)	(15.031)	(15.177)
Log of avg. industrial releases$_{i,t}$	-0.153***	-0.559***	-0.154***	-0.568***
	(0.035)	(0.092)	(0.035)	(0.092)
Proportion of directors in environmental committees$_{j,t-1}$	0.107	0.101	0.028	0.017
	(0.110)	(0.110)	(0.104)	(0.102)
Facility belongs to a listed firm$_{f,t}$	0.084	0.077	0.052	0.041
	(0.069)	(0.068)	(0.069)	(0.069)
Firm effects	Yes		Yes	
Facility effects		Yes		Yes
Located in a special tract	Yes		Yes	
MSA, Urban, and Coastal County effects	Yes		Yes	
Located in a county that border Mexico or Canada	Yes		Yes	
Time effects	Yes	Yes	Yes	Yes
Observations	582,722	582,722	582,722	582,722
R^2	0.404	0.615	0.404	0.614

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Online Appendix E: Effect of Appointing a Clean Director

We examine the evolution of a firm's environmental performance around the appointment of a new director (an event study-type analysis). In this exercise, we consider the appointment of a new director as an event and denote the appointment's year as year zero. In our sample, we include only newly appointed directors who served on the board of their new firm for at least one year after the appointment. This corresponds to 10,716 directors matched with 2,085 firms (corresponding to 16,925 facilities). For each of the 143,672 unique director-facility pairs identified, we create a panel with two years prior to the event and, at most, four years after the event. This generates a panel of 848,475 observations. As an alternative specification, we consider only director-facility pairs for which the newly appointed director serves on the board for at least two years. This method identifies 127,428 unique director-facility pairs, generating a panel of 799,743 observations. The difference in the number of observations between the two specifications is explained by the turnover of board members: 15% of newly appointed directors leave their firm after just one year, and only 51% of new directors serve on the board for more than 5 years. Using this data, we estimate the following panel regression model:

$$\begin{aligned} y_{f,d,j,i,l,t} =& \kappa \, Clean_{f,d,j,i,l,t} + E'_{f,d,j,i,l,t}\lambda + (Clean_{f,d,j,i,l,t} \times E_{f,d,j,i,l,t})'\theta \\ & + C'_{j,t-1}\gamma + F'_{f,t-1}\delta + \eta M_{i,t} + L'_{l,t}\phi + \alpha_j + \tau_t + \epsilon_{f,j,i,l,t} \end{aligned} \tag{3}$$

where y is our dependent variable and represents the log of toxic waste released or the log difference in the total production-related waste managed through RRT, and the total production-related waste from a facility f in year t. *Clean* is a dummy variable that is equal to 1 if the newly appointed director has a past pollution ratio below 25%. A director is, therefore, considered as a clean director if less than 25% of the facilities he oversees are polluting facilities. E is a vector of dummy variables for every year after the appointment. C, F, M, and L represent the control variables at the firm-, facility-, industry-, and location-level. τ_t are time fixed-effects. By including firm-fixed effects (α_j), we control for unobservable firm heterogeneity and examine differences in pollution measures after the appointment of a clean director, taking out the mean effect.

We are primarily interested in the values of the coefficients κ and θ, which measure the effect on releases and RRT one year after the appointment and in the longer term (up to four years after appointment). Compared to the baseline results, this analysis allows us to distinguish the changes in environmental performance associated with a new appointment from the changes associated with variations in pollution measures of "continuing directors".

The results in Table OE.1 indicate that a newly appointed clean director has a significant and immediate (one year after appointment) negative effect on total releases. The effect persists after one year, but its magnitude decreases over time. We observe the same pattern for toxic waste managed through RRT. Looking at Column 1, appointing a new director leads to an average increase in total releases of 9% after one year. However, if the appointed director is a clean director, then the facility total releases will be 58% lower than for a facility appointing a director with a poor environmental record. Column 3 suggests that appointing a new clean director increases the proportion of waste managed through RRT by 17% after one year, compared to a dirty director. We also estimate this model when a director is considered as clean when her/his past pollution ratio is less than 50%. The results (available upon request) are qualitatively the same, even though the magnitude of the coefficients is slightly lower.[22]

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[22] For example, the coefficient of the interaction term for one year after appointment drops from 58% (in column 1 of Table OE.1) to 46%.

Table OE.1: Effect of a clean director

This table reports the OLS regression results for the event study analysis of the effect of a director appointment on facility-level pollution outcomes. In Columns 1 and 3, we consider new directors who served on the board of their new firm for at least one year after the appointment. In Columns 2 and 4, we consider new directors who served on the board of their new firm for at least two years after the appointment. In Columns 1-2, the dependent variable is the log of total toxic material released by a facility in a given year. In Columns 3-4, the dependent variable is the log difference in the total toxic material recovered, recycled, and treated (RRT), and the total production-related toxic material managed by a facility in a given year. All models include firm and time-fixed effects, log number of plants per firm, log of median household income, minority ratio, college ratio, log of population density, and indicator for facilities siting in a special tract.

Variable	Log of toxic releases$_{ft}$		Log $\left(\text{RRT}_{ft}/\text{total toxic waste}_{ft}\right)$	
	Minimum years after appointment		Minimum years after appointment	
	One	Two	One	Two
	(1)	(2)	(3)	(4)
Director's pollution ratio$_{d,t-1}$$\leq$ 0.25	-0.023***	-0.024***	0.013***	0.012***
	(0.007)	(0.008)	(0.004)	(0.005)
One year after$_{d,j,t}$	0.090***	0.085***	-0.028***	-0.027**
	(0.022)	(0.025)	(0.010)	(0.011)
One year after$_{d,j,t}$$\times$ director's pollution ratio$_{d,t-1}$$\leq$ 0.25	-0.577***	-0.549***	0.171***	0.162***
	(0.114)	(0.109)	(0.035)	(0.038)
Two years after$_{d,j,t}$	0.037***	0.035**	-0.008	-0.008
	(0.013)	(0.014)	(0.008)	(0.009)
Two years after$_{d,j,t}$$\times$ director's pollution ratio$_{d,t-1}$$\leq$ 0.25	-0.255***	-0.244***	0.069***	0.065***
	(0.059)	(0.059)	(0.021)	(0.022)
Three years after$_{d,j,t}$	0.017	0.015	0.001	0.001
	(0.010)	(0.011)	(0.006)	(0.006)
Three years after$_{d,j,t}$$\times$ director's pollution ratio$_{d,t-1}$$\leq$ 0.25	-0.165***	-0.157***	0.045***	0.042**
	(0.045)	(0.044)	(0.016)	(0.017)
Four years after$_{d,j,t}$	0.015**	0.014	-0.003	-0.003
	(0.008)	(0.009)	(0.004)	(0.004)
Four years after$_{d,j,t}$$\times$ director's pollution ratio$_{d,t-1}$$\leq$ 0.25	-0.115***	-0.110***	0.026**	0.024**
	(0.030)	(0.030)	(0.011)	(0.011)
Firm's influence$_{j,t-1}$	22.495	23.581	-27.968	-28.174
	(27.092)	(27.156)	(27.560)	(27.938)
Log of total industrial toxic releases$_{j,t}$	0.571***	0.570***	-0.057*	-0.057*
	(0.056)	(0.057)	(0.030)	(0.020)
Director is a CEO$_{d,t-1}$	-0.029	-0.024	0.004	0.004
	(0.032)	(0.031)	(0.015)	(0.015)
Proportion of directors in environmental committees$_{j,t-1}$	0.191	0.185	-0.135	-0.170
	(0.516)	(0.534)	(0.215)	(0.225)
Facility belongs to a listed firm$_{f,t}$	-0.005	0.008	-0.002	0.006
	(0.162)	(0.162)	(0.080)	(0.079)
Firm effects	Yes	Yes	Yes	Yes
Located in a special tract	Yes	Yes	Yes	Yes
MSA, Urban, and Costal County effects	Yes	Yes	Yes	Yes
Located in a county that border Mexico or Canada	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Observations	848,475	799,743	848,475	799,743
R^2	0.334	0.333	0.213	0.211

Robust standard errors clustered by firms are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$