

Yang, Yongliang; Wen, Jing; Yi, Li

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RESEARCH ARTICLE



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The impact of environmental information disclosure on the cost of debt: evidence from China

Yongliang Yang ^{a,b,c}, Jing Wen ^d and Yi Li ^{e,f}

^aSchool of Economics and Management, Zhejiang Sci-Tech University, Hangzhou, China; ^bSilk and Fashion Culture Research Center of Zhejiang Province, Zhejiang Sci-Tech University, Hangzhou, China; ^cGreen and low-carbon technology and industrialization of modern logistics, Zhejiang Engineering Research Center, Wenzhou, China; ^dSchool of Urban and Regional Science, East China Normal University, Shanghai, China; ^eFashion Department/DongHai Academy/Collaborative Innovation Center of Port Economy, Ningbo University, Ningbo, China; ^fTsinghua University-Younger Group Postdoctoral Workstation, Tsinghua University, Beijing, China

ABSTRACT

With the growing attention being paid to environmental issues by the public, environmental information disclosure (EID) has become a vital means for firms to convey their social responsibility and an important information source for lending institutions to assess firm credit risk. Based on the data of listed companies in China, a two-way fixed effects model is applied in this study to determine the impact of EID on the cost of debt. It reveals that EID can decrease companies' cost of debt and that both CEO duality and ownership concentration play vital roles in this relationship. After the consideration of endogeneity problems and robustness testing, the conclusions remain valid.

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Environmental information disclosure; the cost of debt; policy evaluation; corporate social responsibility

1. Introduction

In recent decades, governments, organizations, and corporate stakeholders have paid increasingly greater attention to environmental protection and sustainable corporate development. According to the United Nations Sustainable Stock Exchange initiative, all large companies must disclose their environmental performance by 2030. Environmental information disclosure (EID) is a sufficient tool for governments to promote shared environmental responsibility (Ross & Rowan-Robinson, 1997). Thus, increasingly more stakeholders are expecting firms to conduct their business in a more transparent, ethical, and responsible manner, which has led to the boom in corporate EID (Elias, 2004). In response to these evolving expectations, firms have been proactive in building their brands by enhancing their EID levels. Additionally, lending institutions are recognizing the significance of EID in evaluating corporate reputation (Thompson & Cowton, 2004; Zeidan et al., 2014).

CONTACT Yongliang Yang  royyang@zstu.edu.cn  School of Economics and Management, Zhejiang Sci-Tech University, No. 928, 2nd Street, Qiantang District, Hangzhou, Zhejiang Province 310018, China

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Theoretically, EID influences corporate financial performance through several pathways. First, by disclosing nonfinancial information, firms cater to investor preferences, which improves the evaluations of external stakeholders (Clarkson et al., 2013; Dhaliwal et al., 2012). Second, as nonfinancial information, environmental information can be a key element in measuring a firm's reputation and evaluating a firm's default and reputational risk (Weber et al., 2010, 2014). In turn, the capital market subsequently rewards high-level EID firms with lower interest rates and a lower cost of debt (Sharfman & Fernando, 2008). Thus, significant scholarly efforts have been directed towards assessing the EID and its relevance (Brooks & Oikonomou, 2018; Pedron et al., 2021). Third, EID mitigates the information asymmetry between firms and stakeholders. The information possessed by the firm and the lender is not exactly equal. If a firm intentionally conceals information that could have an adverse impact, it seriously harms the interests of the lender. Conducting high-quality information disclosure can mitigate information asymmetry between creditors and firms and save agency costs related to investigating the credit status of firms (Adusei & Adeleye, 2021). The reduction of this cost is directly reflected in the reduction of the debt financing costs of firms. As an index for measuring a firm's risk, the cost of debt (COD) is significant for the firm's future development because an associated funding gap can limit firm growth. In this regard, some scholars have begun to assess the impact of EID on COD (Fonseka et al., 2019; Franco et al., 2016; Stiglitz & Weiss, 1981).

Due to the different institutional factors in different countries, the legal consequences and penalties surrounding EID may vary greatly from country to country (Seetharaman et al., 2002). Francis et al. (2005) documented the fact that differences in legal and financial systems across countries can affect the observed disclosure levels. Most existing studies are based in developed countries, with limited research conducted in developing countries like China. However, China is in a stage of economic upgrading, economic restructuring, and environmental governance (Hao et al., 2020). With increasing environmental concerns, the government has established many regulations to decrease the pollution arising from firms. Compared with developed countries, China's EID process started late but has developed fast. Thus, discussing the association between EID and COD in an emerging market like China is essential.

In this study, the impact of EID on the COD of Chinese listed firms from 2007 to 2016 is analyzed and the relationship between EID and debt financing in the emerging market is explored. This study offers the following marginal contributions. First, it focuses on the impact of EID on COD in the emerging market, thereby complementing the existing research. The relevant research considers only subindustries (Luo et al., 2019), while this study adopts a sample of all Chinese listed companies in this study. Moreover, it employs a more objective method of measuring the EID level. Second, it provides insights into the heterogeneity of the influence of EID on financing costs, including CEO duality and ownership concentration. Third, it investigates the mediating effect of information asymmetry and firm reputation. Fourth, this study employs the generalized method of moments (GMM) to mitigate endogeneity and adopts the Heckman selection model to avoid selection bias.

The remainder of this paper is organized as follows: In Section 2, the prior literature is reviewed and the hypotheses are developed. In Section 3, our methodology, the data, and the model are described. In Section 4, we present the empirical results and discussions. In

Section 5, we conduct a robustness check. The final section offers conclusions, implications, and directions for future research.

2. Theoretical lens, literature review, and hypothesis development

2.1. Literature review

EID, as an important aspect of corporate social responsibility information disclosure, is not only required by laws and regulations but is also mandated by the development of firms. In addition, firms can reduce their regulatory burden and ultimately increase their financial valuations through disclosure (Aerts & Cormier, 2009; Hahn & Kühnen, 2013). Therefore, many scholars believe that EID positively impacts corporate financial performance (CFP) (Ahmad et al., 2019; Maltby, 2004; Porter & Linde, 1995).

According to stakeholder theory, stockholders and managers can interact to create value (Freeman, 1984). Stakeholders can contribute to the firm, and in return the firm meets the needs of the stakeholders (Ioannou & Serafeim, 2015; Luo et al., 2015). To some extent, the relationship between stakeholders and the firm can be reciprocal. Existing studies have shown that information disclosure is conducive to stakeholders obtaining equal access to financial and nonfinancial information to reduce the level of information asymmetry (Bushman, 1991; Graham et al., 2005). Huang and Kung (2010) documented the fact that stakeholder demands can significantly influence the level of environmental disclosure. Brammer and Pavelin (2006) asserted that decisions related to environmental disclosure are driven by pressure from stakeholders.

A firm cannot survive and develop without a balanced social system. Legitimacy theory posits that organizations should ensure that they operate within the bounds and norms of their respective societies (Brown & Deegan, 1998; Shocker & Sethi, 1973). Thus, environmental disclosure can be regarded as an approach geared towards exposing information in response to public pressure in the social environment (Milne & Patten, 2002). To legitimize corporate actions, corporate EID can be regarded as a reaction to environmental factors (Guthrie & Parker, 1989). Cho and Patten (2007) suggested that firms with poorer environmental performance are expected to disclose more extensive offsetting environmental information to address threats to their legitimacy.

However, some scholars believe that firms disclose their environmental information to affect stakeholder attitudes toward the firms' financial positions and prospects rather than to reduce environmental damage. Thus, these reports lack credibility and reliability (Cohen & Simnett, 2014). In addition, because of the stringent time and economic costs, managers are often uncertain about whether these reports achieve the expected outcomes (García-Sánchez et al., 2019). In this case, firms cannot maximize their profits and EID may negatively impact CFP (Hou, 2019; Palmer et al., 1995).

Debt financing is one of the main external financing channels for firms, especially in China (Xu et al., 2019). It can affect financial flexibility and operating risk, and it plays a crucial role in emerging economies (Legesse & Guo, 2020; Mitton, 2007). According to the pecking order theory, when firms need external financing, they should prioritize debt financing and equity financing. Equity financing often signals overvaluation to outside investors, which harms corporate financial performance (Wu et al., 2020). Compared

with equity financing, the COD financing is relatively low, and the interest expense of debt capital is itemized prior to tax, thus playing a role in tax deduction. Thus, firms prefer debt financing when they require funds (Chen, 2012; Li et al., 2021).

In terms of loan decision-making, the environmental risks faced by lending institutions can be divided into three types. The most common risk is indirect risk, which occurs when a firm defaults on loans due to poor financial consequences resulting from environmental regulations. The second is direct risk, which occurs when a creditor takes over mortgage assets that have lost their market value due to environmental pollution (Boyer & Laffont, 1997). The third type of risk is credit risk. Enterprises' destructive environmental behaviors may lead to reputation losses, and managers need to detect the environmental factors of enterprises to mitigate such risks. Therefore, credit risk is the most obvious way of influencing creditor decisions. Disclosing environmental information helps banks and other creditors make reasonable assessments regarding environmental risks, environmental investment, environmental governance performance, and additional information held by firms to reduce adverse selection. Moreover, the regular disclosure of environmental indicators can motivate firms to take various environmental protection measures to reduce the emergence of environmental pollution problems, thus reducing the possibility of moral hazard.

Signaling theory posits that positive signals can help high-quality firms distinguish themselves from low-quality firms (Connelly et al., 2010). During EID, borrowing firms generally hold a superior information position, while banks and other lending institutions hold an inferior information position. The voluntary disclosure of environmental information can serve as a positive signal to creditors that the firm is confident enough to take full responsibility, especially when specific environmental issues occur. Lo (2014) documented that creditors and borrowers in relationship lending choose informal channels rather than public disclosure to reduce the level of information asymmetry.

Prior studies have shown that firms can reduce information asymmetry and build good reputations with external stakeholders by actively disclosing environmental information. In this sense, firms with higher EID levels are more likely to obtain external debt financing. For example, Francis et al. (2005) found that firms that are sensitive to external financing often have higher disclosure levels due to the need to maintain low debt and equity capital costs. Franco et al. (2016) found that the bonds issued by firms with high-quality disclosures have lower yields than those issued by low-quality disclosure firms. Fonseka et al. (2019) found a statistically significant negative relationship between EID and COD based on a sample of Chinese energy firms from 2008 to 2014. They also found that firms that use less polluting products obtain lower loan costs from banks.

2.2. Hypothesis development

Disclosure is a practical and feasible means of enhancing the transparency of environmental accounting information. Improving the EID level reduces the information risk in the capital market, thus reducing adverse selection and moral hazard in the capital market.

In theory, the level of information asymmetry between lending institutions and firms can be reduced if lending institutions consider firms' environmental information in their lending decision. According to stakeholder theory, by disclosing environmental

information, firms can better cater to the needs of their stakeholders (Huang & Kung, 2010). In return, stakeholders can create value for firms. In addition, EID can lead to increasing valuation during the lending process by improving reputation and reducing the default risk of firms (Weber et al., 2014). Additionally, environmental information can be regarded as a positive signal with which environmentally friendly firms can showcase their social responsibilities to the public.

Empirically, Erragragui (2018) demonstrated that environmental concerns increase firms' debt financing costs, and environmental strengths reduce the COD. China's EID policies are not mandatory, so firms are often unwilling to voluntarily disclose negative environmental information. Therefore, considering the reliability and integrity of the data, we have focused solely on the impact of environmental strength information.

The above analysis leads to our hypothesis:

The level of EID is negatively correlated with the COD.

3. Data and methodology

3.1. Sample

To explore the relationship between the EID level and COD among listed firms in China, we obtained data from the CSMAR database, which provides the COD and other financial data, and the CNRDS database, which includes the EID data.

The initial observation samples were screened according to the following four principles: (1) Chinese firms listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange from 2007 to 2016 were selected as the research samples because of the amount of missing EID data prior to 2007; (2) we excluded samples from the financial industry based on the general treatment methods of previous studies because the regulatory system and statement structure of financial listed companies are quite different from those of other industries; (3) considering the comparability and reliability of the data, we followed most existing studies and excluded special treatment (ST) samples due to their financial information being relatively abnormal as a result of poor management; and (4) the continuous variables were winsorized at the 1% level. Our final sample comprises 5103 firm-year observations.

3.2. Measurement of variables

3.2.1. COD

With the development of the market economy, the credit market can not only generate profits for lenders, such as banks and financial institutions, but it can also provide opportunities for firm development. Debt financing is an important method of external financing for firms. According to firms' different debt repayment risks, the rates of return on funds needed by creditors differ.

The COD can be an effective way of measuring credit and risk. Following many previous authors (Francis et al., 2005; Kim et al., 2011; Pittman & Fortin, 2004), our proxy for COD is interest expenses divided by average total debt. A higher COD indicates that a firm has poor credit and high risk.

3.2.2. EID

There are three main ways to measure the information disclosure level. The first is through the direct application of authoritative data. In theory, this approach is the most objective method of measuring the EID level. However, no official, authoritative, and integrated EID evaluation rating agency exists in China. The second method is to measure the quality of earnings. This method is widely used in financial information disclosure, but it is unfeasible for nonfinancial information, such as environmental information. The third way is to conduct content analysis, which is used to first establish the information disclosure level measurement index system and then to grade the disclosures according to the index (Clarkson et al., 2008; Cormier et al., 2004). In the literature, many studies adopt this method, but it is highly operable so that the results may be subjective to some extent.

To increase the objectivity of the data, we did not add the scores according to weight. Rather, we directly added the scores of six items as a measure of a firm's EID level. These six items are as follows: a composite of three waste measures, reflecting the policies, measures, or technologies adopted by the company to reduce exhaust gas, wastewater, waste residue, and greenhouse gas emissions; a circular economy, which refers to the company's policies and measures geared towards using renewable energy or adopting a circular economy; energy saving, which refers to company policies, measures or technologies instituted to save energy; environmental certification, which references companies with ISO 14,001 certification; environmental recognition, which refers to a company that has received environmental recognition or other positive evaluations; and other advantages, which represent the other advantages in the corporate environment that are not covered by the above indicators.

If the company discloses information about one item, one point is assigned for this item. More specifically, if company i discloses item j in year t , $SEID_{i,j,t}$ is set to 1, and it set to 0 otherwise. For example, if a company disclosed its policies, measures, or technologies for reducing exhaust gas, wastewater, waste residue and greenhouse gas emissions, then they receive one point for this item. We provide the descriptive statistics of these six items in [Appendix A](#). The total score of company i in year t equals the sum of the six items listed above. Thus, the EID level can be calculated as follows:

$$EID_{i,t} = \sum_{j=1}^n SEID_{i,j,t} \quad (1)$$

where $EID_{i,t}$ represents the summed scores of the six environmental information items disclosed by firm i in year t , and $SEID_{i,j,t}$ represents the firm's score for item j in year t , where $j = 1, 2, 3, \dots, 6$.

3.2.3. Control variables

Based on prior studies, we utilize 15 control variables that may be significantly related to the relationship between EID and COD. These variables are defined in [Table 1](#).

3.3. Models and analytical techniques

The goal of this paper is to examine the impact of EID on the corporate COD and how it is affected by analyst forecasts. The traditional fixed effects model only

Table 1. Definition of variables.

Variable name	Variable symbol	Definitions of variables name
Cost of debt (%)	COD	[Interest expense/(short-term debt+ long-term debt)]*100%
EID level	EID	The summed scores of the six environmental information items disclosed by firms
Growth rate of earnings per share	grow	(Eps of this quarter – eps of last quarter)/eps of the last quarter
CEO duality	duality	The dummy variable, i.e., 1 for firms whose CEO is also the COB and 0 otherwise
Composite tax rate	tax	(Business tariff and annex+ Income tax expense)/Gross revenues
Financial pressure	ctdratio	(Current asset- current liabilities)/total borrowing
Financing constraints	constraints	(−0.737*Size) + (0.043*Size2) - (0.040*Age) from Hadlock and Pierce (2010)
Analyst forecast PB	fpb	Analyst forecast price/book value
Leverage	lev	Total assets/Total liabilities
Firm size	size	Firm size
Return on assets	roa	Net profit/total assets
Capital receivable ratio	capital	(Notes receivable +net account receivable) / total assets
Operating liability ratio	liability	(Current liabilities-short-term borrowings-non-current liabilities due within one year-trading financial liabilities-derivative financial liabilities)/Total liabilities
Shareholding rate of executives	mshare	The sum of the executive shareholdings
Analyst forecast BPS	fbps	Analyst forecast equity/capital
Executives	executive	The number of executives
Largest holder rate	largest	The sum of the percentages of the largest shareholders (%)

considers individual effects and does not account for the residual correlations of different companies in different periods. We adopt a two-way fixed effects model to explore the relationship between EID and COD to avoid model selection bias. In addition, in consideration of the endogeneity problem, we use lagged values of the control variables. We constructed the following model:

$$COD_{i,t} = \beta_0 + \beta_1 EID_{i,t} + \sum \tau_j * X_{j,i,t-1} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (2)$$

where the subscript *i* represents different listed companies, *t* represents the time variables, COD represents the cost of debt, EID represents the EID level of firm *i*, *X* is the matrix-vector of the control variables, μ represents a firm-specific effect to control for unobserved heterogeneity, φ represents the control for the year fixed effect, and ε is the stochastic disturbance term.

Considering the potential endogeneity problems, we adopted a moment estimator method. Specifically, we add the lagged value of EID into the regression to mitigate the endogeneity caused by the impact of the previous COD status on the current COD. The regression model is as follows:

$$COD_{i,t} = \alpha_0 + \alpha_1 COD_{i,t-1} + \alpha_2 EID_{i,t} + \sum \tau_j * X_{j,i,t-1} + \mu_i + \varphi_t + \varepsilon_{i,t} \quad (3)$$

where $COD_{i,t-1}$ represents the one-year lagged value of COD. The presentations of other parameters are consistent with those presented in Model (2).

All of the analyses were estimated with robust standard errors and conducted using Stata 15.0.

Table 2. Descriptive statistics of variables.

Variable	N	Mean	Sd	Min	P50	Max
COD	4924	0.220	0.330	0	0.0800	1.640
EID	5103	2.180	1.350	0	2	5
grow	4792	0.0800	5.370	−28.42	−0.0600	25.33
duality	5103	0.170	0.380	0	0	1
tax	5103	0.0400	0.0500	−0.0100	0.0200	0.220
ctdratio	4616	11.56	50.67	−2.440	0.790	420.6
constraints	5103	4.990	1.740	2.120	4.670	10.53
fpb	4821	3.130	2.270	0.630	2.480	12.79
lev	5103	0.490	0.200	0.0600	0.510	0.870
size	5103	22.91	1.430	20.18	22.77	26.95
roa	5103	0.0500	0.0500	−0.110	0.0400	0.210
capital	5103	0.120	0.110	0	0.0900	0.490
liability	5103	0.530	0.260	0.0700	0.500	1
mshare	4853	0.0300	0.0900	0	0	0.510
fbps	4919	5.140	2.790	1.380	4.470	15.40
executive	5092	7.300	2.820	3	7	18
largest	5103	38.67	16.12	8.120	38.76	77.07

4. Results

4.1. Descriptive analyses

Table 2 reports the descriptive statistics of the primary variables. The average EID is 2.18, and the median is 2. This indicates that the overall level of EID of Chinese listed firms is not high. The maximum EID is 5, and the minimum is 0, indicating that the disclosure level varies among firms and years. The median COD is 0.08, while the average COD is 0.22 (SD = 0.33), which indicates that most of the COD rates of Chinese listed firms are under 10%, while the debt financing of a few firms is quite high.

4.2. The impact of EID on the COD

To provide initial empirical evidence on the EID-COD relationship, we display the benchmark regression results in Table 3. Model 1, Model 2, Model 3, and Model 4 are

Table 3. Benchmark regression result.

	Model 1 FE	Model 2 RE	Model 3 POLS	Model 4 POLS_IND	Model 5 Heckman 2-Step	Model 6 Correction
EID	−0.009** (0.004)	−0.013*** (0.004)	−0.019*** (0.006)	−0.016*** (0.006)	−0.010** (0.005)	−0.013** (0.005)
Inverse Mills Ratio						0.248** (0.124)
Constant	−6.492** (2.525)	−1.802** (0.880)	−1.436 (0.942)	−1.208 (0.992)	−7.519 (4.742)	−11.202*** (3.729)
Control	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
Industry	NO	NO	NO	YES	NO	NO
Observations	3,305	3,305	3,305	3,305	2,665	2,665
R-squared	0.123		0.186	0.206	0.109	0.110
Firms	691	691			615	615

*, **, and *** represent the 10%, 5%, and 1% significance levels, respectively; all control variables and the constant term are included but reported, on which the tables that follows is also the same. $IMR_i = \frac{\phi(\hat{y}_i)}{\phi(\hat{y}_i)}$, where \hat{y}_i refers to the fitted value of firm i in the first-step regression, $\Phi(\hat{y}_i)$ refers to Cumulative Distribution Function, and $\phi(\hat{y}_i)$ refers to Probability Density Function.

based on the two-way fixed effect model, random effect model, pooled OLS, and pooled OLS after controlling for the industries, respectively. The p value of the Hausman test is 0.000, thus rejecting the null hypothesis of the random effect. Thus, we used the results of the two-way fixed effect model as our benchmark results. The value for EID is negative and significant in explaining the COD ($\beta_1 = -0.009$, $p < 0.05$). Next, we examine the primary evidence behind this association. This finding is robust across different model specifications, which supports Hypothesis 1, which claims that EID has a negative and significant impact on the COD. Most Chinese firms can choose not to disclose environmental information. Firms disclosing this information are likely those whose profits are not significantly affected by EID. Considering this selection bias, we adopt Heckman's two-step correction in Model 5 and Model 6. In the first step, we apply probit regression while considering whether the firm has a COD that might affect its debt financing level and estimate the inverse Mills ratio (the Mills ratio). In the second step, the Mills ratio is added to the model as a control variable to control possible selection bias in the primary model. The Mills ratio is significant at the 5% level, which indicates the presence of selection bias. The EID is still negative and significant in explaining the COD ($\beta_1 = -0.010$, $p < 0.05$), which is very close to the coefficients obtained without applying Heckman's two-step method. This suggests that lending institutions conduct credit risk analysis that includes EID considerations, thereby reducing financing costs for firms with higher EID levels.

This result is consistent with the results of prior studies (Eliwa et al., 2019; Ge & Liu, 2015; Hasan et al., 2017). First, firms can convey positive signals to fulfill stakeholder demands, which can avoid information asymmetry between creditors and firms and increase the understanding and support of the public. Second, lending institutions can incorporate firms' EID in their lending process to avoid both default risk and reputational risk (Weber et al., 2014).

4.3. Heterogeneity analysis

Many extant studies have investigated the link between CEO duality and corporate disclosure (Lagasio & Cucari, 2019; Samaha et al., 2015). CEO duality refers to the roles of a firm's CEO and its board chairperson being held by the same person simultaneously (Rechner & Dalton, 1991). When the CEO and the chairperson of the board (COB) are the same person, this person has great power, potentially eroding the board's power. Many scholars have found that CEO duality is associated with disclosure levels and corporate governance quality (Giannarakis, 2014; Jizi, 2017). Based on this, we divided the samples into CEO duality and CEO separation groups (where CEO separation is the opposite of CEO duality). The regression results are shown in Table 4, Model 1, and Model 2. These results show that the EID level in firms with CEO separation is significantly negative at the 5% level, which indicates that EID can significantly reduce corporate debt financing costs. However, if the CEO and COB are the same person, the relationship between EID and COD is not statistically significant. A possible reason for this is that powerful CEOs may seek to maximize their private interests at the expense of the shareholders' interests. Therefore, the information asymmetry between the company and the lenders may be exacerbated when the CEO and COB are the same person.

Table 4. Heterogeneity assessment.

	Model 1 CEO duality	Model 2 CEO separation	Model 3 Ownership concentration	Model 4 Ownership dispersion
EID	−0.006 (0.017)	−0.009** (0.005)	−0.012* (0.006)	−0.007 (0.006)
Constant	10.525 (9.430)	−6.593** (2.702)	−7.935** (3.808)	−6.995* (3.844)
Control	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	518	2,787	1,659	1,646
R-squared	0.183	0.123	0.126	0.139
Firms	204	609	377	392

*, **, and *** represent the 10%, 5%, and 1% significance levels, respectively; all control variables and the constant term are included but reported, on which the tables that follows is also the same.

Considering the heterogeneity among the largest shareholders, we have added a further category from the field of corporate governance. With the average percentage of the largest shareholders in China is 38.670%, we have divided our sample into two groups. The sample observations show that the percentages of the largest shareholders in the concentrated ownership group are larger than 38.670% (Table 4, Model 3), and those below that value fall into the dispersed ownership group (Table 4, Model 4). The regression results imply that the EID of the significant shareholder group is negatively correlated with corporate COD. However, EID has no statistically significant influence on COD in the low shareholder group. A possible reason for these results is that more significant shareholders have a stronger incentive to monitor the firm's directors and managers (Zaid et al., 2020). Hence, in a firm where the largest shareholder holds a greater percentage of the shares, the largest shareholder may prefer to disclose environmental information to reduce the COD.

4.4. Mechanism analysis

While the analysis above clarifies that EID is conducive to reducing COD, we also emphasize the mediating role of firm reputation and information transparency in this study. Specifically, firm reputation has been widely confirmed to be conducive to debt financing. On one hand, a better firm's strong reputation affects the attitudes and behaviors of its stakeholders (Bhattacharya et al., 2009). On the other hand, a strong reputation improves employee commitment, which in turn enhances the stability and sustainability of the firm (Rehman et al., 2020). Meanwhile, EID potentially influences firms' default and reputational risk (Weber et al., 2010, 2014).

Furthermore, information transparency is also an effective mechanism through which EID influences COD. Information asymmetries distort firms' investment and financing strategies (Morellec & Schürhoff, 2011). And the enhancement of information transparency is widely recognized as beneficial for debt financing (Raimo et al., 2021). Agency theory posits that in regard to debt financing, information asymmetry exists between lenders and firms (Jensen & Meckling, 1976). In this regard, disclosing environmental information is a potential approach to mitigating information asymmetry.

In summary, to further examine whether EID can influence a firm's COD by improving its reputation and reducing its level of information transparency, the following regression models are constructed:

$$M_{it} = \alpha_0 + \alpha_1 EID_{it} + \sum \tau_j \times X_{jit} + \mu_i + \varphi_t + \varepsilon_{it} \quad (4)$$

where the subscript i represents listed companies. M_{it} represents mediators (i.e., the reputation of firms and information transparency). X is the matrix-vector of the control variables, μ represents a firm-specific effect to control for unobserved heterogeneity, φ represents the control for the year-fixed effect, and ε is the stochastic disturbance term.

Concerning firm reputation, previous studies have generally measured the reputation of firms using Fortune's 500 Most Admired Companies (Rehman et al., 2020) and the scale items presented by Saeidi et al. (2015). However, using Fortune 500 data may not be appropriate for firms in developing countries (Kaur & Singh, 2018), and conducting a standardized survey among all Chinese listed firms covers a period of 10 years is challenging. Firm reputation is an intangible asset; hence, we use intangible assets as a measure of firm reputation. The results are presented in Model 1 of Table 5 and are based on the two-way fixed effect model. It is reported that EID is significantly positive for intangible firms, which indicates that EID can improve firms' reputations.

Considering robustness, we also adopt the logarithm of operating income to measure firm reputation. On the one hand, China's top 500 Fortune companies are appraised and elected by the company's operating income. On the other hand, financial performance is an indicator of the firm's reputation (Laskin, 2013). We employ a two-way fixed effect model in Model 2. We find that EID positively and significantly impacts operating income, indicating that the positive association between EID and firm reputation is robust. In summary, EID has a mediating influence on the reduction of COD through the promotion of firm reputation.

In terms of information asymmetry, we first use the quality of information disclosure to measure the information transparency of the firm. After the disclosure of the annual reports of listed firms, the Shenzhen Stock Exchange assesses the quality of information disclosure and divides it into four grades: excellent, good, pass, and fail. We obtain these data from CSMAR and transform them into numeric data. The higher that the score is,

Table 5. Mechanism analysis results.

Variables	Firm reputation		Information transparency	
	Model 1 Intangible	Model 2 Income	Model 3 Transparency	Model 4 Big4
EID	0.023** (0.011)	0.010** (0.005)	0.153** (0.063)	0.151* (0.084)
Constant	3.099 (5.860)	8.996*** (2.539)		-50.935*** (15.817)
Control	YES	YES	YES	YES
Year	YES	YES	YES	YES
Industry	YES	YES	YES	YES
Observations	3,321	3,394	1,351	3,293
R-squared	0.313	0.573		
Firms	695	700		

*, **, and *** represent the 10%, 5%, and 1% significance levels, respectively; all control variables and the constant term are included but not reported.

the better the quality of information disclosure. Then, we use ordered logit regression to investigate the impact of EID on information transparency. The result is shown in Model 3, where it can be seen that a higher EID level is associated with better information transparency.

Whether a firm has its financial statements audited by a “Big 4” auditing firm can also indicate the information transparency of firms. On the one hand, having an audit conducted by a well-known auditing firm may increase the quality of a firm’s information (Pucheta-Martínez et al., 2019). On the other hand, those who choose well-known auditing firms are signaling their willingness to provide truthful information (Lang & Maffett, 2011). Thus, we adopt the audit by the “Big 4” to reflect information transparency and use logit regression to estimate the association between EID and the “Big 4” in Model 4. The result demonstrates that EID is positively linked to the “Big 4”, indicating that a higher EID level can improve information transparency. In summary, EID mediates the impact of lowering the COD by promoting information transparency.

5. Robustness check

5.1. Alternative independent variables

To verify whether the EID level can alleviate financing costs, we introduce a dummy variable ENV, assigned as 1 for firms that disclose their environmental information and 0 otherwise. Table 6 shows the regression results between ENV and COD. The estimated coefficient of ENV is still statistically significant at the 5% level based on the two-way fixed effects model. Firms that disclose their environmental information often have lower debt costs compared to those that do not, further supporting the results shown above in Table 3.

5.2. Alternative dependent variables

To verify the robustness of the empirical findings, we changed the calculation method for COD. The measurement was switched from interest expenses divided by the average of short- and long-term debts to interest expenses divided by the average of the total debts from this term and those from the previous term (Pittman & Fortin, 2004). These results

Table 6. The impact of EID on COD.

	Model 1 FE	Model 2 RE	Model 3 POLS	Model 4 POLS_IND
env	−0.051** (0.020)	−0.056*** (0.019)	−0.048* (0.026)	−0.031 (0.025)
Constant	−6.586*** (2.523)	−1.766** (0.885)	−1.299 (0.952)	−1.081 (0.996)
Control	YES	YES	YES	YES
Year	YES	YES	YES	YES
Industry	NO	NO	NO	YES
Observations	3,305	3,305	3,305	3,305
R-squared	0.124		0.182	0.203
Firms	691	691		

*, **, and *** represent the 10%, 5%, and 1% significance levels, respectively; all control variables and the constant term are included but reported, on which the tables that follows is also the same.

Table 7. The impact of the EID level on the COD.

	Model 1 FE	Model 2 RE	Model 3 POLS	Model 4 POLS_IND
EID	-0.011** (0.005)	-0.015*** (0.004)	-0.022*** (0.007)	-0.019*** (0.006)
Constant	-8.353*** (2.825)	-2.143** (0.982)	-1.533 (1.018)	-1.307 (1.072)
Control	YES	YES	YES	YES
Year	YES	YES	YES	YES
Industry	NO	NO	NO	YES
Observations	3,305	3,305	3,305	3,305
R-squared	0.106		0.173	0.192
Firms	691	691		

*, **, and *** represent the 10%, 5%, and 1% significance levels, respectively; all control variables and the constant term are included but reported, on which the tables that follows is also the same.

are shown in Table 7, and they illustrate a negative and significant link between the EID level and the COD. The results are consistent with the results shown in Table 3, which implies that our results are robust.

5.3. GMM

Potential endogeneity can affect the interpretation of the causal relationship between EID and COD (Erragragui, 2018). In our context, endogeneity problems can arise from three sources. The first source is omitted variables related to EID and COD. There may be some potentially correlated variables that we have not included with the control variables in the initial model. Furthermore, measurement error is often unavoidable (Fornell & Larcker, 1981). Additionally, according to Waddock and Graves (1997), our study may be affected by the direction of causation, as it is impossible that the EID activities of firms are completely conducted without considering their debt financing costs.

To address these concerns, we implemented the GMM estimator. The method of moment estimators can be used to mitigate endogeneity problems and is robust to failures of auxiliary distributional assumptions that are not necessary to identify key parameters (Wooldridge, 2001). We adopt the difference GMM developed by Arellano

Table 8. The results based on the GMM.

	Model 1 DIFF1	Model 2 DIFF2	Model 3 DIFF2_or	Model 4 SYS1	Model 5 SYS2	Model 6 SYS_or
EID	-0.070** (0.033)	-0.085*** (0.032)	-0.063** (0.031)	-0.120*** (0.036)	-0.077** (0.038)	-0.078** (0.035)
Constant				0.000 (0.000)	7.825 (11.138)	-2.133 (3.737)
Control	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
AR (1)	0.000	0.000	0.000	0.000	0.000	0.000
AR (2)	0.820	0.944	0.109	0.739	0.272	0.272
Sargan	0.129	0.058	0.610	0.000	0.000	0.000
Hansen	0.605	0.261	0.853	0.125	0.111	0.121
Observations	1,470	1,464	1,450	1,529	2,076	2,127
Firms	452	451	442	476	536	541

AR(1) and AR(2) respectively refer to the first-order and second-order serial correlation in the first differenced residuals. The Hansen test and the Sargan test are used to examine whether the instrumental variables are overidentified.

and Bond (1991) in the first three columns of Table 8, as well as the system GMM developed by Blundell and Bond (1998). Columns 1 and 4 display the results based on the one-step estimator, Columns 2 and 5 display the results based on the two-step estimator, and Columns 3 and 6 display the results based on the orthogonal deviations transformation. In addition, the results of specification tests for instruments verify that instrumental variables are sufficiently appropriate. In this regard, EID still has a negative and significant impact on COD, which indicates that better EID can decrease COD, *ceteris paribus*.

6. Conclusion

Since the Club of Rome first released its research report, *Limits to Growth*, in 1972, corporate EID has attracted increasing attention. Many firms have sought to strengthen their communication with stakeholders by disclosing their environmental information. Using a sample of Chinese listed firms covering the period from 2007 to 2016, we adopted the two-way fixed effects model to examine the relationship between EID and the COD, and our findings reveal the following:

First, EID reduces the COD for reporting firms. According to stakeholder theory, stakeholders can contribute to the firm, and in turn, the firm needs to meet the needs of the stakeholders (Freeman, 1984; Ioannou & Serafeim, 2015). EID provides stakeholders with equal access to the firm's environmental performance and reduces the level of informational asymmetry between them (Bushman, 1991; Huang & Kung, 2010). Moreover, signaling theory posits that positive signals are conducive to high-quality firms (Connelly et al., 2010). In this regard, firms that disclose environmental information release positive signals to lending institutions and hold a superior position.

Second, EID lowers COD by mitigating information asymmetry and improving firm reputation. EID helps stakeholders obtain access to the firm's environmental performance and reduce the level of information asymmetry (Bushman, 1991; Graham et al., 2005). Better information transparency results in a lower debt financing for firms (Raimo et al., 2021). In terms of firm reputation, EID can be used to evaluate the reputational risk of a firm (Weber et al., 2010, 2014). A high reputation leads to firms obtaining lower debt financing costs.

Third, the association above is statistically significant in firms where the CEO and the chairperson are not the same person. The dominant role played by the large shareholder can lead to information asymmetry, as such shareholders' have access to private and value-relevant information (Vo, 2023). Thus, in firms where the CEO and COB are not the same person, information asymmetry can be mitigated, and hence, the debt financing can be reduced. In addition, the impact of the EID level on corporate debt financing costs is also significantly negative in firms where the shares held by the largest shareholders are more significant than the average percentage in China. One plausible reason for this is that despite the most significant shareholder incentives to monitor managers (Zaid et al., 2020), ownership concentration is of great importance in reducing the principal-agent problem. Large shareholders have advantages in imposing their interests and influencing firms through aligning with or directly monitoring management (La Porta et al., 1999). Thus, the largest shareholder has a stronger incentive to disclose environmental information to achieve lower financing costs."

While the literature that examines the association between nonfinancial information and financing costs is quite rich, our study fills several gaps. We focus on the cost of debt financing rather than the cost of equity financing. Previous research has confirmed that nonfinancial information disclosure can reduce the cost of equity financing (Francis et al., 2005; Wang et al., 2021), whereas only a few researchers have considered its influence on debt financing. However, signaling theory posits that firms prefer debt to equity when they need outside funds due to the relatively low costs associated with debt issues (Morellec & Schürhoff, 2011). Moreover, we focus on environmental disclosure in the context of nonfinancial disclosure. Indeed, several researchers have discussed the impact of nonfinancial disclosure, such as CSR disclosure (Wang et al., 2021) and ESG disclosure (Raimo et al., 2021), on COD. However, there is a lack of research concerning environmental disclosure at the scale of specific environmental issues. For example, Luo et al. (2019) selected the content scoring of the RKS MCT system, which is based on four secondary indicators, to measure EID levels. They found that this system reduced the debt financing cost in Chinese heavy-polluting listed companies. In contrast, we adopt the sample of all Chinese listed companies rather than that of subindustries (Fonseka et al., 2019; Luo et al., 2019).

Our research makes the following four contributions. First, our study extends the limited literature on the relationship between EID and debt financing costs. The results indicate that firm EID activities help the public understand the environmental responsibilities that firms have undertaken in greater depth and result in lower the financing costs in China. Second, we fully discuss the significant heterogeneity related to CEO duality and ownership concentration in different groups. The impact of the EID level on the COD is more significant in firms where the CEO and COB are the same person, those with a high shareholding ratio of the largest shareholders and those with a low disclosure level. Third, we explore the potential influencing mechanism between EID and COD. The results show that EID lowers COD by improving firm reputation and reducing information asymmetry. Fourth, we adopt the GMM and Heckman selection models to check the robustness of the results.

Second, our study encourages investors and other stakeholders in the capital market to consider the EID levels of firms. Compared with financial or other nonfinancial information, environmental information is more professional and more easily hidden, giving creditors an information disadvantage.

Third, our results are important for government departments and other regulatory bodies, as they highlight the importance of linking corporate interests with environmental activities to fulfill environmental responsibilities effectively. An advanced and integrated EID system can serve as an effective method of urging firms to improve their EID level and of enhancing EID's impact on the capital market.

The above findings carry several policy implications. First, our results can help boost firm confidence in the disclosure of environmental information. Firms can alleviate information asymmetry with their creditors through high-level EID to intensify their reputation and alleviate the risk of default, thus reducing the debt financing costs of firms. Therefore, firms should raise their awareness of EID to improve the quality of environmental disclosure. In addition, firms can establish a special environmental management department and strengthen the internal audits for environmental issues. Second, disclosing environmental information benefits not

only firms but also the sustainable development of the environment. Second, additional EID-related policies should be established, especially in emerging economies. Such policies should clarify the content and form of EID to urge firms to better fulfill their environmental responsibilities. Third, financing policies should be introduced to enhance the impact of EID on the capital market by, for example, giving financing discounts to firms with high EID levels.

Nonetheless, several limitations of this study should be acknowledged. First, despite considering debt financing, we do not consider other financial market reactions, such as equity indices and bonds. Second, we use the dataset from 2007 to 2016 because of the introduction of two EID-related policies in 2017. Future studies can provide insight into the impact of EID on debt financing following the institution of these policies through the use of more recent datasets to examine the impact of EID.

Authors' contributions

Y YL proposed the direction of the research and the framework of the manuscript, and provided the data sources. W J integrated and analyzed the data, used the model for accounting, screened the results and was a major contributor in writing the manuscript. L Y set the pace and oversaw the process. All authors read and approved the final manuscript.

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Notes on contributors

Yongliang Yang is an associate professor at Zhejiang Sci-Tech University. He received his Ph.D. in economics from Zhejiang University. His research interests cover Environmental Economics, Environmental information disclosure, Environmental and Social Governance, Green finance, and Green supply chain.

Jing Wen a Master's graduate from the School of Geographic Sciences at East China Normal University, specializes in environmental information disclosure, carbon emissions, and digital transformation.

Dr. Li Yi is a distinguished professor at Ningbo University, whose research field mainly focuses on how to balance pollution and carbon emission in sustainable development.

ORCID

Yongliang Yang  <http://orcid.org/0000-0002-6088-574X>

Jing Wen  <http://orcid.org/0000-0002-8541-176X>

Yi Li  <http://orcid.org/0000-0002-2882-5720>

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Appendix

Table A1. The descriptive statistics of six EID items.

EID components	N	Mean	Sd	Min	P50	Max
Three waste measures	5103	0.670	0.470	0	1	1
Circular economy	5103	0.330	0.470	0	0	1
Energy saving	5103	0.600	0.490	0	1	1
Environmental certification	5103	0.280	0.450	0	0	1
Environmental recognition	5103	0.200	0.400	0	0	1
Other advantages	5103	0.100	0.300	0	0	1

If the company disclose the item, this item is equal to 1, otherwise 0.