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Board Centrality and Environmental Disclosures: Evidence from the Polluting Industries in China

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Abstract

We examine the association between board centrality and corporate environmental disclosure using hand-collected data from Chinese-listed firms in heavily polluting industries. We find that board centrality has a positive effect on corporate environmental disclosure. We also show that this positive effect emanates from the critical role of the board in monitoring and resource distribution, and its incentive to promote information transparency. Our results, which are robust to a set of robustness checks, have important implications for both regulators and investors.

Keywords: Board centrality; environmental disclosures; heavily polluting industries; China; Emerging markets.

1. Introduction

In recent years, issues related to climate change have consistently hit headlines in both traditional and social media. In a recent survey-based study conducted by Ilhan *et al.* (2023) among global institutional investors, the authors revealed that the existing environmental disclosures provided by companies are inadequate in terms of providing comprehensive information, partially because of the absence of mandatory regulations regarding environmental disclosure. Prior research is, however, inconclusive on the determinants of the environmental disclosure (Boiral and Gendron, 2011; Elliott *et al.*, 2017). To help tackle this issue, we examine the relationship between board centrality¹ and environmental disclosure in China, one of the world's largest emerging economies. Board centrality reflects the board members' importance, prestige and access to resources to fulfil their responsibilities in corporate governance (Freeman, 1978; Schabus, 2022).

We are interested in the environmental disclosure of Chinese enterprises operating in heavily polluting industries, given the critical state of environmental deterioration in China. This deterioration is seen as one of the consequences of China's remarkable economic growth over the past four decades (Chang, Li and Lu, 2015). The Chinese government has addressed environmental concerns and issued several laws and regulations to protect the environment.² One of the aspects introduced by Chinese regulator is a set of guidelines of environmental disclosures targeting domestic enterprises. However, though environmental reports are legally mandated for Chinese listed companies, the descriptions and/or format

¹ Throughout this paper, we use the terms "centrality", "connectedness" and "networks", interchangeably.

² For instance, China's Environmental Protection Law was drafted in 1979 and officially implemented in 1989. A new version of the Environmental Protection Law was enacted in 2014.

of these reports are not standardized, so the environmental disclosure can be influenced by the composition of the boards of directors (Jizi, 2017; Nguyen *et al.*, 2021). Given the influence of the board of directors on a firm's environmental strategy, it is crucial to examine how board centrality, a key aspect of the board, can impact environmental disclosure practices. Our research question is particularly relevant in an emerging market such as China where network effects tend to be more prominent given the weak formal legal system and inefficiency of the market (Tao *et al.*, 2019).

The boardroom functions as a formal avenue for directors to foster connections and exchange ideas. This exchange of ideas takes place not only within individual organizations but also extends across multiple firms when directors serve on various boards. Moreover, directors who belong to well-connected boards play a pivotal role in facilitating the dissemination of information within the network. Consequently, they are more inclined to stay well-informed about trends, best practices, and current challenges, and gain swift access to novel information. Previous research indicated that networks of directors facilitate the flow of information, resulting in various advantages for firms that have highly connected directors. These benefits include increased firm value (Larcker *et al.*, 2013; Omer *et al.*, 2014; Bakke *et al.*, 2024), improved post-merger performance (Schonlau and Singh, 2009), enhanced financial reporting quality (Omer *et al.*, 2024), better ethical and environmental behavior (Homroy and Slechten, 2017), and higher CSR performance (Amin *et al.*, 2020).

Board connectedness can also negatively influence a firm's behavior. As pointed out by Larcker *et al.* (2013), the network can serve as a pathway for the transmission of both

beneficial and detrimental business practices. Directors with multiple board memberships may have insufficient time and attention to play their key monitoring role (Fich and Shivdasani, 2006). In addition, several studies have associated the presence of more connected board members with value-destroying management practices or dissemination of misleading information (e.g., Bizjak *et al.*, 2009; Snyder *et al.*, 2009; Chiu *et al.*, 2013). In the Chinese context, Tao *et al.* (2019) find that board centrality is associated with value-destroying mergers and acquisitions. Considering the potential advantages and disadvantages of board connectedness, it is not clear how board centrality influences a firm's environmental information disclosure practices.

To examine the nature of the relationship between board centrality and corporate environmental disclosure, we hand-collect data on environmental disclosure from Chinese listed companies' annual reports, environmental reports, and other disclosures. Our final sample comprises 5,324 observations for 1100 Chinese firms operating in heavily polluting industries over the period 2012-2020.³ Consistent with Clarkson *et al.* (2008), we compute the corporate environmental disclosure score, and we follow Larcker *et al.* (2013) to calculate board centrality. Our results suggest that environmental information disclosure is positively affected by board centrality. We also find that the effect emanates from their critical role in monitoring and resource distribution, and their incentive to promote information transparency. Our results remain consistent even after implementing both two-stage least

³ We have identified steel, mining, chemical and other 16 heavily polluting industries based on the "Guidelines for Environmental Information Disclosure of Listed Firms" (2010) and the "List of Industry Classification Management of Listed Firms for Environmental Protection Verification" (Document No. 373 in 2008) issued by the Chinese government, as well as the industry classification standards of the Chinese Securities Regulatory Commission.

squares (2SLS) and difference-in-differences approaches to mitigate the endogeneity concerns.

Our contribution to the literature is multifaceted. First, our research complements prior research on the cross-sectional variation of environmental disclosure. In previous literature, the role of media coverage (Rupley *et al.*, 2012; El Ghouli *et al.*, 2019) and government regulation (Reid and Toffel, 2009), sustainability committee (Driss *et al.*, 2024), and board ancestral diversity (Barg *et al.*, 2023) have been examined as a factor influencing environmental disclosure. Our research seeks to extend the extant literature by investigating the role of board centrality in environmental disclosure.

Second, we extend the strand of research on board connections' consequences. Previous literature has studied the influence of board connections on, among others, the accuracy of the management forecast (Ke *et al.*, 2020), new product development (Mazzola *et al.*, 2016), and cost of debt (Chakravarty and Rutherford, 2017). Furthermore, the majority of extant studies of board connections focus on specific connected companies, so it is limited to the local effects of the information transmission (Omer *et al.*, 2020). In contrast, our research scrutinizes the director network from a broader perspective to understand the global effect of connectedness on non-financial information disclosure.

The remainder of the paper is structured as follows. Section 2 introduces the regulation of environmental disclosure in China and provides a review of the relevant literature. Section 3 presents our hypothesis. Section 4 outlines our research design. In section 5, we present the empirical results, channel analysis and robustness tests. Section 6

concludes the paper.

2. Literature Review

2.1. Corporate Social Responsibility and Environmental Disclosures

According to Carroll (1979), corporate social performance comprises three elements: 1) identifying corporate social responsibility; 2) what are the social issues (environment, consumerism, product safety, Occupational safety, discrimination, etc.) for which we have a responsibility? 3) specification of the philosophy of response. It is of high importance to identify different social responsibilities, because they may be evaluated in different manners by different groups of stakeholders, and may trigger different management actions (Chen *et al.*, 2008).

There are multiple dimensions of corporate social responsibility, each of which is inherently incompatible with the others (Chen *et al.*, 2008; Du *et al.*, 2016; Roeck *et al.*, 2016). The means by which companies can strengthen their competitiveness through proactive environmental strategies are not without contention, and the view that “it costs to be green” seems convincing (Clarkson *et al.*, 2011). Prior research documents that for pollution prevention and control technologies, more investments are needed for the update of related infrastructure and operational systems (Tang *et al.*, 2012). Meanwhile, shareholders might have a keen interest in the company’s financial performance (Walker *et al.*, 2019; Temouri *et al.*, 2022). To meet shareholders’ expectations of financial returns, managers may choose to reduce investments in pollution prevention or control technologies. At the same time, other stakeholder groups, especially residents located near the company, may not think that

reducing environmental expenditure is an ethical management practice. Consumers, investors, and other stakeholders can also be misled when companies manipulate their environmental performance (Du *et al.*, 2016). Taking the conflicts between the environment and other corporate social responsibility issues into consideration, environmental disclosure may vary substantially across firms and from time to time (Patten, 2002). In this paper, we concentrate on one specific dimension of corporate social responsibility, namely the disclosure of firms' environmental information.

2.2. Corporate Environmental Disclosure

Corporate environmental disclosure refers to the process by which companies communicate their environmental performance, impact, risk and initiatives to various stakeholders (Muniandy *et al.*, 2023). The Chinese government has successfully promoted corporate environmental information disclosure in China through several environmental information disclosure policies.

The first regulation on corporate environmental information disclosure, "Announcement on the Disclosure of Environmental Information by Enterprises" was issued in 2003 by the State Environmental Protection Administration. It requires the regular publication of a list of seriously polluting enterprises that emit pollutants more than the standard or exceed the limits set for the total amount of pollutants discharged. The Measures on Disclosure of Environmental Information, implemented in 2008, encourage enterprises to voluntarily disclose relevant corporate environmental information. Enterprises whose pollutant emissions exceed national or local emission standards, or whose

total pollutant emissions exceed the total amount approved by local governments, are required the mandatory disclosure of environmental information. In 2010, the Ministry of Environmental Protection issued the Guidelines for Disclosure of Environmental Information by Listed Companies, which mandates that listed companies in 16 categories of heavily polluting industries (such as thermal power, iron and steel, and cement) issue annual environmental reports and regularly disclose environmental information on pollutant emissions, environmental compliance, and environmental management in a timely and accurate way. The revised Environmental Protection Law, which came into effect on 1 January 2015, explicitly requires that key emission firms truthfully disclose to the community the names of their major pollutants, the method of emission, the concentration and total amount of emission, the exceedance of emission standards, and the construction and operation of pollution prevention and control facilities. From a legal perspective the new environmental protection law clarifies for the first time the responsibility of heavy polluters to disclose detailed environmental information.

To summarize, environmental disclosure is a developing trend driven by government policies, environmental challenges, and stakeholder expectations in China. As the Chinese business sector evolves, environmental disclosure will continue to play a key role in establishing a more sustainable and responsible corporate landscape.

A growing body of studies attempts to identify factors associated with the cross-sectional variation in the corporate environmental disclosure (Boiral and Gendron, 2011; Elliott *et al.*, 2017). For instance, environmental information disclosure has been associated with environmental media coverage (Rupley *et al.*, 2012). Managerial decisions regarding

environmental issues are only influenced by institutional investors in the face of negative environmental media (Rupley *et al.*, 2012). Shareholder resolutions filed against firms in their industry and threats posed by state regulations can increase the likelihood that a firm will engage in environmental practices (Reid and Toffel, 2009). In general, management tends to favor accounting narratives, such as environmental disclosures, over financial or other quantitative information. This preference primarily stems from the fact that narrative disclosures can be intentionally adjusted to shape public perceptions, serving as a tool for information management to enhance the company's legitimacy and establish a positive corporate image (Cho *et al.*, 2010; Merkl-Davies *et al.*, 2011; Brennan and Merkl-Davies, 2014).

Prior research suggests that profitability is positively associated with environmental management practices (Klassen and McLaughlin, 1996). Companies can obtain sustainable competitive advantages by taking steps to reduce the negative environmental impact of their operations (Clarkson *et al.*, 2011). Some people think that pollution is wasteful, which indicates a low efficiency in product design, input selection and fabrication process (Nehrt, 1996; Clarkson *et al.*, 2011). Therefore, firm performance can be improved by an active environmental management strategy through technological innovation and product differentiation (Hart, 1995; Clarkson *et al.*, 2011). Klassen and McLaughlin (1996) show that environmental management initiative reflected by awards to environmental performance has a positive effect on firm financial performance, and that weak environmental management suggested by environmental crises has a negative effect.

2.3. Directors' Network

There are two fundamental functions of directors: monitoring managers as representatives of shareholders and supporting strategic decision-making (Hillman and Dalziel, 2003; Zhu *et al.*, 2016; Usman *et al.*, 2022). Boards are official channels for firms' directors to obtain social resources and exchange ideas (Omer *et al.*, 2020). When a director holds several positions, new ideas will spread between companies. In addition, well-connected directors who serve in the overall information flow center of the board connections have a better understanding of current and potential market challenges, trends, and best practices (Omer *et al.*, 2020).

A large volume of research has reported that the board connection is the channel through which knowledge, ideas and market information are exchanged (Jing and Zhang, 2021). The trading of the shares of a company where one of the board members is a director, for example, can lead to substantial abnormal returns for other directors (Berkman *et al.*, 2020; Schabus, 2022). Information is spread in the network of directors, making companies with directors who have well-connected networks enjoy higher abnormal returns (Larcker *et al.*, 2013). Therefore, it is crucial for directors to obtain external information to fulfill their responsibility of supervising corporate information disclosure, because better access to information can give directors a comparative advantage in making decisions (Larcker *et al.*, 2013; Omer *et al.*, 2020).

Because of the complexity of information provided by managers to the board of directors, directors need to access external information about trends in the market, industry developments and other important information. Directors positioned at the core of their

networks are believed to have acquired greater information, as evidenced by the significantly higher abnormal returns observed when they engage in stock purchases. This suggests that the interconnections among directors have generated an informational edge, amplifying the market's reaction to their transactions (Goergen *et al.*, 2019).

3. Hypothesis Development

We discuss the important impact of board centrality on environmental disclosure from the perspective of the stakeholder theory (Rowley, 1997; Bouguerra *et al.*, 2023). Stakeholders have the right to obtain benefits and information, although priorities are self-evident, and interests may be incompatible or even conflicting between stakeholders (Collier, 2008; Laplume *et al.*, 2022). Stakeholder theory emphasizes the intensity of stakeholders' incompatible goals and preferences (Macve and Chen, 2010), thereby providing a potential explanation for the heterogeneity of corporate environmental information disclosures.

The environmental costs have increased substantially in recent years as companies are under increasing pressure to incorporate environmental issues into their business strategy (Christmann, 2000). Generally speaking, environmental decision-making is rarely supported by cost management information systems, but as a response to environmental regulations (Clarkson *et al.*, 2011). Recent studies on environmental management suggest that, by reducing their negative effect on our environment, companies can obtain sustainable competitive advantages (Clarkson *et al.*, 2011). Strategic decisions made by companies could impact their future development in a variety of ways, so that multiple interest groups may be affected differently, ultimately leading to strong support from some stakeholders or

strong opposition from other stakeholders (Liao *et al.*, 2015). In this context, stakeholder theory appears particularly relevant. It is important to disclose the company's environmental strategy and its results, and the company's environmental disclosure must clearly illustrate how the environmental actions can create value for the company and benefit its stakeholders. This suggests that stakeholders require information on the environmental actions to evaluate the company's operation (Gray *et al.*, 1995; Liao *et al.*, 2015).

Firms' environmental strategies and actions often involve large amounts of investment with different effects on various stakeholders. For instance, some stakeholders may be concerned with financial performance, but others may focus on the potential adverse impact of company operations on the environment, so stakeholders may have to balance their conflicting demands (Liao *et al.*, 2015). Consequently, a board should properly address issues raised by different stakeholders (Liao *et al.*, 2015).

Prior research documents numerous benefits of directors' networks. For example, well-connected directors have a positive impact on innovation activities and quality, which will be stronger when enterprises face more serious agency problems (Chang and Wu, 2020). Companies with better-networked directors with previous experience in environmental issues can produce better environmental results (Homroy and Slechten, 2017). Ke *et al.* (2020) report a higher accuracy of management forecasting in the firm with directors who also serve as executives or directors in the firms' related industries.

Due to the influence of external network connections on a board's involvement in the

strategic decision-making process (Carpenter and Westphal, 2001), we expect board connection to have a positive impact on the level of corporate environmental disclosure. Well-connected board members might anticipate industry trends, market conditions, and regulatory changes better (Mizruchi, 1996; Mol, 2001), can offer the company valuable business and political contacts (Mol, 2001; Nicholson et al., 2004), and help lessen the information gap between the company and the external market (Schoorman *et al.*, 1981), making it easier for firms to exchange information on innovations and practices that create value (Haunschild and Beckman, 1998). Additionally, well-connected directors may play a crucial role in improving the firm's ability and effectiveness in enhancing the quality of environmental disclosure in response to stakeholder demands (Rowley, 1997; Harjoto and Wang, 2020). Accordingly, we propose the following testable hypothesis:

Hypothesis 1. Board centrality has a positive impact on the level of corporate environmental disclosure.

We follow prior literature (e.g., Amin *et al.*, 2020) and proxy for board connectedness using the average of four board centrality measures used in social network theory to describe each director's relative importance or access to information in the network: (1) *Degree Centrality*, (2) *Closeness*, (3) *Betweenness Centrality*, and (4) *Structural Holes*.⁴ We expect each of the four measure to have a positive effect on corporate environmental disclosure. First, the information a director is able to access is likely an increasing function of the number of direct contacts a director has (captured by *degree centrality*), and the director may

⁴ Detailed descriptions of each of the four centrality measures are provided in Appendix C.

utilise the information to enhance the environmental disclosure of the firm, which suggests a positive impact of degree centrality on the level of corporate environmental disclosure. Second, if a director holds close relationship with others in the director's network (measured by *closeness centrality*), useful information such as industry best practice and potential regulatory changes is more likely to be shared, which can be used to improve environmental disclosure of the firm. This suggests a positive influence of closeness centrality on the level of corporate environmental disclosure. Third, *betweenness centrality* represents the extent to which a director lies between others and makes pass-through information in the network. Directors occupying advantageous positions in the network are better positioned to collect and exchange information, which empowers the director to contribute to high quality environmental disclosure. This indicates a positive effect of betweenness centrality on corporate environmental disclosure. Similarly, if a director sits on favorable position to bridge the gap in the network (measured by *structural hole access*), the available resources could help the director contribute to better environmental disclosure. In addition, highly networked directors who hold positions in multiple boards are motivated to excel in each role to receive recognition and rewards in the directors' labor market (Srinivasan, 2005; Brown *et al.*, 2019). Assisting a company in achieving improved environmental disclosure enhances a director's reputation, thereby granting them a competitive edge in future job market opportunities. Based on the discussion, we propose the following four hypotheses:

Hypothesis 2a. Degree centrality has a positive impact on the level of corporate environmental disclosure.

Hypothesis 2b. Closeness centrality has a positive impact on the level of corporate environmental disclosure.

Hypothesis 2c. Betweenness centrality has a positive impact on the level of corporate environmental disclosure.

Hypothesis 2d. Structural hole access has a positive impact on the level of corporate environmental disclosure.

4. Research design

4.1. Measure of Environmental Disclosures

To test our hypothesis, we regress environmental disclosures on board centrality and a set of control variables. For our dependent variable of environmental disclosures, we use the index developed by Clarkson *et al.* (2008) as our measure of corporate environmental disclosures. Clarkson *et al.* (2008) proposed the content analysis method for evaluating the credibility of environmental disclosures in environmental and social responsibility reports. This measure has been widely used in a variety of studies, and it takes the following information into consideration: corporate governance and management, quality of environmental information, performance of environmental activities, environmental expenditure, vision and strategy recommendations, environmental overview and environmental initiatives (Du, 2015; Du *et al.*, 2017). Detailed descriptions of this measure are provided in Appendix B.

4.2. Measure of Board Centrality

Consistent with the literature, we employ five measures of board centrality to explore the

board's comparative importance, prestige and resourcefulness (Zaheer and Bell, 2005; Amin *et al.*, 2020). Specifically, the degree centrality (*DegreeCentrality*) is a score for the number of channels through which one individual could reach others in the director network. Closeness centrality (*ClosenessCentrality*) presents the number of interpersonal links a director has in the director's network. The betweenness centrality (*BetweennessCentrality*) is the number of director networks that pass through the director network to reach other networks. Structural holes (*StructureHoles*) reflect the number of bridging opportunities for directors in their social networks. Our fifth measure of board centrality is a composite measure (*CentralityComposite*) calculated by taking the mean values of the previous four individual measures. These centrality scores evaluate the importance of the board in the director's networks (Omer *et al.*, 2020).

As part of our approach to measuring board centrality at the firm level, we rank director-level centrality scores into deciles every year, where ten is designated as the group with the highest scores and one with the lowest. Then we use the mean value of director-level centrality scores within each board as the measure of the board centrality. Appendix C provides detailed descriptions of our centrality measures.

4.3. Empirical Model

We use the following regression model to estimate the effects of board centrality on environmental disclosures:

$$Disclosure_{i,t} = \alpha_0 + \alpha_1 Centrality_{i,t-1} + Controls_{i,t-1} + IndustryandYearFixedEffects + \varepsilon_{i,t} \quad (1)$$

In equation (1), *Disclosure* denotes our measure of environmental disclosures. *Centrality* is

one of our five measures of board centrality. When the coefficient a_1 is significantly positive, H1 is supported.

Following prior studies, we include a series of director-level control variables in our empirical analysis. Specifically, we control for board size (*BoardSize*) because large boards are positively connected with the corporate environmental, social, and governance (ESG) performance (Beji *et al.*, 2020; Harjoto and Wang, 2020). We control for the ratio of female directors to all directors (*Female*) because gender could influence environmental disclosures (Liao, Lin and Zhang, 2016; Katmon *et al.*, 2017; Yuan *et al.*, 2017; Harjoto and Wang, 2020). We control for the average directors' age (*DirectorAge*) because age diversity is positively associated with the sustainable development disclosure (Jizi, 2017).

In line with prior research, we also include several firm-level control variables. In particular, we control for the dual roles of the chairman and CEO (*Duality*), the firm's total assets (*FirmSize*), firm liquidity (*Liquidity*), firm profitability (*ROA*), leverage ratio (*Leverage*), the firm's investment opportunity set (*TobinQ*), the nature of firm ownership (*SOE*) and the firm age (*FirmAge*) (Clarkson *et al.*, 2008; Dhaliwal *et al.*, 2011; Lawrence *et al.*, 2018). We lag all the explanatory variables in our regression to mitigate endogeneity issues. We include industry and year-fixed effects in equation (1) to control for industrial and intertemporal variations in our sample.⁵ The standard errors are clustered at the firm level. Appendix A provides variable definitions and sources for all variables used in the paper.

⁵ We use the standards of industry classification issued by the Chinese Securities Regulatory Commission (CSRC) in the year 2012.

5. Empirical Results

5.1. Sample and Descriptive Statistics

We include all Chinese A-share listed companies in the Shanghai and the Shenzhen Stock Exchange in heavily polluting industries.⁶ From the annual and environmental reports of 1,100 firms for the period 2012–2020, we hand-collect corporate environmental disclosure data. We collect the data on board centrality and firm financials from the China Securities Markets and Accounting Research Database (CSMAR). Our final sample contains 5,324 firm-year observations. All continuous variables have been winsorized at the 1st and 99th percentiles. Table 1 outlines the sample selection process and the sample distribution by industry.

The descriptive statistics are presented in Table 2. The mean value of the composite centrality measure (*CentralityComposite*) is 5.72. The average score of environmental disclosures (*Disclosure*) for our sample firms is 10.46, which is comparable to that reported in Du et al. (2015). As for control variables, the average board size (*BoardSize*) is 8.76. The board gender (*Female*) shows that our sample firms have a low percentage (14 percent) of female directors, as having female directors on board is not mandatory in China. On average, director age (*DirectorAge*) is about 52 years. In our sample, 21 percent of the firms' chairman and CEO positions are held by one person (*Duality*).

Table 3 reports the correlations between the variables. Consistent with the hypothesis,

⁶ The heavily polluting industries are included according to the list in the Guide to Environmental Information Disclosure of Listed Companies (2010) and the Catalogue of Classified Management of Environmental Verification Industries of Listed Companies (2008) issued by the Chinese government. These industries are listed in Table 1, Panel B.

the quality of corporate environmental disclosures is positively and significantly correlated with board centrality at the one percent level. Correlations among the variables are below 0.5, with a maximum variance expansion factor of 1.94. This result suggests that multicollinearity is not a major concern in the sample.

<< Insert Tables 1, 2 and 3 about here >>

5.2. Main Regression Results

Table 4 reports the regression results of estimating equation (1). Our findings suggest that, except for the *BetweennessCentrality*, all the remaining four measures of board centrality are positively and significantly associated with environmental disclosures.⁷ The coefficient on *CentralityComposite* is significant at the one percent level, which indicates that firms in the highest decile of the composite board centrality enjoy an increase of 0.936 points [$0.104 * (10 - 1) = 0.936$] in their environmental disclosure indices. The coefficients on *DegreeCentrality*, *ClosenessCentrality* and *StructuralHoles* are qualitatively similar. These results are consistent with our prediction of the positive role of board centrality in improving corporate environmental disclosures. Our results support the stakeholder theory that a well-networked board may achieve a better balance between the firm's financial and non-financial objectives by moderating the conflicting interests between stakeholders (Liao *et al.*, 2015; Harjoto and Wang, 2020).

As to the control variables, our results are generally in line with those documented in prior research (Liao *et al.*, 2016; Beji *et al.*, 2020). The coefficient on firm size (*FirmSize*) is

⁷ The insignificance of the betweenness centrality is also seen in a prior study by Renneboog and Zhao (2011).

positive, which indicates that larger firms tend to engage more in environmental disclosures. The coefficient on *Leverage* is negative, which indicates that highly leveraged firms in China are less willing to invest in environmental performance and disclosures due to their greater concerns about financial risks.

<< Insert Table 4 about here >>

5.3. Addressing Endogeneity Concerns

5.3.1. Instrumental Variable Approach

As firms with better environmental disclosures might attract better-connected directors to join their boards, our estimations may suffer from endogeneity concern (Beji *et al.*, 2020). Hence, we re-estimate equation (1) using the approach of two-stage-least-squares (2SLS). 2SLS approach has been considered as an effective tool to address such endogeneity concerns (Chakravarty and Rutherford, 2017; Park *et al.*, 2018). Following prior research (Cheng *et al.*, 2016; Kang and Xu, 2019), we identify two instrumental variables for board centrality, which include the travel convenience of directors (*DirectorConvenience*) and the one-year lagged value of the composite measure of board centrality (*L.CentralityComposite*).

We employ the travel convenience of the director (*DirectorConvenience*) as our first instrument. Director travel convenience is calculated using the passenger throughput of the airport near the firm in the year, which reflects the director's potential travel costs to attend board meetings (Chakravarty and Rutherford, 2017).⁸ The travel convenience enables the

⁸ We collect airport throughput data from the official website of Civil Aviation Administration of China. We select just the airports with the highest traffic throughput when there is more than one airport in a city. The sample size drops from 5,324 to 3,476 due to the data requirements (instrumental

company to hire well-connected directors to enhance board centrality, but it does not directly impact environmental disclosures. These attributes make director travel convenience a valid instrument, which has a high correlation with the independent variable and is uncorrelated with the dependent variable. In accordance with prior research, the value of board centrality is one-year lagged as our second instrument (Reed, 2015; Coles *et al.*, 2006; Cheng *et al.*, 2016), and that is because board centrality that persists over time is more likely to be exogenous to management decisions during a particular year.

Table 5 reported the results of estimating the 2SLS model. In the first stage, the travel convenience variable is significantly positive at the one percent level, and the lagged value of board centrality is significantly positive at the one percent level, which is in line with prior research (Chakravarty and Rutherford, 2017). We utilize the weak identification test to investigate whether our two instruments are relevant and powerful. We find that the F-statistic for the joint explanatory power of the instruments is significantly higher than the critical value of 11.59 for our two instruments, which suggests the relevance and power of the instruments are acceptable (Stock *et al.*, 2002; Semadeni *et al.*, 2014; Cheng *et al.*, 2016). In the second stage, the independent variable is the predicted board centrality obtained from the first-stage regression. The under-identification test shows a significant P-value and the Sargan test of overidentification is not significant, which shows that our two instrumental variables are valid. In the second step, as shown in the regression results, the coefficients on board centrality are positively significant at the one percent level, which is consistent with our primary results.

variables of *DirectorConvenience* and lagged value of directors' network centrality).

<< Insert [Table 5](#) about here >>

5.3.2. *Difference-in-Differences Approach*

It is likely that firms providing better environmental disclosure may recruit well-connected directors, so our study might suffer from reverse causality. To mitigate this concern, we rely on an external shock that reshapes directors' networks. On October 19th, 2013, the Chinese government issued "Principles of Government Leading Officials Working in Companies" (Document No.18), banning high-ranking government officials from engaging in employment within private enterprises. According to this regulation, those independent directors who are currently government officials must resign from the board. The network change due to Document No. 18 in a firm's network represents exogenous shocks to the availability of connected candidates, reducing the probability of appointing new connected directors. To the extent that the flow of resources and ideas through the boardroom network is driven by a director's presence in the boardroom, and due to the resources gathering and transfer that occurs in that setting, a shocked director is more likely to lose access to a board's resources. But there is no obvious reason why the exogenous shocks should affect the level of corporate environmental disclosures. We, therefore, perform a difference-in-difference test by assigning firms to treatment and control groups based on whether their directors have resigned as a result of Document No. 18. Following prior research (Bradshaw *et al.*, 2021), we partition firms into treatment and control groups based on whether there is a director who resigned because of Document No. 18, and estimate the following difference-in-differences model:

$$\begin{aligned}
Disclosure = & \beta_0 + \beta_1 Resignation + \beta_2 Post + \beta_3 Resignation \times Post \\
& + Controls + IndustryandYearFixedEffects + \varepsilon
\end{aligned}
\tag{2}$$

In equation (2), *Resignation* is a dummy variable equal to one when a director resigned from the board due to Document No. 18, and zero otherwise. *Post* denotes an indicator variable equal to one when the year is after the year 2013 when Document No. 18 was issued, and zero otherwise. Other variables are the same as presented in equation (1). The coefficient of the interaction term of *Resignation* and *Post* compares the change in the relation between board centrality and environmental disclosures for the treatment group relative to the control group. A significantly negative coefficient β_3 suggests a decrease in board centrality decreases the quality of environmental disclosures.

Table 6 presents the results of the difference-in-differences analysis. The negative and significant coefficient on the interaction term of *Resignation* and *Post* is consistent with our hypothesis and the primary results, suggesting that the decrease of directors' network centrality may decrease corporate environmental disclosures. When a director resigns due to Document No. 18, the "media" for resource and information communication disappears, and the board centrality is diminished, leading to a lower quality of environmental disclosures.

<< Insert Table 6 about here >>

5.4. Additional Analyses

5.4.1. Monitoring Effects of Board Connectedness

As an additional analysis, we examine whether and how the positive relationship between

board centrality and corporate environmental disclosures is affected by CEO duality. To do so, we separate our sample into two sub-samples based on whether the firm is characterized by the CEO serving as the chairman of the board at the same time. We then estimate equation (1) separately for both subgroups. As shown in Table 7, the positive effect of board centrality on environmental disclosures is mainly driven by the subgroup with CEO duality.

<< Insert Table 7 about here >>

5.4.2. Directors' Incentives to Promote Transparency

We also investigate whether directors' incentive to promote transparency affects the relationship between board centrality and environmental disclosures. To shield directors from personal liabilities in litigations, firms can purchase liability insurance for their directors. Such insurance reduces the probability of directors being held liable for low-quality disclosures (Baker and Griffith, 2010), and reduces their incentive to provide high-quality disclosure.

In order to test the impact of director liability insurance, we create a dummy variable (*Insurance*) which equals one if the firm purchased the liability insurance for their directors in the fiscal year, and zero otherwise (Lin *et al.*, 2013). Then we separated our sample into two sub-samples according to the indicator of *Insurance*. We test equation (1) separately for the two subsamples. The results, reported in Table 8, indicate that the positive effects of board centrality on environmental disclosures concentrate in the sub-sample without the liability insurance for directors.

<< Insert Table 8 about here >>

5.4.3. *The Influence of the Ratio of Shareholding*

Board directors are representatives of shareholders, and board directors are supposed to monitor the behaviors of professional top managers and CEOs. The influence of board centrality on corporate environment disclosure may be different due to different context of corporate governance. To test the influence of different context of corporate governance, we use the ratio of shareholding of the first largest shareholder to the second largest shareholder (*Z-score*) as the proxy of a firm's environment of corporate governance.

We construct two sets of sub-samples for firms by the sample median *Z-score* of each year. We test Equation (1) for the low and high *Z-score* subsamples, respectively. We expect the effect of board connections on corporate environmental disclosures to be more pronounced in the sub-sample characterized with higher *Z-score* because a higher *Z-score* concentrates power in the biggest shareholder. Consistent with our expectations, as is shown in Table 9, well-connected directors only significantly increase environmental disclosures for firms with higher *Z-score*.

<< Insert Table 9 about here >>

5.4.4. *The Influence of the New Environmental Protection Law*

The Chinese legislature carried out a major amendment to the Environmental Protection Law of China in April 2014, which has significantly increased the environmental protection cost of enterprises. The amendment also significantly enhanced the law enforcement

authority of environmental protection departments and expanded and strengthened the scope and quality of the mandatory information disclosure (Zhang *et al.*, 2017; Yu *et al.*, 2021). To test the influence of the new Environmental Protection Law, we conduct additional analyses based on two subperiods: Before and after the amendment year of the Environmental Protection Law of China (2012-2014 and 2015-2020). As is shown in Table 10, the effect of well-connected directors is of greater significance during the year 2015 and 2020, which indicate that the new Environmental Protection Law is more effective.

<< Insert Table 10 about here >>

5.4.5. *The Influence of Political Connections*

Political connections may have considerable influence on corporate governance (Hillman, 2005; Claessens *et al.*, 2008). To test whether political connections influence the nature of the relationship between board centrality and environmental disclosure in China, we use *PoliticalConnections* as a proxy of political connections, which is an indicator variable equals to one if the CEO or board chairman is politically connected, and zero otherwise. We predict that the positive effect of board centrality on environmental disclosure is more pronounced in politically connected firms. Table 11 shows that the effect of well-connected directors would be of greater significance for firms in which the CEO or board chairman is politically connected.

<< Insert Table 11 about here >>

5.4.6. *The Influence of the State Ownership*

Different types of ownership have very different impacts on corporate value and performance (Boubakri *et al.*, 2018; Boubakri *et al.*, 2019; Megginson, 2017). We condition our analysis upon the proxy of *SOE* for testing the effect of ownership. State-owned enterprises (SOEs) are government-controlled, and are easier to acquire tax relief, low-interest loans, and public grants comparing to non-state-owned enterprises (non-SOEs) (Gao and Yang, 2021; Ren *et al.*, 2021). Our sample was split into two groups conditional on *SOE*. Table 12 presents the results. As expected, well-connected directors contribute to better environmental disclosures in the SOEs sub-sample.

<< Insert Table 12 about here >>

5.5. *Other Sensitivity Tests*

We also conduct other sensitivity tests. First, we lag the board centrality measures by two years, assuming that going back two years further reduces the concern of reverse causality. To maintain conformity with the main test, we use the one-year lagged value of all the other explanatory variables. As shown in Table 13, the positive relationship between the second lag of board centrality and environmental disclosures holds.

Second, we employ the alternative index of environmental disclosures (*Disclosure_AT*) based on Al-Tuwaijri *et al.* (2004). The regression results using this alternative measure of environmental disclosures are presented in Table 14. Due to the data availability required to compute *Disclosure_AT*, the size of the sample drops to 1,750. The regression results indicate that the coefficients on board centrality measures continue to be positive and statistically

different from zero.

Third, because the values of *Disclosure* in several sample firms are zero, we use the Tobit regression method for robustness checks to mitigate any potential influence of the constrained dependent variable (Du *et al.*, 2014). Tobit regression is a model used under the assumption that the dependent variable has values that converge to a limit such as zero (Tobin, 1958; McDonald and Moffitt, 1980). The results of estimating the Tobit regression are presented in Table 15. The coefficients on board centrality measures continue to be positively significant.⁹

<< Insert Table 13,14,15 about here >>

6. Conclusion

We examine the relationship between board centrality and environmental disclosure using a sample of Chinese-listed firms between 2012 and 2020. Our results indicate that board centrality has a positive effect on the level of environmental disclosure in China. These results are robust to a battery of sensitivity checks including the 2SLS and the difference-in-differences approaches. Our results have implications for regulators, managers, and investors. In the “Corporate Governance Code”, regulators may emphasize the importance of recruiting directors with multiple directorships, which can speed up the dissemination of good practices, such as better environmental disclosure. Investors who prioritize the environmental performance of companies may deliberately adjust their investment portfolios based on publicly available information regarding the backgrounds of board

⁹ We also replace the mean values of the five centrality measures with the median values. The results, unreported here, remain qualitatively similar to the primary results.

members. This is because directors who serve on multiple boards can potentially contribute to more comprehensive environmental disclosure practices, which are valued by investors.

Because we test our hypotheses using Chinese-listed firms, we caution against generalizing our findings to other developing countries with different institutional backgrounds. In addition, our board centrality measure might overlook other forms of connections that could also facilitate the flow of information and affect the centrality of a director in the network. Precisely, our measure covers only the cross-employment of directors but fails to include other types of networks (e.g., online networks). Along the same lines, because of the data limitation, our study does not consider independent directors' social and educational connections. Consequently, our study may underestimate the impact of board centrality on environmental disclosure.¹⁰ Furthermore, despite our efforts using techniques such as the 2SLS and the difference-in-differences to alleviate the endogeneity issues, we cannot completely exclude the possibility that firms with better quality of environmental disclosure are more attractive directors with higher centrality in the network.

¹⁰ We thank an anonymous reviewer for pointing out this limitation.

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Appendix A: Variable Definitions

Variable	Definition
Dependent variables	
<i>Disclosure</i>	Environmental disclosure scores calculated following Clarkson <i>et al.</i> (2008). Details are provided in Appendix B.
<i>Disclosure_AT</i>	Environmental disclosure scores calculated following Al-Tuwaijri <i>et al.</i> (2004).
Independent variables	
<i>CentralityComposite</i>	
<i>DegreeCentrality</i>	A mean score of degree, closeness, betweenness centrality and structural holes. Details are provided in Appendix C.
<i>ClosenessCentrality</i>	Degree centrality calculated by mean values of directors in the same board, which refers to the number of directors whom a director directly contacts in the network. Details are provided in Appendix C.
<i>BetweennessCentrality</i>	Closeness centrality calculated by mean values of directors in the same board, which is the inverse of the average distance between one director and the other directors. Details are provided in Appendix C.
<i>StructuralHoles</i>	Betweenness centrality calculated by mean values of directors in the same board, which is the average proportion of paths between two directors on which a director lies. Details are provided in Appendix C.
Control variables	
<i>BoardSize</i>	Board size, number of directors on the board.
<i>Female</i>	The number of female directors to the total number of directors.
<i>DirectorAge</i>	The average age of directors on the board.
<i>Duality</i>	CEO/Chair duality. An indicator variable which is equal to one if the positions of chairman and CEO are held by the same person at the same time, and zero otherwise.
<i>FirmSize</i>	Firm size, which is measured as the natural log of total assets.
<i>Liquidity</i>	The ratio of the number of shares during the year divided by the number of shares issued at the end of the year.
<i>Leverage</i>	Financial leverage, which is defined as the ratio of total liabilities to the total assets.
<i>ROA</i>	Return on assets, which is measured as net operating income deflated by total assets.
<i>TobinQ</i>	Tobin'Q, which is measured as the market value of a firm to its book value of assets.
<i>SOE</i>	An indicator variable, which is equal to one if the final controlling shareholder of a listed company is a government agency or a state-owned enterprise controlled by the government, and zero otherwise.
<i>FirmAge</i>	The number of years since a firm's IPO.

Other variables

DirectorConvenience

Director convenience, measured as the passenger throughput of the airport near the firm in the year. We use the passenger throughput of the airport with the highest throughput when there is more than one airport located in the same city.

Resignation

An indicator variable, which is equal to one if one or more of a firm's directors resigned due to Document No. 18 issued by Chinese government in 2013 in the sample period, and zero otherwise.

Post

An indicator variable, which is equal to one if the fiscal year is after the year 2013 in which Document No. 18 was issued, and zero otherwise.

Insurance

An indicator variable, which is equal to one if the company has purchased liability insurance for its directors in the fiscal year, and zero otherwise.

Z-score

The concentration of shareholders' equity, measured as the ratio of shareholding between the biggest shareholder and the second biggest shareholder.

PoliticalConnections

Political connections, an indicator variable equals to one if the CEO or board chairman in a firm is politically connected, and zero otherwise.

Appendix B: Computation of Index for Environmental Disclosures

This appendix is reproduced from Table 1 of Clarkson et al. (2008, page 9–11). We use the index based on the content analysis framework proposed by Clarkson et al. (2008) as our measure of environmental disclosures. There are forty-five items in the index and all the items in the index are classified into two categories of ‘hard’ and ‘soft’ disclosures. The forty-five items in the environmental disclosure index are obtained from relevant information on: corporate governance structure and management systems, credibility, environmental performance indicators, environmental expenditure, vision and strategic propositions, environmental profile and environmental initiatives.

First, we extract information on environmental disclosures from annual reports and environmental reports. After that, we utilize the content analysis to compute the value of the forty-five items of corporate environmental disclosures. Then we add the scores of forty-five items according to the index proposed by Clarkson et al. (2008) to get the total score of the firm’s environmental disclosures.

Appendix C: Estimation of Measures for Board Centrality

Degree centrality refers to the number of first-level connections in the network (Freeman, 1978; Omer, Shelley and Tice, 2020). In order to compute degree centrality, we first construct an annual adjacency matrix A that represents the director network. In matrix A , each row i and column j represent a director. A_{xy} reflects ties among directors and takes the value of 1 if directors i and j are connected, and 0 otherwise. We assume that each link between two directors is equally important and ties in the network are undirected, yielding in a binary or unweighted network matrix. We construct proxies that measure how central a director is in the network by these matrices. Because the size of the director networks changes by time, we divide the raw scores of first-degree connections by the total number of nodes in the component minus 1 (Wasserman and Faust, 1994; Omer *et al.*, 2020).

Closeness centrality describes how close an individual is to other individuals in the network (Schabus, 2022), which is measured as the inverse of the average length of the shortest distances between one director and all the other directors. As the scale of networks changes by time, we multiply the original scores by the total number of nodes in the network minus 1 (Wasserman and Faust, 1994; Omer *et al.*, 2020). We let i represent the director of interest, k represents another director, and n represents the total number of directors connected in the group. Considering the scale of the network, closeness centrality for i is calculated using the following equation:

$$Closeness\ centrality_i = \left[\frac{\sum_{k=1}^{n-1} d(i,k)}{n-1} \right]^{-1} \quad (A1)$$

Betweenness centrality represents the extent to which a director lies between others and

makes pass-through communications in the network. A director with high betweenness centrality is considered to be an important intermediary person, so they are the center of the network (Freeman, 1978; Chahine *et al.*, 2019). If a director is well-connected and sits on more paths between pairs of other directors, he or she could be the key broker of the resource exchange (Nandy *et al.*, 2020). Betweenness centrality for individual i represents the fraction of shortest paths between any other two individuals in the network that i lies on. We let G_{jk} represent the total number of shortest paths between individual j and individual k , and let G_{ijk} represent the number of shortest paths between individual j and individual k that passes through i . The maximum value of betweenness centrality is equal to $(n - 1)(n - 2)/2$ (Wasserman and Faust, 1994; Omer *et al.*, 2020). We compute betweenness centrality for i using the following equation:

$$\text{Betweenness centrality}_i = \frac{\sum_{j < k} G_{ijk} / G_{jk}}{(n-1)(n-2)/2} \quad (\text{A2})$$

Structural holes are the gaps in the network between directors who were otherwise connected in the network. When directors occupy a favorable network position to bridge the structural holes, they enjoy stronger performance due to better access to resources (Burt, 1992). These resources could be the contacts and the connections binding the firms together to obtain information, resources, and opportunities (Burt, 1992; Bizzi, 2013). We compute network constraint using the following formula:

$$\text{Network constraint}_i = P_{jk} + \sum P_{ji}P_{ki} \quad (\text{A3})$$

where P_{jk} is equal to the strength of direct ties from j to k , and $\sum P_{ji}P_{ki}$ is the total value of the indirect tie strength from j to k via all i . i is a director other than j or k . We compute structural

hole access as one minus the firm's network constraint score except the cases that network constraint is zero. A score of zero in network constraint arises only when the firm is unconnected to others and doesn't have any access to structural holes.

It is not clear which aspects of the four centrality measures contribute most to the company's environmental disclosures. Hence, following Larcker et al. (2013) and Amin et al. (2020), we calculate our composite centrality measure (*CentralityComposite*) using the mean value of the four centrality measures using the following formula:

$$\text{Centrality} = \frac{1}{4} [\text{Quint}(\text{Degree}_i) + \text{Quint}(\text{Betweenness}_i) + \text{Quint}(\text{Closeness}_i) + \text{Quint}(\text{Structural Holes}_i)] \quad (\text{A4})$$

Then, similar to (Omer, Shelley and Tice, 2020), we aggregate the centrality measures calculated by directors into the board centrality measure at the firm level. To do so, we start by ranking the director-level centrality scores into annual deciles, where ten is designated as the group for the highest scores and one as the lowest. Then we use the mean value of director-level centrality scores within each board as the measure of the board centrality for the specific firm.

TABLE 1
Sample Selection and Distribution

Panel A: Sample selection		
China A-share listed firms in polluting industries with corporate environmental disclosures, 2012–2020		7,685
Excluding firms within one year of IPO		-316
Excluding firms that are specially treated (ST)		-301
Excluding firms with missing control variables		-213
Excluding firms with total liabilities greater than total assets		-66
Excluding firms with missing board centrality data		-8
Missing observations due to lagging the dependent variable by 1 year		-1,457
Total number of observations		5,324
Panel B: Sample distribution by industry		
Industry	n	%
Petroleum, Chemical, Plastics, and Rubber Products	1,535	28.83
Metal and Non-Metal	1,267	23.80
Medicine and Biological Products	882	16.57
Production and supply of electricity, steam and tap water	470	8.83
Mining	446	8.38
Textile, Apparel, Fur, and Leather	284	5.33
Food and Beverage	250	4.70
Paper and Allied Products; Printing	168	3.16
Other Industries	22	0.42
Total	5,324	100

Notes: We report the sample selection in Panel A. The sample includes all A-share listed companies in the polluting industries covered in the China Stock Market and Accounting Research Database (CSMAR). Panel B reports sample distribution by industry. Other industries include Machinery, Equipment, and Instrument Manufacturing, Wholesale and Retail Trades, Real Estate, Conglomerates, and Electronics.

TABLE 2
Descriptive Statistics

Variables	Mean	STD	P25	Median	P75
<i>Disclosure</i>	10.46	8.17	4.00	9.00	15.00
<i>CentralityComposite</i>	5.72	2.58	3.50	5.75	7.75
<i>DegreeCentrality</i>	5.83	2.81	4.00	6.00	8.00
<i>ClosenessCentrality</i>	5.57	2.83	3.00	6.00	8.00
<i>BetweennessCentrality</i>	5.63	2.84	3.00	6.00	8.00
<i>StructuralHoles</i>	5.84	2.80	4.00	6.00	8.00
<i>BoardSize</i>	8.76	1.79	8.00	9.00	9.00
<i>Female</i>	0.14	0.13	0.00	0.11	0.22
<i>DirectorAge</i>	51.92	3.51	49.64	52.00	54.22
<i>Duality</i>	0.21	0.41	0.00	0.00	0.00
<i>FirmSize</i>	22.58	1.30	21.69	22.36	23.36
<i>Liquidity</i>	0.85	0.21	0.75	0.98	1.00
<i>Leverage</i>	0.44	0.20	0.28	0.43	0.58
<i>ROA</i>	0.04	0.06	0.01	0.03	0.07
<i>TobinQ</i>	1.93	1.26	1.16	1.51	2.17
<i>SOE</i>	0.45	0.50	0.00	0.00	1.00
<i>FirmAge</i>	12.96	6.82	7.00	13.00	19.00

Notes: This table shows the descriptive statistics of the variables used to test the relationship between board centrality and environmental disclosures. We winsorized the continuous variables at the 1 and 99 percentiles of the distribution. There are 5,324 observations in the sample. The variables definitions are contained in Appendix A.

TABLE 3
Correlations Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) <i>Disclosure</i>	1																
(2) <i>Centrality</i>	0.14	1															
(3) <i>DegreeCentrality</i>	0.15	0.95	1														
(4) <i>ClosenessCentrality</i>	0.12	0.90	0.75	1													
(5) <i>BetweennessCentrality</i>	0.09	0.91	0.77	0.87	1												
(6) <i>StructuralHoles</i>	0.16	0.90	0.94	0.68	0.66	1											
(7) <i>BoardSize</i>	0.16	0.30	0.40	0.15	0.09	0.45	1										
(8) <i>Female</i>	-0.07	-0.10	-0.10	-0.08	-0.06	-0.10	-0.13	1									
(9) <i>DirectorAge</i>	0.21	0.08	0.07	0.10	0.07	0.06	0.11	-0.14	1								
(10) <i>Duality</i>	-0.09	-0.09	-0.13	-0.04	-0.04	-0.13	-0.16	0.09	-0.07	1							
(11) <i>FirmSize</i>	0.48	0.23	0.26	0.19	0.14	0.26	0.32	-0.14	0.31	-0.16	1						
(12) <i>Liquidity</i>	0.15	0.09	0.10	0.07	0.06	0.10	0.06	-0.07	0.09	-0.12	0.12	1					
(13) <i>Leverage</i>	0.12	0.11	0.14	0.05	0.04	0.16	0.19	-0.11	0.01	-0.11	0.43	0.17	1				
(14) <i>ROA</i>	0.05	0.03	0.00	0.07	0.06	-0.02	-0.01	0.07	0.08	0.04	0.03	-0.13	-0.42	1			
(15) <i>TobinQ</i>	-0.19	-0.08	-0.09	-0.05	-0.05	-0.10	-0.15	0.06	-0.10	0.08	-0.41	0.16	-0.24	0.18	1		
(16) <i>SOE</i>	0.19	0.17	0.22	0.09	0.07	0.23	0.30	-0.22	0.19	-0.26	0.36	0.27	0.28	-0.13	-0.17	1	
(17) <i>FirmAge</i>	0.20	0.14	0.17	0.08	0.07	0.18	0.12	-0.12	0.10	-0.19	0.31	0.42	0.25	-0.11	0.01	0.42	1

Notes: This table shows Pearson correlation between the main variables. There are 5,324 observations in the sample. Correlations significant at the 5 percent level or higher are in boldface. Variables definitions are contained in Appendix A.

TABLE 4
Board Centrality and Environmental Disclosures

Dep. Var.=Disclosure	(1)	(2)	(3)	(4)	(5)
<i>CentralityComposite</i>	0.104** (2.85)				
<i>DegreeCentrality</i>		0.082** (2.34)			
<i>ClosenessCentrality</i>			0.119*** (3.68)		
<i>BetweennessCentrality</i>				0.048 (1.50)	
<i>StructuralHoles</i>					0.107*** (2.99)
<i>BoardSize</i>	0.138** (2.47)	0.129** (2.25)	0.157*** (2.88)	0.171*** (3.14)	0.107* (1.83)
<i>Female</i>	-1.842** (-2.47)	-1.879** (-2.52)	-1.785** (-2.39)	-1.895** (-2.54)	-1.881** (-2.52)
<i>DirectorAge</i>	0.014 (0.52)	0.015 (0.56)	0.011 (0.41)	0.013 (0.48)	0.017 (0.64)
<i>Duality</i>	-0.340 (-1.52)	-0.335 (-1.50)	-0.356 (-1.59)	-0.350 (-1.56)	-0.331 (-1.48)
<i>FirmSize</i>	2.745*** (27.40)	2.753*** (27.51)	2.728*** (27.18)	2.759*** (27.57)	2.749*** (27.49)
<i>Liquidity</i>	2.338*** (5.28)	2.362*** (5.34)	2.312*** (5.22)	2.351*** (5.30)	2.357*** (5.32)
<i>Leverage</i>	-1.266** (-2.15)	-1.274** (-2.17)	-1.223** (-2.08)	-1.254** (-2.13)	-1.284** (-2.18)
<i>ROA</i>	-0.274 (-0.15)	-0.167 (-0.09)	-0.384 (-0.20)	-0.205 (-0.11)	-0.136 (-0.07)
<i>TobinQ</i>	0.007 (0.08)	0.005 (0.06)	0.004 (0.05)	0.008 (0.08)	0.007 (0.08)
<i>SOE</i>	1.082*** (4.79)	1.074*** (4.75)	1.101*** (4.87)	1.095*** (4.85)	1.061*** (4.69)
<i>FirmAge</i>	-0.014 (-0.84)	-0.014 (-0.87)	-0.013 (-0.79)	-0.013 (-0.79)	-0.015 (-0.89)
<i>Constant</i>	-55.134*** (-24.51)	-55.188*** (-24.52)	-54.849*** (-24.36)	-55.388*** (-24.63)	-55.153*** (-24.52)
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
N	5,324	5,324	5,324	5,324	5,324
adj. R ²	0.378	0.378	0.379	0.378	0.378

Notes: This table presents the OLS regression results of estimating equation (1). The sample includes all A-share listed firms in heavily polluting industries in China from the year 2012 to 2020. Variables definitions are given in Appendix A. All the independent variables in the regression are lagged by one year. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 5
Board centrality and environmental disclosures: Instrumental variable approach

	First-stage	Second-stage
	<i>CentralityComposite</i>	<i>Disclosure</i>
	(1)	(2)
<i>L.CentralityComposite</i>	0.636*** (48.65)	
<i>DirectorConvenience</i>	0.045*** (2.63)	
<i>P.CentralityComposite</i>		0.230*** (3.40)
Controls	Yes	Yes
Year fixed effect	Yes	Yes
Industry fixed effect	Yes	Yes
N	3,476	3,476
adj. R ²	0.500	0.441

Notes: This table reports the results of estimating the 2SLS regressions using two instruments. The first-stage regression instrumentalizes the endogenous variable of board centrality (*CentralityComposite*) using exogenous variables of *DirectorConvenience* and the lagged value of board centrality (*L.CentralityComposite*). In Column 1, the first-stage regression results are reported, and in Column 2, the second-stage regression results are reported. The dependent variable in Column 2 is environmental disclosures (*Disclosure*). The independent variable of interest in Column 2 is the predicted board centrality estimated from the first stage regression (*P.CentralityComposite*). The other variables are defined as in Appendix A. All the independent variables are lagged by one year in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 6
Board centrality and environmental disclosures: Difference-in-differences approach

Dep. Var.=Disclosure	(1)
<i>Resignation</i>	1.445*
	(1.71)
<i>Post</i>	0.116
	(0.21)
<i>Resignation</i> × <i>Post</i>	-1.549*
	(-1.76)
Controls	Yes
Year fixed effect	Yes
Industry fixed effect	Yes
N	2,691
adj. R ²	-0.400

Notes: This table reports the regression results from estimating the difference-in-differences equation (2). *Resignation* is a dummy variable equal to one if one or more of a firm's directors resigned due to Document No. 18 issued by Chinese government in 2013, otherwise, it equal to zero. *Post* is an indicator variable equal to one if the fiscal year is after the year 2013 in which Document No. 18 was issued, otherwise, it equal to zero. The other variable definitions are given in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 7
Board Centrality and Environmental Disclosures: CEO Duality

Dep. Var. = Disclosure	Non-Duality					Duality				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.058 (1.38)					0.269*** (3.63)				
<i>DegreeCentrality</i>		0.051 (1.27)					0.187*** (2.65)			
<i>ClosenessCentrality</i>			0.066* (1.79)					0.310*** (4.73)		
<i>BetweennessCentrality</i>				0.011 (0.31)					0.183*** (2.87)	
<i>StructuralHoles</i>					0.073* (1.78)					0.213*** (2.97)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4,183	4,183	4,183	4,183	4,183	1,141	1,141	1,141	1,141	1,141
adj. R ²	0.371	0.371	0.371	0.370	0.371	0.403	0.400	0.408	0.401	0.401

Notes: This table reports the OLS regression results from estimating equation (1) separately for the sub-samples with and without CEO duality. In Column 1 to 5, the results of baseline regression in the subsample without CEO Duality are reported. In Column 6 to 10, the results of baseline regression in the subsample with CEO Duality are reported. Variables definitions are given in Appendix A. The independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 8
Board centrality and environmental disclosures: Director liability insurance

Dep. Var.= Disclosure	Non-Insurance					Insurance				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.095** (2.57)					0.102 (0.68)				
<i>DegreeCentrality</i>		0.076** (2.16)					0.106 (0.73)			
<i>ClosenessCentrality</i>			0.105*** (3.21)					0.104 (0.77)		
<i>BetweennessCentrality</i>				0.052 (1.61)					-0.010 (-0.08)	
<i>StructuralHoles</i>					0.089** (2.45)					0.169 (1.15)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4,848	4,848	4,848	4,848	4,848	476	476	476	476	476
adj. R ²	0.335	0.335	0.335	0.334	0.335	0.457	0.457	0.457	0.456	0.458

Notes: This table presents the OLS regression results from estimating equation (1) separately for the sub-samples with and without the director liability insurance. We separate the sample into two sub-samples according to whether the firm purchased director liability insurance in the fiscal year. In Column 1 to 5, the regression results of the subgroup without director liability insurance are reported. In Column 6 to 10, the regression results of the subgroup with director liability insurance are reported. Variables are defined as in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 9
Board centrality and environmental disclosures: Ratio of shareholding

Dep. Var.= Disclosure	Low ratio of shareholding					High ratio of shareholding				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.056 (1.04)					0.137*** (2.71)				
<i>DegreeCentrality</i>		0.037 (0.74)					0.116** (2.38)			
<i>ClosenessCentrality</i>			0.041 (0.98)					0.105*** (2.65)		
<i>BetweennessCentrality</i>				-0.010 (-0.21)					0.085* (1.93)	
<i>StructuralHoles</i>					0.070 (1.35)					0.135*** (2.71)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2596	2596	2596	2596	2596	2726	2726	2726	2726	2726
adj. R ²	0.415	0.415	0.415	0.415	0.415	0.341	0.340	0.341	0.340	0.341

Notes: This table presents the OLS regression results from estimating equation (1) separately for the sub-samples with low and high ratio of shareholding of the first largest shareholder to the second largest shareholder (*Z-score*). We separate the sample into two sub-samples according to the ratio of shareholding. In Column 1 to 5, the regression results of the subgroup with low ratio of shareholding are reported. In Column 6 to 10, the regression results of the subgroup with high ratio of shareholding are reported. Variables are defined as in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 10
Board centrality and environmental disclosures: The New Environmental Protection Law

Dep. Var.= Disclosure	Before the New Environmental Protection Law					After the New Environmental Protection Law				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.085 (1.25)					0.108** (2.51)				
<i>DegreeCentrality</i>		0.102 (1.57)					0.074* (1.79)			
<i>ClosenessCentrality</i>			0.075 (1.24)					0.130*** (3.43)		
<i>BetweennessCentrality</i>				0.035 (0.60)					0.052 (1.39)	
<i>StructuralHoles</i>					0.085 (1.28)					0.111*** (2.63)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1297	1297	1297	1297	1297	4027	4027	4027	4027	4027
adj. R ²	0.335	0.336	0.335	0.335	0.335	0.347	0.347	0.348	0.347	0.348

Notes: This table presents the OLS regression results from estimating equation (1) separately for the sub-samples before and after the issue of New Environmental Protection Law. We separate the sample into two sub-samples according to the issue of New Environmental Protection Law. In Column 1 to 5, the regression results of the subgroup before the issue of New Environmental Protection Law are reported. In Column 6 to 10, the regression results of the subgroup after the issue of New Environmental Protection Law are reported. Variables are defined as in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 11
Board centrality and environmental disclosures: Political connections

Dep. Var.= Disclosure	Non-politically-connected firms					Politically-connected firms				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.068 (1.54)					0.191*** (2.88)				
<i>DegreeCentrality</i>		0.052 (1.24)					0.163** (2.54)			
<i>ClosenessCentrality</i>			0.051 (1.48)					0.146*** (2.82)		
<i>BetweennessCentrality</i>				0.013 (0.35)					0.131** (2.26)	
<i>StructuralHoles</i>					0.082* (1.94)					0.168** (2.54)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3797	3797	3797	3797	3797	1526	1526	1526	1526	1526
adj. R ²	0.365	0.365	0.365	0.365	0.366	0.420	0.419	0.420	0.418	0.419

Notes: This table presents the OLS regression results from estimating equation (1) separately for the sub-samples with and without political connections. We separate the sample into two sub-samples according to whether the CEO or chairman of a firm is politically connected. In Columns 1 to 5, the regression results of the subgroup without political connections are reported. In Columns 6 to 10, the regression results of the subgroup with political connections are reported. Variables are defined as in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 12
Board centrality and environmental disclosures: State ownership

Dep. Var.= Disclosure	Non-state-owned firms					State-owned firms				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
<i>CentralityComposite</i>	0.066 (1.61)					0.116** (2.07)				
<i>DegreeCentrality</i>		0.060 (1.55)					0.085* (1.67)			
<i>ClosenessCentrality</i>			0.051 (1.61)					0.086** (1.99)		
<i>BetweennessCentrality</i>				0.011 (0.31)					0.029 (0.58)	
<i>StructuralHoles</i>					0.080 (1.59)					0.145** (2.13)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2919	2919	2919	2919	2919	2404	2404	2404	2404	2404
adj. R ²	0.440	0.440	0.440	0.440	0.440	0.414	0.413	0.414	0.413	0.414

Notes: This table presents the OLS regression results from estimating equation (1) separately for the sub-samples according to whether a firm is state-owned. We separate the sample into two sub-samples according to whether the firm is state-owned. In Column 1 to 5, the regression results of the state-owned subgroup are reported. In Column 6 to 10, the regression results of the subgroup that is not state-owned are reported. Variables are defined as in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 13
Board centrality and environmental disclosures: Lagging board centrality for two years

Dep. Var.= <i>Disclosure</i>	(1)	(2)	(3)	(4)	(5)
<i>L2.CentralityComposite</i>	0.110*** (2.66)				
<i>L2.DegreeCentrality</i>		0.069* (1.73)			
<i>L2.ClosenessCentrality</i>			0.133*** (3.64)		
<i>L2.BetweennessCentrality</i>				0.055 (1.52)	
<i>L2.StructuralHoles</i>					0.118*** (2.91)
Controls	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
N	4,171	4,171	4,171	4,171	4,171
adj. R ²	0.384	0.383	0.385	0.383	0.384

Notes: This table presents the OLS regression results after lagging board centrality measures by two years. The other variable definitions are given in Appendix A. All the independent variables are one-year lagged in the regression. Controls are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 14
Board centrality and environmental disclosures: Alternative measure of environmental disclosures

Dep. Var.= <i>Disclosure_AT</i>	(1)	(2)	(3)	(4)	(5)
<i>CentralityComposite</i>	0.014** (2.48)				
<i>DegreeCentrality</i>		0.011* (1.91)			
<i>ClosenessCentrality</i>			0.014*** (2.81)		
<i>BetweennessCentrality</i>				0.011** (2.23)	
<i>StructuralHoles</i>					0.012** (2.09)
Controls	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
N	1,750	1,750	1,750	1,750	1,750
adj. R ²	0.339	0.338	0.340	0.339	0.339

Notes: This table presents the OLS regression results by using *Disclosure_AT* as dependent variable. The other variable definitions are defined in Appendix A. All the independent variables are one-year lagged in the regression. Control variables are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.

TABLE 15
Board centrality and environmental disclosures: Tobit regression

Dep. Var.= <i>Disclosure</i>	(1)	(2)	(3)	(4)	(5)
<i>CentralityComposite</i>	0.115*** (3.05)				
<i>DegreeCentrality</i>		0.091** (2.53)			
<i>ClosenessCentrality</i>			0.128*** (3.85)		
<i>BetweennessCentrality</i>				0.055* (1.69)	
<i>StructuralHoles</i>					0.117*** (3.19)
Controls	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
N	5,324	5,324	5,324	5,324	5,324

Notes: This table presents the results of estimating equation (1) using the Tobit regression. Variable definitions are given in Appendix A. All the independent variables are one-year lagged in the regression. Control variables are the same as that included in equation (1). The t-statistics in the parentheses are shown below the estimated coefficients. *, **, and *** show two-tailed statistical significance at 10%, 5%, and 1%, respectively.