Effective Environmental regulations: Evidence of China's Capital Market

Research field: Resource and environmental economics

Abstract: Taking a comprehensive dataset from 2006 to 2020 of Chinese listed companies as the research sample, this paper assesses whether environmental penalties and environmental information disclosure affect the firm's stock returns. We provide evidence that the environmental penalties can have significantly positive effects on firm's risk premiums, while environmental information disclosure exhibit negative effects on firm's risk premiums. Environmental penalties will lead to higher risk premiums due to environmental compliance costs and financing constraints. In contrast, environmental information disclosure (EID) can alleviate the information asymmetry and providing better financing environment, thus decreasing the risk premiums. We further discuss the role of political connection in affecting environmental regulations and firm's stock returns and find that political connection can no longer be the protection of corporate irresponsible environmental behaviors. We have also noticed that non-heavy polluting firms can acquire lower risk premium after disclosing environmental information. Overall, our empirical results indicate that China's environmental penalties are playing an important role in affecting the stock returns, which are in general in line with the interpretation that investors are demanding compensation for their exposure to environmental risk.

Keywords: Environmental penalties; Environmental information disclosure; Risk premium; Information asymmetry; Investors

JEL Classification: Q58; D82; G14

1. Introduction

To meet the increasingly stringent environmental objectives, China has attached great importance to environmental protection and has accordingly formulated a series of environmental regulations. For example, to restrain environmental behaviors and promote the social supervision of listed firms, Chinese government has improved the corporate environmental administrative penalties intensity in the recent decade, formulated the information disclosure system for listed companies in 2006 and has gradually established a formal social responsibility reporting system [1]. Such environmental regulations have greatly influenced the firm's environmental behaviors and environmental risk (Huang and Chen, 2015; Bizet et al., 2022). More importantly, with China already committing to carbon peak by 2030 and carbon neutrality by 2060, firms have to abide by more stringent regulator standards on their environmental behaviors, which suggests that firms may burden higher environmental transition risks. Therefore, With the rising concerns about environmental degradation and the continual policy efforts towards environmental protection, environmental dimension has gradually become one of the most important aspects for investors when it comes to evaluating firm's performance and choosing portfolio holdings (Carpentier and Jean-Marc, 2015; Flammer, 2015; Fernando et al., 2017; Benlemlih et al., 2018; Carattini et al., 2021; Bolton and Kacperczyk, 2021).

To date, environmental penalties and environmental information disclosure (EID) are two main measures of environmental regulations. Fig. 1 presents the number of firms with environmental penalties and EID of Chinese listed firms from 2006 to 2020. Under tougher environmental regulation and increasing investor awareness of corporate environmental responsibility, firms disclosing environmental information exhibit a steady increase over time. The number of environmental penalties and mandatory disclosure also increased significantly compared to the early period, implying that corporate environmental behaviors have aroused great concerns from the government and society. Previous researchers have tried to explore the factors affecting stock returns based on firm-specific characteristics that reflect the firm's risk exposures, such as corporate size and stock volatility (Novy-Marx, 2013; Fama and French, 2015). Driven by policy requirements and investor concerns about the environment, the influences of environmental regulations have also been attached to great importance to a firm's stock returns and environmental risk.

[1] Guidelines on Social Responsibility of Listed Companies: http://www.szse.cn/aboutus/trends/news/t20060925_517525.html

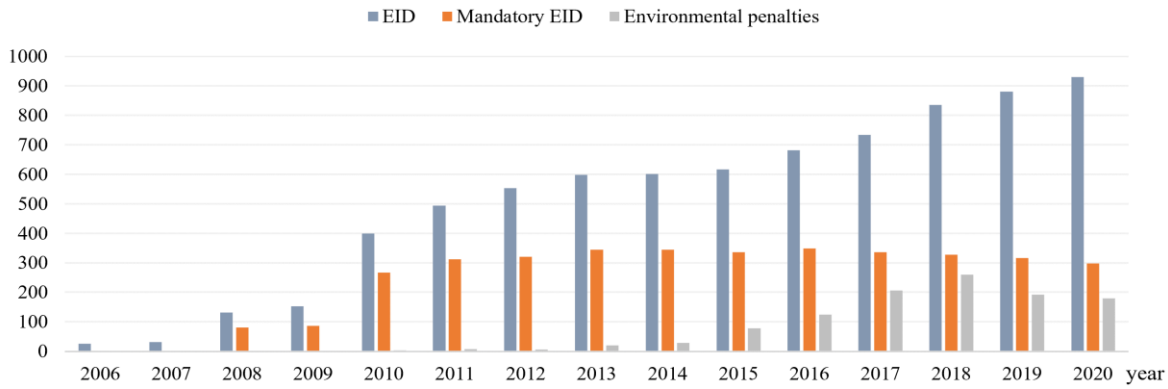

Fig. 1 The number of firms with EID, mandatory EID, and environmental penalties of Chinese listed firms from 2006-2020.

Note: The data source is the website of cninfo and the Chinese Research Data Services (CNRDS), and the data sample period is 2006-2020. EID represents the number of firms with environmental information disclosure, mandatory EID represents the number of firms with mandatory environmental information disclosure, and environmental penalties represent the number of firms subject to environmental penalties per year.

In this paper, we examine whether environmental regulation, including environmental penalties and environmental information disclosure (EID), can affect the firm's stock excess returns. If so, how can we explain the premium caused by environmental regulations? To answer these questions, we select the companies listed on the Chinese Shenzhen and Shanghai Stock Exchange from 2006 to 2020 as the research sample. Importantly, we provide evidence that the environmental penalties exhibit positive effects on stock excess returns, suggesting that firms with environmental penalties have to undertake higher risk premiums and financial costs in the capital market. In contrast, however, EID leads to a lower stock excess return, thus enabling firms to acquire financing at lower costs in the capital market. Our results indicate that investors are already demanding compensation for their exposure to environmental risk. Not only is this result statistically significant, but it is also economically meaningful. A one-standard deviation change in environmental penalties is associated with a increase in the risk premium of 0.59%, while a one-standard deviation change in EID is associated with a decrease in the risk premium of 0.98%.

Our results survived a series of robustness checks. As the stock return changes with high frequency, we firstly recalculate the stock return using the monthly data to ensure the accuracy of the results. We then apply the propensity score matching (PSM) method to avoid sample biases and causal interferences. We also eliminate the unstable periods of financial crisis in 2008 and 2009, along with the China's stock market crash in 2015. Moreover, we consider the confounding impacts of other environmental protection policies in recent years. We further apply the placebo test to construct a series

of counterfactual tests that makes contrary assumptions about the impact of penalties and EID and find that the counterfactual treatment effect of environmental information disclosure does not exist. Importantly, to solve the self-selection bias of EID, we introduce the total sum of regional tele services as the instrumental variable and conduct the two-stage least squares regression(2SLS). Our results remain stable after the robustness checks above. We find that, in aggregate, environmental penalties exhibit positive significant influences on firms' stock returns. In contrast, EID can lead to lower risk premiums and enable firms to acquire lower financial costs. All the evidence suggests that the results are reliable.

Subsequently, we discuss the mechanisms of environmental penalties and EID in affecting firm's stock return premiums. Using the environmental compliance costs estimated by environmental tax and pollutant charge, we find that higher compliance costs result in higher risk premiums as for the firms with environmental penalties. Besides, for firms in areas with high intensity of environmental regulations, environmental penalties will tighten the firm's financing constraints, thus resulting in higher risk premiums. Furthermore, we apply the principal component analysis (PCA) to construct the information asymmetry index (*ASY*) using the daily data of stock returns from China's capital market from 2006 and 2020. We find that alleviating the information asymmetry between firms and investors by EID is an important approach to reducing the firm's risk premium. In addition, once the firm has already reduced its information asymmetry through other approaches, such as Internet and media coverage, the effects of EID on risk premiums will be weakened, which reinforce the results of alleviating information asymmetry by EID. Simliarly, EID can release the firn's financing constraints, thereby reducing the risk premiums.

We finally analyze whether the effects of environmental regulations can be affected by firms' political connection and industries feature. Results show that higher political connection level will increase the risk premium for firms with environmental penalties, indicating that political connection can no longer be the protection of corporate irresponsible environmental behaviors and further suggest the effective of China's environmental regulations. Moreover, non-heavy polluting firms can better reduce their environmental risks by disclosing environmental information due to their green features.

In comparison to earlier research, the contributions of this study are apparent in the following aspects. Our paper first contributes to the general literature on environmental regulations. Previous studies have discussed the pollution control effects of traditional regulations and information strategies (Foulon et al., 2002; Kim and Lyon, 2011; Huang and Chen, 2015; Tu et al., 2019; Choi et al., 2021; Kang and Silveira,

2021). This paper analyzes the effectiveness of environmental penalty and information strategy from the perspective of asset pricing and market reaction. We provide evidence that China's environmental regulation is effective in capital market.

Second, our paper contributes to the literature on corporate environmental risk premiums. Previous studies have demonstrated that carbon emissions will lead to higher environmental transition risks, which is reflected in the price of high-carbon assets (Campiglio, 2016; Battiston et al., 2017; Ehlers et al., 2021; Bolton & Kacperczyk, 2021). Therefore, firms in the carbon intensive sector have to provide higher returns to investors to compensate for their exposure to environmental risk (Krueger et al., 2020; Sen & Schickfus, 2020; Bolton & Kacperczyk, 2022). We extend the relevant research and consider the environmental penalties and EID as potential environmental risks of firms. More importantly, we find that firms can benefit from disclosing the potential risks, that is, investors are demanding a relatively lower compensation for their environmental exposure to firms with EID.

The remainder of this paper is organized as follows. Section 2 briefly describes the literature on environmental regulations and puts forward the hypotheses. Section 3 describes the sample. Section 4 tests whether environmental regulations influence the firm's stock return and explores the mechanisms of environmental regulations on stock excess returns. Section 5 discusses the impacts of firm's political connections and industrial features on environmental regulations and stock returns. Section 6 concludes.

2. Literature review and hypotheses development

2.1 Environmental penalties and risk premiums

With the raising awareness of environmental protection, environmental dimension has become one of the most important aspects when evaluating firm's performance (Carpentier and Jean-Marc, 2015; Benlemlih et al., 2018; Bolton and Kacperczyk, 2021). To further restrain the environmental behaviors of Chinese listed companies, China has implemented a series of environmental regulations. On the one hand, the government increase the intensity of environmental penalties and measures, including fines, charging correction, warning letters, public censure, and criticism. According to the reports from the Ministry of Ecology and Environment of China, the environmental regulators issued a total of 91,000 administrative penalty decisions, with a cumulative fine of 7.672 billion yuan in 2022. On the other hand, to increase the environmental information transparency of listed companies, China formulated the information disclosure system for listed companies in 2006 and has gradually established a formal

social responsibility reporting system. According to the *Evaluation Report on Environmental Responsibility Information Disclosure of Listed Companies in China (2021),* both the quantity and quality of firms releasing environmental information have steadily improved in recent years. To be specific, 1178 firms have disclosed their carbon information and exhibits a 17.67% rise in disclosure proportion from the previous year.[2]

At present, environmental penalty and environmental information disclosure (EID) have become the two most important environmental regulations. A considerable amount of academic research has discussed the effectiveness of environmental regulations in the capital market. Previous studies have manifested that environmental administrative penalties may lead to adverse economic consequences and increase firm's risks, thus resulting in higher risk premiums. Firstly, environmental penalties increase firm's compliance costs. researches have found that environmental penalties can reduce the firms' frequency of violations and improve their environmental performance (Nadeau, 1997; Earnhart, 2004). Moreover, firms with environmental penalties are in general heavy industrial firms with excess pollutant emission. Thus, to meet the requirements of regulation, firms have to bear higher costs of environmental management, including the expenditure on environmental protection tax and pollutant charge. Furthermore, to comply with strict environmental regulations, firms may incur additional costs of new green technology from R&D investments (Aghion et al., 2016).

Secondly, After the Ambient Air Quality Standard was revised in 2012 by China Ministry of Environmental Protection, corporate environmental risks have aroused widely concern. Studies have demonstrated that adverse events such as environmental violations will increase corporate information risks and credit risks, thus impacting the bank lending decisions (Haß et al., 2019). As a consequence, firms with environmental penalties may have more difficulties in obtain financing resources. Researcher have found that financial institutions tend to consider firm's environmental risks into their lending decisions and credit management systems (Weber, 2012; Zhou et al., 2018; Jung et al., 2018). Specifically, firms with environmental penalties have to face the requirements of production restriction, shutdown and business suspension, so that increasing the operation risks. On the other hand, environmental penalties inevitably tarnished the firm's reputation, thus increasing firm's reputation risks (Haddock-Fraser and Tourelle, 2010; Zou et al., 2015). Therefore, financial institutions will charge higher lending returns to compensate the environmental risks for firms with environmental penalties (Chava, 2014).

Moreover, Pastor et al. (2021) proposed the asset pricing model that consider

[2] Data resource: *Evaluation Report on Environmental Responsibility Information Disclosure of Listed Companies in China (2021).*

environmental, social, and governance (ESG), which is characterized by heterogeneous firms and investors in the capital market. The model describes the change of expected returns of *N* firms (n=1, …, *N*) during a single period, from time 0 to time 1. They finally find that the expected excess return ($E(\tilde{r}_i)$) of investor *i*'s portfolio can be expressed as the following equation:

$$E(\tilde{r}_i) = \mu_m - \varphi_i \left(\frac{1}{a^3} g_n' \bar{\tau} g_n \sigma^{-1} \right) \quad (1)$$

where $\varphi_i = \tau_i - \bar{\tau}$, τ_i denotes the investors' green preference, $\bar{\tau}$ reflects the average green preference of the market. μ_m represents market equity premium. a denotes the investor *i*'s relative risk aversion. σ is the variance of the return on firm n's shares net of the riskless rate. Consequently, investors' expected returns are decreasing in firm's green characteristics g_n. As environmental penalties indicate firm's irresponsible environmental behaviors, firms with environmental penalties thus having higher brown features. Therefore, for firms with environmental penalties, g_n decreased. Therefore, firms with environmental penalties have to provide investors with higher returns to compensate investors' environmental risk when including these firms into their portfolio holdings. Consistent with this, we propose the following hypotheses:

Hypothesis 1: Environmental penalties can have positive impacts on firm's stock excess return and increase firm's financing costs.

2.2 Environmental information disclosure and risk premiums

In contrast, EID can reduce firms' risk premiums by alleviating information asymmetry and financing constrains. Firstly, EID can alleviate the information asymmetry between firms and investors, thus providing lower risk premiums. Previous studies have demonstrated that investors are already charging a significant risk premium for information uncertainty and information asymmetry (Lu et al., 2010; Lin et al., 2018). Specifically, detailed environmental information will lead to more extensive scrutiny from the media and investors, thus requiring higher operational transparency (Zhang et al., 2022). Hence, transparent environmental information enables investors to monitor firm's operation activities effectively and reduce the stock price crash risks, thus obtaining lower risk premium in the capital market (Hutton et al., 2009; Wu and Lai, 2020). Moreover, such information disclosure can increase firm's compliance substantially and build a responsible and positive reputation, thus decreasing corporate reputation risks and violation risks (Cui et al., 2018; Benlemlih et al., 2018; Bizet et al., 2022). Consequently, with more environmental information

available, investors improve their trust and purchase intention of firms (Lys et al., 2015; Cui et al., 2018). Therefore, a positive relationship exists between risk and compensation and the information risk is priced (Li et al., 2019; Yang et al., 2020). Taken together, EID can reduce information asymmetry between firms and investors and thereby improve the firm's competitiveness and investors' purchase intention. Investors are willing to include firms with EID into their portfolio holdings though such assets provide them with lower returns, thus inversely enabling firms to acquire lower financing costs in the stock market.

Besides, EID can alleviate firm's financing constraints, thereby gaining investors' supports and reducing the risk premiums. China Banking Regulatory Commission (CBRC) promulgate the document of Green Credit Guideline in 2012 (referred to as the "Guidelines"). The Guidelines stated clearly to relax the loan requirements and encourage the commercial banks to offer loans for green industries. The implementation of green credit of commercial banks has been a vital criterion for banks' performance after the enforcement of the Guidelines. Hence, the environmental performance is one of the most important factors affecting the lending decision of banks. According to the signal theory, environmentally friendly firms can set themselves apart more easily from others by delivering information of good quality, which can be regarded as a signal of firm's prospects (Sinclair-Desgagne and Gozlan, 2003; Lys et al., 2015). Furthermore, previous studies have demonstrated that a transparency information environment can save the costs of debt and equity and reduce the equity misevaluation, thus reducing the mispricing of loans and default risks (Bhattacharya et al., 2012; Derrien et al., 2016; Li, 2020; Blanco and García, 2021). Therefore, banks are more inclined to offer loans to firms with more environmental information disclosure. Firms with EID are thus easier to obtain credit resources to operate business effectively and gain lower risk premiums.

Moreover, as EID provide more environmental information and alleviate the information asymmetry, firms with EID gain higher green features. Therefore, according to the asset pricing model proposed by Pastor et al. (2021), g_n increased for forms with EID. Consequently, investors are asking for lower return if the firm disclose its environmental information. Thus, in the light of this theoretical motivation and the supporting empirical evidence, we hypothesize that:

Hypothesis 2: Environmental information disclosure can have negative impacts on firm's stock excess return and decrease firm's financing costs.

3. Data and sample

In this section, we firstly describe the data sources in Section 3.1, we then give a introduction to the variables that should be used in the empirical models in Section 3.2, and Section 3.3 discusses the descriptive statistics of our research sample.

3.1 Data sources

China has gradually established a formal social responsibility information disclosure system for listed companies since 2006. To construct a balanced sample with a stable structure, in this study, we choose the listed companies in China's capital market from 2006 to 2020 for our analysis. Besides, to ensure the reliability and accuracy of the regression results, we eliminate the companies under special treatment and companies with less than three years of listing[3]. Also, we eliminate the data with too many missing values and firms of the financial industry. In addition, to mitigate the impact of outliers, all the continuous variables are standardized at the 1% and 99% quantiles. Finally, we construct a dataset including 25082 firm-year separate observations covering 3094 firms during the period 2006-2020.

We collect environmental information data from the website of cninfo[4], which is the listed company information disclosure website designated by the China Securities Regulatory Commission (CSRC). The environmental penalty data are collected from the Chinese Research Data Services Platform (CNRDS)[5] and the pkulaw database.[6] Specifically, to acquire a more comprehensive research sample of environmental penalties, we collect the environmental penalties of subsidiaries of listed companies and match the environmental penalties of subsidiaries with their parent companies. The corporate financial data are collected from the CSMAR[7] database.

3.2 Variables

Studies have demonstrated that the capital market can identify the environmental risk of listed companies and reflect the impact of environmental regulations on investor response, which can be finally reflected in the corporate stock returns (Carpentier and

[3] Companies under special treatment means that they are not in robust corporate financial situations due to years of losses or excessively low net assets. Hence, companies under special treatment and companies with less than three years of listing cannot provide robust and reliable financial data. We, therefore, eliminate these samples to ensure the reliability and accuracy of our conclusions.
[4] Data resource: http://www.cninfo.com.cn
[5] Data resource: https://www.cnrds.com
[6] Data resource: http://ai.pkulaw.com/home.html
[7] Data resource: https://www.gtarsc.com

Jean-Marc, 2015; Oestreich and Tsiakas, 2015; Mayberry, 2020; Ilhan et al., 2021). Thus, we choose the annual excess return on stocks (*STRET*) as the dependent variable in the empirical model, which is equal to the annual corporate stock yield, net of the yield on the one-year national debt (Bolton and Kacperczyk, 2021, 2022). *PEN* is the core independent variable that indicates whether or not firm *i* is subject to the environmental penalties, and it is 1 if firm *i* is subject to the environmental penalties at year *t*, otherwise it is 0. Besides, EID is another core independent variable that indicates whether or not firm *i* has disclosed the environmental information, and it is 1 if firm *i* has disclosed the environmental responsibility report or social responsibility report at year *t*, otherwise it is 0.

Referring to the studies of Bolton and Kacperczyk (2021) and Ilhan et al. (2021), we select several other control variables that may influence the variation in the corporate stock return of listed companies. These control variables are defined as follows: market capitalization (*SIZE*) is firms' the logarithm of market capitalization (price times shares outstanding, in thousand *CNY*); stock volatility (*VOL,* %) is the standard deviation of monthly returns on the past one year; the book value of leverage(*LEVERAGE*) is defined as the book value of debt divided by the book value of assets; return on equity (*ROE*) is the ratio of net profit to equity; operating revenue ratio (*SALES*) is the ratio of operating revenue to total assets; ownership concentration (*Sharehld*) is defined as the shareholding ratio of the top 3 shareholders of the company; *ESGP* describe firm's performance on environmental, social, and governance; CEO duality (*Dual*) is set to 1 if the manager has the duality of CEO, chairman, and general manager, otherwise it is 0; management shareholding (*Manage*) is defined as the ratio of shareholding ratio of directors, supervisors, and management of the company; board size (*Drscale*) is the number of directors of the company; corporate ownership (*SOE*) is set to 1 if the company is a state-owned company, otherwise it is 0.

3.3 Descriptive statistics and sample comparisons

Table 1 provides the descriptive statistics of the research sample. Moreover, as different industries exhibit different environmental characteristics, we further describe the environmental regulations among industries in Fig. 2. From Table 1, we can find that the average firm's excess return on stocks is 0.180%, with a standard variation of 0.706%. The mean of *PEN* and *EID* are 0.029 and 0.133, respectively, which indicate that nearly 727 samples have been subject to environmental penalties and over 3335 samples have disclosed their environmental information in our research sample. Fig. 2 exhibits the summary statistics of environmental penalties and EID among different

industries classified by the China Securities Regulatory Commission (CSRC) in 2012. Some sectors, like mining, construction, production, and supply of electric power, steam, gas, and hot water, are more likely to be punished due to environmental violations. However, such industries are also the ones with higher proportions of EID. Over 50% of firms in the manufacturing sector and transportation sector have disclosed their environmental information. The results also show significant variations exist in the firm's environmental penalties and EID across industries. We control for most of these sources of variation with fixed effects.

Table 1 Summary statistics.

This table reports the summary statistics (observations, means, standard deviations, minimum values, and maximum values) for all the variables in our analysis. *STRET* is the annual excess stock return defined as the difference between the annual corporate stock yield and the yield on the one-year national debt; *PEN* is the dummy variable of whether the firm *i* is subject to environmental penalties at year *t*; *EID* is the dummy variable of whether the firm *i* discloses environmental information at year *t*; *SIZE* is firms' the logarithm of market capitalization (price times shares outstanding, in thousand *CNY*); *VOL* is the monthly stock return volatility defined as the standard deviation of monthly returns on the past 12 months; *LEVERAGE* is the book value of leverage defined as the book value of debt divided by the book value of assets; *ROE* is the return on equity defined as the ratio of net profit to equity; *SALES* is the operating revenue ratio calculated as the ratio of operating revenue to total assets; *Sharehld* represents the ownership concentration defined as the top 3 shareholders of the company; *ESGP* describe firm's performance on environmental, social, and governance; *Dual* is the firm's CEO duality which is set to one if the manager has the duality of CEO, chairman or the general manager; *Manage* is the management shareholding defined as the ratio of shareholding ratio of directors, supervisors and management; *Drscale* is the board size defined as the logarithm of directors numbers; *SOE* describe the corporate ownership which is set to one if the company is a state-owned company. The sample period is 2006-2020. All variables are winsorized at the 1st and 99th percentiles. Table A1 defines all variables in detail.

Variable	Observations	Mean	Standard deviation	Min	Max
STRET(%)	25082	0.180	0.706	-0.725	3.026
PEN	25082	0.029	0.168	0	1
EID	25082	0.133	0.339	0	1
SIZE	25082	22.419	0.974	20.161	25.824
VOL(%)	25082	0.134	0.062	0.042	0.441
LEVERAGE	25082	0.442	0.211	0.052	0.978
ROE	25082	5.314	17.060	-115.800	43.790
SALES	25082	0.631	0.440	0.027	2.536
Sahrehld	25082	0.482	0.152	0.167	0.862
ESGP	25082	6.423	1.125	3.000	9.000
Dual	25082	0.256	0.436	0	1
Manage	25082	14.329	27.478	0	122.886
Drscale	25082	2.223	0.285	1.386	2.890

SOE	25082	0.360	0.480	0	1

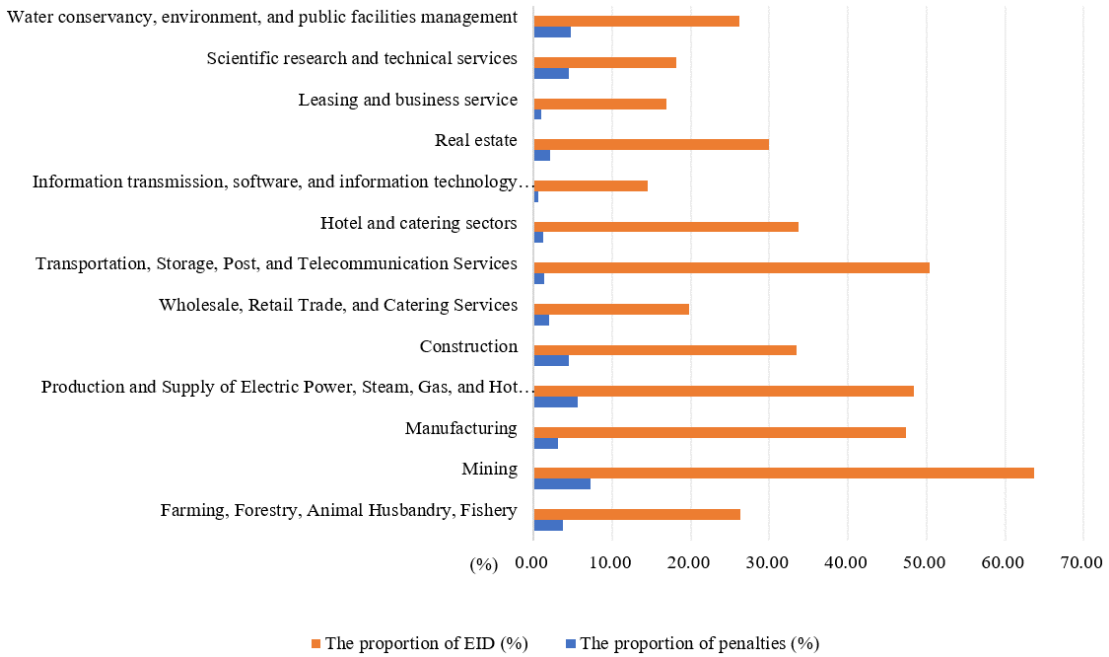

Fig. 2 The proportion of environmental regulations by industry of Chinese listed firms from 2006-2020. *Note:* The data source is the website of cninfo and the Chinese Research Data Services (CNRDS), and the data sample period is 2006-2020. The proportion of EID (%) denotes the ratio of samples with EID to the total samples, while the proportion of penalties (%) denotes the ratio of samples with environmental penalties to the total samples.

4. Do environmental regulations affect corporate stock returns?

In this section, we first construct the empirical model and explore the effects of environmental penalties and EID on a firm's stock returns. We conduct a series of robustness checks to verify the authenticity of the results. Then we discuss the mechanism of environmental penalties and EID on a firm's stock returns, respectively.

4.1 Effects of environmental penalties and EID on environmental risk premium

We first estimate the following regression model (1) to examine the effects of environmental penalties and EID on firms' stock returns:

$$STRET_{it} = \alpha_0 + \alpha_1 PEN_{it} + \alpha_2 EID_{it} + \alpha_3 Control_{it} + \theta_i + \eta_{tk} + \gamma_t + \varepsilon_{it} \quad (1)$$

where the dependent variable ($STRET_{i,t}$) is the excess stock return of firm i in year t, PEN_{it} is the dummy variable of whether the firm is subject to environmental penalties. EID_{it} is the dummy variable of whether the firm discloses its environmental information. The vector of controls includes a host of firm-specific variables known to predict returns, including total assets (*SIZE*), stock volatility (*VOL*), leverage (*LEVERAGE*),

return on equity (*ROE*), operating revenue ratio (*SALES*), ownership concentration (*Sharehld*), CEO duality (*Dual*), management shareholding (*Manage*), board size (*Drscale*), and corporate ownership (*SOE*). Moreover, to alleviate the impact of environmental performance on EID, we include firm's performance on environmental, social, and governance (*ESGP*) in the regression model. α_1 and α_2 are the key coefficients of interest. α_1 reflects the change in stock returns after being subject to environmental penalties. α_2 reflects the changes in stock return after the EID. α_0 is the intercept term. θ_i is the firm fixed effect, and γ_t is the year fixed effect. ε_{it} is the random error. We cluster standard errors at the firm level.

We report the regression results in Table 2. The coefficients of environmental penalties are both significantly positive in Column 1 to Column 3. Meanwhile, the coefficients of EID are both significantly negative in Column 1 to Column 3. The results are consistent with the propositions we proposed in Section 2, which suggest that environmental penalties lead to higher stock returns and higher corporate risk premium, while EID results in a lower risk premium and enable firms to having a lower financing costs in the capital market. These results are not only statistically significant but also economically meaningful. To illustrate, in Column 2, a one standard deviation change in *PEN* (0.168) and *EID* (0.339) is associated with a 0.50% increase in stock return (calculated as 0.168×0.030) and 0.98% decrease in stock return (calculated as (-0.029)×0.339), respectively. The consistent results across different schemes give us confidence that the relation between *PEN*, *EID* and the firm's stock returns are relatively stable.

Table 2 The effects of environmental penalties and EID on stock returns.

The sample period is 2006-2020. The dependent variable is the stock return estimated in each period. Column 1 to Column 2 reports the effects of environmental penalties and EID on stock return under different circumstances. All variables are winsorized at the 1st and 99th percentiles. Control variables are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1)	(2)	(3)
PEN	0.045***	0.022*	0.030**
	(2.71)	(1.70)	(2.03)
EID	-0.016*	-0.029***	-0.029***
	(-1.73)	(-5.38)	(-3.29)
Constant	0.186***	-2.828***	-7.797***
	(48.90)	(-32.20)	(-32.90)
Control variables	No	Yes	Yes
Year fixed effects	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes
Observations	25,082	25,082	25,082
Adjusted R^2	0.581	0.669	0.681

We then conduct a series of robustness checks. Firstly, as the stock return changes with high frequency, the annual stock return may not reflect the market reaction accurately. We therefore recalculate the dependent variable with the monthly excess stock return and then reexamine the relationship between environmental penalties, EID, and corporate stock excess returns. Therefore, the two variables are required to be recalculated using the monthly data, including the monthly excess stock return (*STRETM*) defined as the monthly corporate stock yield net of the yield on the one-month national debt and the monthly stock volatility (*VOLM*) defined as the standard deviation of returns on the past 12 months of monthly returns. Other variables are defined as before. More importantly, we control for the monthly fixed effect. We report the results in Column 1 of Table 3. Consistent with the results of EID on stock returns, the evidence indicates a positive effect of environmental penalties on firms' stock returns, meanwhile, the effective of EID on stock returns are negative.

Secondly, the selection bias may lead to the inaccuracy of the results in Table 2. Consequently, we use the propensity score matching (PSM) method to avoid sample biases and causal interferences (Cole et al., 2021). Specifically, we apply the logit model and the nearest neighbors matching method with the matching proportion of 1:3. The covariates represent the firm's characteristics, including total asset (*TA*), invest rate (*INVEST/A*), firm's fixed asset (*FA*), firm's growth rate of earnings per share (*EPSGR*), the ratio of shares held by institutional investors to circulation shares (*Ihld*), and firm's age of listing (*Age*). The results after matching are shown in Column 2 of Table 3, and the results are in line with our main conclusions.[8]

In addition, we eliminate the financial crisis period of 2008 and 2009, along with the China's stock market crash in 2015, which resulted in the unstable fluctuation of stock returns. We report the results in Column 3 Table 3. The results are consistent with our conclusions. Moreover, China has formulated a series of policies aiming at encouraging firm's environmental responsible behaviors and discourage firm's pollution behaviors, including the Green Credit Policy in 2012, the Carbon Emissions Permit trading since 2013, and so on. Thus, firm's environmental penalties and EID may be affected by such policies. To exclude the impacts of relevant policies, we eliminate heavy-industrial firms in our sample. We report the results in Column 4 Table 3. We find that, in aggregate, environmental penalties can have significant positive effect on a firm's environmental stock returns, while EID enable firms to obtain a lower premium in the financial market.

[8] Table A2 and Fig. A1 present the results of the balancing assumption test and the standardized bias across covariates before and after matching. We can find that there exist significant differences between different groups before matching. However, the biases are substantially reduced and the statistics of difference in different groups are insignificant after matching. Thus, the sample selection bias has been greatly reduced.

Table 3 The effects of environmental penalties and EID on stock return under a series of robustness checks.

The sample period is 2006-2020. The dependent variable is the stock return estimated in each period. Column 1 reports the results when recalculating the environmental risk premium using the monthly returns. Column 2 shows the results after considering sample selection bias. Column 3 shows the results after eliminating the financial crisis periods of 2008, 2009 and 2015. Column 4 shows the results after considering the policy impacts. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) Reestimate the environmental risk premium	(2) Sample selection bias	(3) Eliminating the financial crisis periods	(4) Eliminating other policy impacts
PEN	0.002*	0.030**	0.031**	0.033*
	(1.84)	(2.00)	(2.14)	(1.66)
EID	-0.002***	-0.029***	-0.018**	-0.026**
	(-3.17)	(-3.30)	(-1.97)	(-2.31)
Constant	-0.626***	-7.762***	-7.609***	-7.886***
	(-33.44)	(-32.68)	(-30.13)	(-27.50)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Monthly fixed effects	Yes	No	No	No
Observations	265,231	24,967	20,916	17,798
Adjusted R^2	0.430	0.681	0.637	0.666

More importantly, previous studies have demonstrated that firms are eager to present themselves as environmentally responsible through overly positive disclosures aiming at attaining higher market reaction, therefore, firms with better environmental performance are more inclined to disclose their environmental information (Kim and Lyon, 2011; Jahn and Brühl, 2019). Consequently, the decision of EID may not be random. Besides, with the raising awareness on environmental protection of investors, the impacts of EID on investors' portfolio holdings are becoming more and more prominent. The stock excess return may thus affect firm's decision of EID. Apparently, the factors above may lead to biased and inaccurate results. To solve this problem, we apply the 2SLS regression to reinforce the stability and reliability of our conclusions. Specifically, we use the teleservice (*TELE*) defined as the total sum of tele services of city *j* at year *t* to represent the instrument variable in the 2SLS regression. For one thing, with the prevalent use of Internet, investors have been used to acquire information via internet media. Thus, higher sum of regional tele services represents higher probability of that investors obtain the corporate environmental information. For another, there exists no direct relationship between the sum of regional teleservice and firm's stock returns. We report the result of 2SLS regression in Table 4. The effect of EID on stock returns remains negative, which is still consistent with our conclusions before.

Moreover, the statistics also show that the instrument variable *TELE* has passed the under-identification test and weak identification test.

Table 4 The effects of environmental penalties and EID on stock return by 2SLS regression.

The sample period is 2006-2020. The dependent variable is the stock return estimated in each period. Column 1 reports the first stage of 2SLS regression result. Column 2 reports the result of 2SLS regression. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	*EID*	*STRET*
	(1)	(2)
TELE	0.018**	
	(2.37)	
EID		-1.250*
		(-1.78)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Observations	22,626	22,626

Although we have controlled the systematic differences by controlling corporate characteristic variables such as market capitalization, leverage, and ROE, there may still exist unobservable factors that will interfere with the regression results. Therefore, we apply the placebo test to construct a series of counterfactual tests that makes contrary assumptions about the impact of penalties and EID to examine the robustness of the regression results. If the impact of penalties and EID on stock return is still significant under the counterfactual conditions, it means that the impacts come from the unobservable factors, but not from the disclosure of penalties and EID. Specifically, we use bootstrap to randomly select the disclosure date of environmental information for each company, and repeat the experiments 10,00 times according to regression model (6). The regression results are reported in Fig.A2. We can find that the estimator of the coefficient is nearly normally distributed and mostly around 0, which means that the hypothetical event may have a relatively small probability that the regression coefficient of penalties and EID disclosure will be significant. Hence, the counterfactual treatment effect of environmental information disclosure does not exist.

4.2 Mechanisms of environmental penalties on stock returns

In this section, we examine the influencing mechanisms of environmental penalties on stock excess return. Specifically, we discuss the mechanisms from the perspective of compliance costs and Financing constraints.

4.2.1 Environmental compliance costs

We firstly discuss the influential mechanism of environmental penalties from the perspective of compliance costs. As firms with environmental penalties have to allocate more resources on restricting their environmental behaviors. Investors will inevitably charge for higher returns for their environmental risks if they include such firms into their portfolio holdings. Consequently, we provide the evidence that whether the environmental penalties can lead to higher compliance costs. The results are shown in Table 5. We use the pollution fees and corporate environmental tax to represent the firm's compliance costs. In Column 1, the coefficient of *PEN* is significantly positive at 1% level, which suggests the positive relationship between environmental penalties and environmental compliance costs. In column 2, the coefficient of the interaction term is also significantly positive at 5% level. In aggregate, our results show that higher compliance costs after being environmental penalties contribute investors to charge for a higher compensation for their environmental risks and firms are consequently with higher risk premiums.

Table 5 The impact of compliance costs on environmental penalties and stock returns.

The sample period is 2006-2020. In Column 1, the dependent variable is the compliance costs. In Column 2, the dependent variable is firm's stock excess return. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *Compliance costs*	(2) *STRET*
PEN	0.116***	-0.350*
	(4.23)	(-1.90)
Compliance costs		-0.117***
		(-14.23)
*PEN*Compliance costs*		0.026**
		(2.01)
Constant	-0.611	-8.185***
	(-1.44)	(-29.60)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Number of observations	19,136	19,136
Adjusted R^2	0.874	0.691

4.2.2 Financing constraints

We then discuss the effect of Financing constraints in environmental penalties and firm's risk premiums. In recent years, China has formulated a series of environmental-

friendly policies. On of the most important policies is the Green Credit Policy implemented in the year of 2012,[9] which encourages commercial banks to offer loans to the firms with environmental responsible behaviors. Thus, firms with environmental penalties are more difficult to acquire credit loans and thus faced with stricter Financing constraints. Therefore, we then explore whether Financing constraints caused by environmental penalties will contribute to higher risk premiums.

We apply the *SA* index to measure firm's Financing constraints. Form Fig. 2 in Section 3, we can find that firms subject to environmental penalties are mainly heavy industrial firms. However, researchers have pointed that the allocation of credit resources is highly related to the pollutant emission. For one thing, heavy polluting firms are generally equipped with substantial mortgage assets of high quality. For another, such firms are mainly state-owned enterprises and are more inclined to acquire guarantee from the government and thus more preferred by credit resources.

Moreover, regional environmental regulation is another vital factor affecting the credit resources allocation. As higher intensity of environmental regulation brings about more difficulties for heavy polluting firms when applying for credit loans. Consequently, firms of heavy polluting industries may hardly be restricted by Financing constraints especially in the areas lacking of environmental regulation. Therefore, we in addition include the environmental regulation factor in our regression model.

Referring to the studies of Levinson (1996) and Wu et al. (2020), we construct the intensity of the regional environmental regulation index (ER_{it}) using the industrial sulfur dioxide removal rate and industrial dust removal rate at the city level. We firstly standardize the industrial sulfur dioxide removal rate and industrial dust removal rate following Eq. (3):

$$pollutant_{ij} = \frac{pollutant_{ij} - min(pollutant_{ij})}{max(pollutant_{ij}) - min(pollutant_{ij})} \tag{2}$$

where $pollutant_{it}$ represents the removal rate of pollution j (industrial sulfur dioxide or industrial dust) of city i, $\min(pollutant_{it})$ and $max(pollutant_{it})$ represent the minimum and maximum of pollution j of city i, respectively. We then estimate the pollution weight by using the pollutant proportion and the GDP weight of each city following Eq. (4):

$$w_{ij} = \frac{pollutant_{ij}}{\sum_i pollutant_{ij}} / \frac{gdp_i}{\sum_i gdp_i} \tag{3}$$

where $\sum_i pollutant_{ij}$ represents the pollutant j of the city i in the whole country, while $\sum_i gdp_i$ represents the national GDP. Finally, we obtain the environmental regulation (ER_{it})

[9] https://www.gov.cn/gongbao/content/2012/content_2163593.htm

intensity index of city *i:*

$$ER_{it} = \sum_{j=1}^{2} w_{ij}\, pollutant / 2 \quad (4)$$

We report the results of Financing constraints and environmental regulation in Table 6. The number of observations changes because the raw data of pollutant removal rate are partially missing. In column, the coefficient of environmental penalties is significantly positive at 1% level, indicating the environmental penalties may induce higher Financing constraints. However, the coefficient of the interaction term in Column 2 is not significant, which is possible due to the preference of credit allocation and insufficient environmental regulation. Therefore, we introduce the environmental regulation in Column 3. The coefficient of *PEN*Financing constraints*ERS* is positive at 10% level. The results demonstrate that in reginal of strict environmental regulations, firms with environmental penalties have to face higher Financing constraints, thus resulting in higher risk premiums.

Table 6 The impact of Financing constraints on environmental penalties and stock returns.

The sample period is 2006-2020. In Column 1, the dependent variable is the compliance costs. In Column 2 and Column 3, the dependent variable is firm's stock excess return. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1)	(2)	(3)
	Financing constraints	*STRET*	*STRET*
PEN	0.016***	-0.307	-0.344
	(3.21)	(-1.05)	(-1.17)
Financing constraints		0.523***	0.524***
		(5.39)	(5.39)
*PEN*Financing constraints*		-0.085	-0.095
		(-1.14)	(-1.26)
ERS			0.043
			(0.23)
*PEN*ERS*			3.607*
			(1.92)
*ERS*Financing constraints*			0.004
			(0.07)
*PEN*Financing constraints*ERS*			1.004*
			(1.89)
Constant	-3.432***	-6.062***	-6.057***
	(-42.24)	(-16.78)	(-16.77)
Control variables	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Number of observations	24,292	24,292	24,292
Adjusted R^2	0.951	0.679	0.679

4.3 Mechanisms of EID on stock returns

In this section, we examine the influencing mechanisms of EID on stock excess return. Specifically, we discuss the mechanisms from the perspective of information asymmetry and Financing constraints.

4.3.1 Alleviating information asymmetry

Referring to the studies of Amihud et al. (1997), Amihud (2002) and Pastor and Stambaugh (2003), we use the daily transaction data of China's capital market from 2006-2020 to calculate the liquidity ratio (LR), illiquidity ratio (IR) and return reversal (RR). We then use the principal component analysis (PCA) to extract the common component related to asymmetric information, which is used to measure information asymmetry (*ASY*) (Bharath et al., 2009).

We then discuss the effects of information asymmetry in EID and firm's excess returns. We report the results in Table 7. The coefficient of EID in Column 1 is significantly positive at the 1% significant level, suggesting that there exists a significant positive relationship between EID and stock information asymmetry. In addition, the coefficient of the interaction term in Column 2 is significantly negative, which indicate that for firms with higher information asymmetry, EID can better reduce the risk premiums. The results provide evidence that disclosing environmental information can increase information transparency and alleviate the information asymmetry between firms and investors, thus reducing firm's risk premiums.

Table 7 The impact of information asymmetry on EID and stock returns.

The sample period is 2006-2020. In Column 1, the dependent variable is the information asymmetry (*ASY*). In Column 2, the dependent variable is the firm's stock return. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *ASY*	(2) *STRET*
EID	-0.012*** (-3.44)	-0.023*** (-2.58)
ASY		0.886*** (21.74)
*EID*ASY*		-0.237*** (-8.09)
Constant	5.515*** (54.95)	-12.092*** (-32.24)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes

Firm fixed effects	Yes	Yes
Number of observations	25,082	25,082
Adjusted R^2	0.818	0.704

To reinforce the mechanism of alleviating information asymmetry, we further consider the effects of information leakage via the Internet and social media. Media coverage tend to attract investors' attention and motivate them to change their purchase preferences (Carpentier and Suret, 2015).

As investors can acquire more firm's information by searching on the Internet or news report, the effectiveness of EID on risk premiums may thus be weakened for firms with higher times of internet searches or news report. Consequently, we use the web search index (*WSI*) defined as the search times of the firm's stock code and firm's name to represent the internet search factor. Also, we use the times of corporate news reported by the media (*NEWS*) to represent news report factor. We then include the interaction term of *EID* and the two factors in the regression function. The results are shown in Table 8. In Column 1 and Column 3, the coefficients of *EID* are both significantly positive, indicating that firms with EID tend to have higher times of internet searches and news report. In Column 2 and Column 4, the coefficients of *EID*WSI* and *EID*NEWS* are significantly positive at 1% level, suggesting that the effectiveness of EID on risk premiums will be weakened for firms with lower information asymmetry. Our results are consistent with previous studies. Taken together, EID can reduce information asymmetry between firms and investors and thereby improve the firm's competitiveness and investors' purchase intention, thus finally enabling firms to acquire lower financing costs in the stock market.

Table 8 The impact of news reports on EID and stock return.

The sample period is 2006-2020. In Column 1 and Column 3, the dependent variables are the search times of the firm's stock code and firm's name of firm *i* at the end of year *t* (*WSI*) and the times of news reports of firm *i* at the end of year *t* (*NEWS*), respectively. In Column 2 and Column 4, the dependent variables are the firm's stock return. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *WSI*	(2) *STRET*	(1) *NEWS*	(2) *STRET*
EID	0.008* (1.75)	-0.163*** (-8.16)	0.277*** (3.28)	-0.041*** (-4.40)
NEWS				-0.003** (-2.03)
*EID*NEWS*				0.005*** (3.29)
WSI		-0.045***		

		(-2.59)		
*EID*WSI*		0.062***		
		(8.06)		
Constant	1.834***	-7.739***	-14.296***	-7.821***
	(12.15)	(-32.71)	(-7.06)	(-32.92)
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Number of observations	25,082	25,082	25,082	25,082
Adjusted R^2	0.973	0.682	0.744	0.681

4.3.2 Financing constraints

In previous discussions, we have analyzed the effects of Financing constraints in environmental penalties and risk premiums. In addition, many pieces of researches have pointed that information disclosure can also alleviate firm's Financing constraints. Moreover, the environmental policies on financing have paid much attention on firm's information disclosure. Firms with higher quality of EID have higher possibility of gaining loans. We, therefore, examine whether financing constraints can play an important role in affecting EID and risk premiums. Similarly, we also consider the effect of regional environmental regulation. We report the results in Table 9. In column, we test the relationship between EID and financing constraints. However, the result does not show there exists significant relationship between them. We then include the interaction term of *EID and Financing constraints* in the regression model. In column 2, the coefficient of the interaction term is significantly negative at 1% level, indicating that for firms with higher financing constraints, EID can better reduce the firm's risk premiums. In Column 3, we consider the factor of environmental regulation. The coefficient of *EID*Financing constraints*ERS* is also significantly negative at 1% level, suggesting that the effect of financing constraints on EID and risk premium are more prominent in areas with stricter environmental regulation, which is consistent with the results of Column 3, Table 6.

Table 9 The impact of financial constraints on EID and stock returns.

The sample period is 2006-2020. In Column 1, the dependent variable is the compliance costs. In Column 2 and Column 3, the dependent variable is firm's stock excess return. All variables are winsorized at the 1st and 99th percentiles. Controls are defined in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1)	(2)	(3)
	Financing constraints	*STRET*	*STRET*
EID	-0.002	-0.720***	-0.725***
	(-0.93)	(-5.35)	(-5.35)

Financing constraints		0.570***	0.570***
		(5.58)	(5.56)
EID Financing constraints*		-0.182***	-0.183***
		(-5.16)	(-5.15)
ERS			0.392
			(1.31)
*EID*ERS*			-0.858**
			(-2.05)
ERS Financing constraints*			0.105
			(1.28)
EID Financing constraints*ERS*			-0.253**
			(-2.17)
Constant	-3.433***	-5.897***	-5.886***
	(-41.93)	(-15.93)	(-15.87)
Control variables	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Number of observations	24,292	24,292	24,292
Adjusted R^2	0.951	0.680	0.680

5. Political connection, investor attention and different industries

In this section, we further analyze the impacts of environmental regulations on stock returns under different political connection, different investor attention intensity, and different industries. Specifically, we use the firm's political background and analyst frequency to represent the political connections and investor attention and then discuss their effects on environmental risk premium respectively.

5.1 The effects of political connection on stock returns

Researchers have demonstrated that political connection has always be a vital factor affecting firms' environmental behavior and investors' choice. We then discuss the effects of political connection on environmental regulations and stock excess return. Referring to the studies of Boubakri et al. (2008), we use firm's political experiences (PC_{it}) to measure whether the firm has political connection. Specifically, *PC* is set to be 1 if one of the companies' directors or managers is or was a senior government official, or any other top bureaucrat, otherwise it is 0. We include the interaction term of environmental regulations and political connection into the regression model and the results are shown in Table 10. In Table 10, Column 1, the coefficient of *PEN*PC* is significantly positive while that of *EID*PC* is significantly negative. The results are suggesting that for firms with political connection, environmental penalties will lead to

higher risk premium. However, EID can further enable firms to acquire lower risk premium.

Table 10 The impact of environmental regulations on stock returns under different political connections.

The sample period is 2006-2020. Column 1 and Column 2 report the effects of environment penalties and EID on stock returns with political connections, respectively. All variables are winsorized at the 1st and 99th percentiles. Controls are as in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *STRET*	(2) *STRET*
PEN	0.012	
	(0.72)	
*PEN*PC*	0.067**	
	(2.00)	
PC	-0.042***	-0.029***
	(-4.35)	(-2.70)
EID		-0.019*
		(-1.91)
*EID*PC*		-0.029**
		(-2.02)
Constant	-7.795***	-7.817***
	(-32.96)	(-33.04)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Number of observations	25,082	25,082
Adjusted R^2	0.681	0.681

To further explore the effects of political connection level on environmental regulations and firm's risk premium, we define the political connection level (*PLevel*) according to the rank of officials. Specifically, we classified five categories: national level (ministerial level), provincial level (departmental level), city level (division level), district and county level (section level), and no political connection. And we assign the variables from four to zero in sequence (Fan et al., 2007). Similarly, we introduce the interaction term of environmental regulations and political connection level (*PLevel*) into the regression model. We show the results in Table 11. In Table 11, Column 1, the negative and significant coefficients of *PEN*PCLevel* suggest the negative impact of political connection on a firm's risk premium. Consistent with the results in Table10, Column 2, the coefficient of *EID*PCLevel* remain to be negative. Our results indicate that firms with political connection are more inclined to face higher risk premium. Besides, firms of higher political levels can acquire lower risk premium by disclosing environmental information. Compared with previous researches claiming that political

connection enables firms to acquire more political protection and lower risk premiums, , we demonstrated that it may not work when it comes to environmental regulations, that is, political connection can no longer provide administrative protection for politically affiliated firms.

Table 11 The impact of environmental regulations on stock returns under different political connections levels.

The sample period is 2006-2020. Column 1 and Column 2 report the effects of environment penalties and EID on stock returns under different political connections, respectively. All variables are winsorized at the 1st and 99th percentiles. Controls are as in Table 1. Standard errors are clustered at the firm level, and t-statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *STRET*	(2) *STRET*
PEN	0.010	
	(0.60)	
*PEN*PCLevel*	0.024**	
	(2.25)	
PCLevel	-0.015***	-0.011***
	(-4.79)	(-3.14)
EID		-0.020**
		(-2.08)
*EID*PCLevel*		-0.008*
		(-1.79)
Constant	-7.804***	-7.827***
	(-33.01)	(-33.09)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Number of observations	25,082	25,082
Adjusted R^2	0.681	0.681

5.2 The effects of EID on stock returns of different industries

Heavy polluting firms undertake higher costs of environmental management and are more exposed to environmental regulation risk, which is reflected in their asset prices (Ihan et al., 2020). Specifically, heavy-polluting firms are more likely to be exposed to litigation risk, poor reputations, and environmental administrative penalties, which reduce their future profitability under stricter environmental regulations (Hsu et al., 2022). Consequently, the effects of environmental regulations on environmental risk premium may vary among different industries.

According to the *Environmental Information Disclosure Guidelines for Listed Companies* released by the Ministry of Environmental Protection of China in 2010, we include sixteen industries, including steel, cement, coal, and chemicals as heavily

polluting industries. *HP* is a dummy variable indicating whether the firm belongs to heavy polluting industries. *HP* is set to 1 if the firm belongs to heavy polluting industries, otherwise it is 0. We then analyze the impact of EID on different industries by dividing the sample into heavy-polluting industries and non-heavy-polluting industries. The results are reported in Table 13. In Column 1, the coefficient of *PEN*HP* is insignificant, suggesting that the effects of environmental penalties do not exhibit differences in different industries. In Column 2, however, the coefficient of *EID*HP* is significantly positive at 1%, which indicates that heavy polluting industries have more difficulties in acquiring lower risk premiums. In other words, non-heavy polluting firms can obtain lower risk premiums after EID. The results above conclude that non-heavy-polluting firms can better reduce their risks premiums by disclosing environmental information. As heavy-polluting firms may have higher risks of environmental violation (Hsu et al., 2022), investors are asking higher compensation for the environmental risks to the heavy-polluting industries. In contrast, non-heavy polluting industries can earn lower financing costs by providing more environmental information.

Table 13 The impact of environmental regulation on risk premium in different industries.

The sample period is 2006-2020. The table reports the impact of corporate fame on environmental regulation risk premium. All variables are winsorized at the 1st and 99th percentiles. Column 1 reports the effects of environmental penalties on stock returns under different industries. Column 2 reports the effects of EID on stock returns under different industries. Controls are as in Table 1. Standard errors are clustered at the firm level, and t- statistics are reported in parentheses. ***1% significance; **5% significance; *10% significance.

Variables	(1) *STRET*	(2) *STRET*
PEN	0.024	
	(1.22)	
*PEN*HP*	0.014	
	(0.49)	
EID		-0.053***
		(-4.71)
*EID*HP*		0.070***
		(4.00)
Constant	-7.798***	-7.817***
	(-32.91)	(-32.97)
Control variables	Yes	Yes
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Number of observations	25,082	25,082
Adjusted R^2	0.681	0.681

6. Conclusions

With the policy requirements and rising concerns of investors about the environment, the environmental risk resulting from environmental regulations has been an important aspect for investors when considering the investment portfolio. To examine this issue of great importance, accordingly, we collect the comprehensive sample of Chinese listed firms from 2006-2020 and discuss the influences of environmental regulations on firm's stock excess return. Specifically, we consider the two most important environmental regulation: environmental penalties and environmental information disclosure (EID).

We provide evidence that the environmental penalties can have positive effects on stock excess returns, suggesting that firms with environmental penalties have to burden higher risk premiums and financial costs in the capital market. In contrast, however, EID leads to a lower stock excess return, thus enabling firms to acquire financing at lower costs in the capital market. Our results indicate that investors are already demanding compensation for their exposure to environmental risk. The results survive a series of robustness checks.

We further find that environmental penalties will lead to higher environmental compliance costs and stricter financing constraints, thus resulting in higher risk premiums. However, the information asymmetry and financing constraints are alleviated by EID, thereby reducing firm's risk premiums and financing costs. Importantly, the effects of financing constraints are more effective under higher intensity of regional environmental regulations.

Moreover, firms with political connections are more inclined to bear higher risk premium after being punished by environmental penalties. Besides, firms of higher political levels can acquire lower risk premium by EID. Our results suggest that political connection can no longer provide administrative protection for politically affiliated firms when it comes to environmental regulations. Finally, we have also noticed that compared to heavy polluting firms, non-heavy polluting firms can acquire lower risk premium after disclosing environmental information.

Our results shed light on significant policy implications. Firstly, our results show that investors are discerning the corporate environmental behavior differences and are pricing in environmental regulation risk. Furthermore, we have demonstrated the effectiveness of environmental penalties in affecting firm's stock returns and investors' choices. Consequently, the governments are supposed to enhance the enforcement of environmental penalties and to apply the uniform standards for administrative punishment, thereby constraining firms' environmental behaviors. Secondly, given that

EID enables firms to provide a lower required return to investors and reduce firms' environmental risk premium, consequently, firms should disclose environmental information integrally and accurately. Doing so alleviates the information asymmetry with investors and financing constraints, thus reducing the firm's risk premium and financial costs. Moreover, firms should be aware of corporate fame and establish a positive and reliable corporate image, thus giving full play to the effectiveness of environmental information disclosure in reducing risk premiums. Finally, as financing constraints are playing important role in affecting firm's environmental behaviors, government should constantly improve the green financing policies, so as to jointly achieve the purpose of regulating corporate environmental behavior through the credit market and capital market.

References

[1] Aghion, P., Dechezlepretre, A., Hemous, D., Martin, R., Van Reenen, J., 2016. Carbon taxes, path dependency, and directed technical change: evidence from the auto industry. J. Polit. Econ. 124, 1–51.

[2] Amihud Y., 2002. Illiquidity and stock returns: Cross-section and time-series effects. Journal Of Financial Markets, 5(1): 31-56.

[3] Amihud Y., Mendelson H., Lauterbach B., 1997. Market microstructure and securities values: Evidence from the Tel Aviv Stock Exchange. Journal of Financial Economics, 45(3): 365-390.

[4] Battiston, S., A. Mandel., I. Monasterolo, F. Schütze., and G. Visentin, 2017, "A Climate Stress-Test of the Financial System", Nature Clim. Change, 7, 283-288.

[5] Benlemlih, M, Shaukat, A., Qiu, Y., Trojanowski, G. Environmental and Social Disclosures and Firm Risk[J]. J. Bus. Ethics, 2018,152(3):613-626.

[6] Bharath, S. T., Pasquariello P., Wu, G. 2009, Does Asymmetric Information Drive Capital Structure Decisions? Review of Financial Studies, 22(8):3211-3243.

[7] Bhattacharya N, Ecker F, Olsson PM, Schipper K. 2012. Direct and Mediated Associations among Earnings Quality, Information Asymmetry, and the Cost of Equity. Account. Rev., 87(2):449-82.

[8] Bizet R, Bonev P, Lévêque F. 2022, The effect of local monitoring on nuclear safety and compliance: Evidence from France. J. Environ. Econ. Manag., 113.

[9] Blanco I, García SJ. 2021. Options trading and the cost of debt. J. Corp. Financ., 69.

[10] Bolton, P. and M. Kacperczyk, 2021, "Do Investors Care about Carbon Risk?", J. Financ. Econ., 142, 517-549.

[11] Bolton, P. and M. Kacperczyk, 2022, "Global Pricing of Carbon-Transition Risk", J. Financ. Econ., Forthcoming.

[12] Boubakri, N., Cosset, J., & Saffar, W. 2008. Political connections of newly private firms. J. Financ. Econ., 14, 654-673.

[13] Campiglio, E., 2016, "Beyond Carbon Pricing: The Role of Banking and Monetary Policy in Financing the Transition to a Low-Carbon Economy", Ecol. Econ., 121, 220-230.

[14] Carattini, S., G. Heutel, and G. Melkadze, 2021. "Climate Policy, Financial Frictions, and Transition Risk", NBER Working Paper no.28525.

[15] Carpentier C. and S. Jean-Marc, 2015, Stock market and deterrence effect: A mid-run analysis

of major environmental and non-environmental accidents. J. Environ. Econ. Manag., 71:1-18.
[16] Chava, S., 2014. Environmental externalities and cost of capital. Manag. Sci. 60, 2223–2247.
[17] Chi, S. S., & Shanthikumar, D. M., 2017. Local Bias in Google Search and the Market Response around Earnings Announcements. Account. Rev., 92(4), 115–143.
[18] Choi B, Luo L. 2021. Does the market value greenhouse gas emissions? Evidence from multi-country firm data. Brit. Account. Rev., 53(1).
[19] Cole, M. A., R. J. R. Elliott, T. Okubo and L. Zhang 2021. Importing, outsourcing and pollution offshoring. Energy Econ. 103, 105562
[20] Cui J., Jo, H., Na H., 2018. Does Corporate Social Responsibility Affect Information Asymmetry. J. Bus. Ethics, 2018, 148:549–572
[21] Derrien F, Kecskés A, Mansi SA. 2016. Information asymmetry, the cost of debt, and credit events: Evidence from quasi-random analyst disappearances. J. Corp. Financ., 39:295-311.
[22] Derrien F, Kecskés A, Mansi SA. 2016. Information asymmetry, the cost of debt, and credit events: Evidence from quasi-random analyst disappearances. J. Corp. Financ., 39:295-311.
[23] Earnhart, D., 2004. Regulatory factors shaping environmental performance at publicly-owned treatment plants. J. Environ. Econ. Manag. 48 (1), 655–681.
[24] Ehlers, T., F. Packer, and K. de Greiff, 2021, "The Pricing of Carbon Risk in Syndicated Loans: Which Risks are Priced and Why?", J. Bank. Financ., 106180.
[25] Fama, E.F., French, K.R., 2015. A five-factor asset pricing model. J. Finan. Econ., 116, 1-22.
[26] Fan, J., Wong, T. J., & Zhang, T., 2007. Politically connected CEOs, corporate governance and post-IPO performance of China's newly partially privatized firms. J. Finan. Econ., 84, 330-357.
[27] Fernando, C. S., M. P. Sharfman and V. B. Uysal 2017. Corporate environmental policy and shareholder value: Following the smart money. J. Financ. Quant. Anal., 52, 2023-2051.
[28] Flammer, C., 2015. Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. Manage. Sci. 61, 2549-2568.
[29] Foulon J, Lanoie P, Laplante Bt. 2002. Incentives for Pollution Control: Regulation or Information? J. Environ. Econ. Manag., 44(1):169-87.
[30] Haddock-Fraser, J.E.; Tourelle, M. Corporate motivations for environmental sustainable development: Exploring the role of consumers in stakeholder engagement. Bus. Strategy. Environ. 2010, 19, 527–542.
[31] Haß, L.H., Vergauwe, S., Zhang, Z., 2019. State-ownership and bank loan contracting: evidence from corporate fraud. Eur. J. Finance 25, 550–567.
[32] Hsu P-H, Li K, Tsou C-Y. 2023. The Pollution Premium. J. Financ., 78(3): 1343-1392.
[33] Huang R, Chen D. 2015. Does Environmental Information Disclosure Benefit Waste Discharge Reduction? Evidence from China. J. Bus. Ethics, 129(3):535-52.
[34] Hutton, A.P., Marcus, A.J., Tehranian, H., 2009. Opaque financial reports, R2, and crash risk. J. Financ. Econ. 94, 67–86.
[35] Ilhan, E., Z. Sautner, and G. Vilkov., 2020, "Carbon Tail Risk", Rev. Financ. Stud., 34, 1540-1571.
[36] Jahn J, Brühl R. Can bad news be good? On the positive and negative effects of including moderately negative information in CSR disclosures.2019, J. Bus. Res., 97:117-28.
[37] Jung, J., Herbohn, K., Clarkson, P., 2018. Carbon risk, carbon risk awareness and the cost of debt financing. J. Bus. Ethics 150, 1151–1171.
[38] Kang; K, Silveira BS. 2021. Understanding Disparities in Punishment: Regulator Preferences and Expertise. J. Polit. Econ., 129(10): 2947-2992.
[39] Kim E-H, Lyon T.P., 2011, Strategic environmental disclosure: Evidence from the DOE's

voluntary greenhouse gas registry. J. Environ. Econ. Manag., 61(3):311-26.
[40] Krueger, P., Z. Sautner, and L.T. Starks, 2020, "The Importance of Climate Risks for Institutional Investors", Rev. Financ. Stud., 33, 1067-1111.
[41] Levinson, A., 1996. Environmental regulations and manufacturers' location choices: evidence from the Census of Manufactures. J. Public Econ. 62 (1-2), 5-29.
[42] Li J, Yang J, Zou Z. 2019. Compensation and risk: A perspective on the Lake Wobegon effect. J. Bank. Financ., 108: 105626.
[43] Li J, Yang J, Zou Z. 2019. Compensation and risk: A perspective on the Lake Wobegon effect. J. Bank. Financ., 108: 105626.
[44] Li K. 2020. Does Information Asymmetry Impede Market Efficiency? Evidence from Analyst Coverage. J. Bank. Financ., 118(9): 1-7.
[45] Lin Z-Y, Chang C-C, Wang Y-H. 2018. The impacts of asymmetric information and short sales on the illiquidity risk premium in the stock option market. J. Bank. Financ., 94:152-65.
[46] Lin Z-Y, Chang C-C, Wang Y-H. 2018. The impacts of asymmetric information and short sales on the illiquidity risk premium in the stock option market. J. Bank. Financ., 94:152-65.
[47] Lu C-W, Chen T-K, Liao H-H. 2010. Information uncertainty, information asymmetry and corporate bond yield spreads. Journal of Banking & Finance. 34(9):2265-79.
[48] Lu C-W, Chen T-K, Liao H-H. 2010. Information uncertainty, information asymmetry and corporate bond yield spreads. Journal of Banking & Finance. 34(9):2265-79.
[49] Lys, T., Naughton, J., & Wang, C., 2015. Signaling through corporate accountability accounting. J. Account. Econ., 60(1), 56-72.
[50] Lys, T., Naughton, J., & Wang, C., 2015. Signaling through corporate accountability accounting. J. Account. Econ., 60(1), 56-72.
[51] Mayberry, M., 2020. Good for managers, bad for society? Causal evidence on the association between risk-taking incentives and corporate social responsibility. J. Bus. Fin. Acc. 47, 1182-1214.
[52] Nadeau, L. W., 1997. EPA effectiveness at reducing the duration of plant-level noncompliance. J. Environ. Econ. Manag. 34 (1), 54–78.
[53] Novy-Marx, R., 2013. The other side of value: The gross profitability premium. J. Finan. Econ., 108, 1-28.
[54] Oestreich A.M., and I. Tsiakas, 2015, "Carbon Emissions and Stock Returns: Evidence from the EU Emissions Trading Scheme", J. Bank. Financ., 58, 294-308.
[55] Pastor L., Stambaugh R F., Taylor L A. 2021. Sustainable investing in equilibrium. J. Finan. Econ., 142(2):550-571.
[56] Pástor, Ľ., Stambaugh, R. F., 2003. Liquidity Risk and Expected Stock Returns. Journal of Political Economy, 111 (3): 642-685.
[57] Sen, S., and M.-T. von Schickfus, 2020, "Climate Policy, Stranded Assets, and Investors' Expectations", J. Environ. Econ. Manag., 102277.
[58] Tu Z, Hu T, Shen R. 2019. Evaluating public participation impact on environmental protection and ecological efficiency in China: Evidence from PITI disclosure. China Econ. Rev., 55:111-23.
[59] Weber, O., 2012. Environmental credit risk management in banks and financial service institutions. Bus. Strat. Environ. 21, 248–263.
[60] Wu K., Lai S., 2020. Intangible intensity and stock price crash risk. J. Corp. Financ., 64, 101682.
[61] Wu, H T., Xu, L.N., Ren, S. Y., Hao, Y., Yan, G. Y. 2020. How do energy consumption and environmental regulation affect carbon emissions in China? New evidence from a dynamic threshold panel model. Resour. Policy, 67: 101678.

[62] Yang YC, Zhang B, Zhang C. 2020. Is information risk priced? Evidence from abnormal idiosyncratic volatility. J. Finan. Econ., 135(2):528-54.
[63] Yang YC, Zhang B, Zhang C. 2020. Is information risk priced? Evidence from abnormal idiosyncratic volatility. J. Finan. Econ., 135(2):528-54.
[64] Zhou, Z., Zhang, T., Wen, K., Zeng, H., Chen, X., 2018. Carbon risk, cost of debt financing and the moderation effect of media attention: evidence from Chinese companies operating in high-carbon industries. Bus. Strat. Environ. 27, 1131–1144.
[65] Zou, H.L.; Zeng, R.C.; Zeng, S.X.; Shi, J.J. How do environmental violation events harm corporate reputation? Bus. Strateg. Environ. 2015, 24, 836–854.

Table A1 Description of all variables.

Variables	Definitions
STRET (%)	Annual excess return on stocks, defined as the difference between the annual corporate stock yield and the yield on the one-year national debt.
PEN	Environmental penalties, it is set to 1 if the company is subject to environmental penalties, otherwise it is 0.
EID	Environmental information disclosure, it is set to 1 if the company has disclosed environmental information, otherwise it is 0.
SIZE	The logarithm of the total assets of the company at the end of year *t.*
BETA	Market risk, defined as the regression coefficient calculated based on the CAPM model over the one-year period using daily data.
VOL (%)	Stock volatility, defined as the standard deviation of returns on the past 12 months of monthly returns.
IDVOL (%)	Idiosyncratic volatility, defined as the residual of the regression model calculated based on the CAPM model by using the past 12 months of monthly returns.
LEVERAGE	Leverage, defined as the ratio of total liabilities to total assets.
INVEST/A	Invest rate, defined as the ratio of capital expenditure to total assets.
ROE	Return on equity, defined as the ratio of net profit to equity.
SALES	Operating revenue ratio, the ratio of operating revenue to total assets.
Sharehld	Ownership concentration, the shareholding ratio of the top 10 shareholders of the company.
Dual	CEO duality, it is set to 1 if the manager has the duality of CEO and chairman or duality of chairman and general manager, otherwise it is 0.
Manage	Management shareholding, defined as the ratio of shareholding ratio of directors, supervisors and management of the company.
Drscale	Board size, defined as the numbers of directors of the company.
SOE	Corporate ownership, it is set to 1 if the company is a state-owned company, otherwise it is 0.

Table A2 Balancing assumption test of PSM covariates.

This table reports the results of the balancing assumption test of PSM covariates, including the mean of treated group, the mean of control group, the bias of the covariates between different groups, the reduction of bias after matching, and the statistics of significance before and after matching (t-value and p-value). *TA* is the logarithm of the total assets of the company at the end of year *t* (in thousand *CNY*) ; *INVEST/A* is the ratio of capital expenditure to total assets; *FA* is the logarithm of the firm's fixed; *EPSGR* is the firm's growth rate of earnings per share; *Ihld* is the ratio of shares held by institutional investors to circulation shares; Age is the firm's duration of listing. All variables are winsorized at the 1st and 99th percentiles.

Variables	Unmatched/ Matched	Treated	Control	Bias%	Reduction of bias%	t-value	p-value
TA	Unmatched	22.756	22.006	60.20	97.00	16.010	0.000
	Matched	22.756	22.733	1.80		0.330	0.744
INVEST/A	Unmatched	0.050	0.051	-3.00	85.50	-0.770	0.442
	Matched	0.050	0.049	0.40		0.090	0.930
FA	Unmatched	21.195	20.088	71.20	99.50	17.780	0.000
	Matched	21.195	21.201	-0.40		-0.070	0.942
EPSGR	Unmatched	-0.760	-0.552	-5.30	54.20	-1.580	0.115
	Matched	-0.760	-0.665	-2.40		-0.440	0.663
Ihld	Unmatched	40.703	37.219	14.90	96.10	4.010	0.000
	Matched	40.703	40.567	0.60		0.110	0.912
Age	Unmatched	12.134	9.979	30.40	93.30	8.510	0.000
	Matched	12.134	11.989	2.00		0.390	0.694

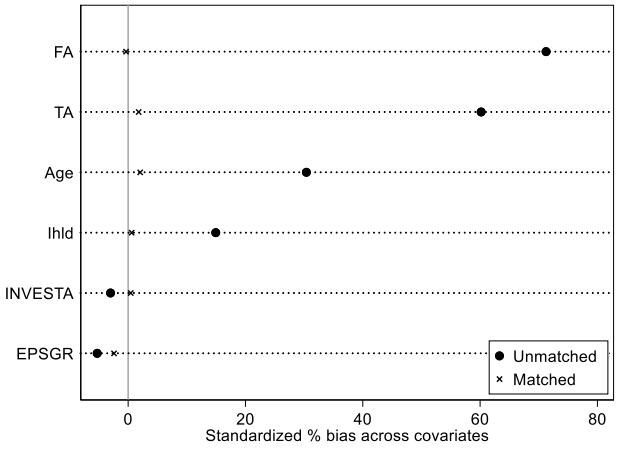

Fig. A1. Standardized bias across covariates before and after matching

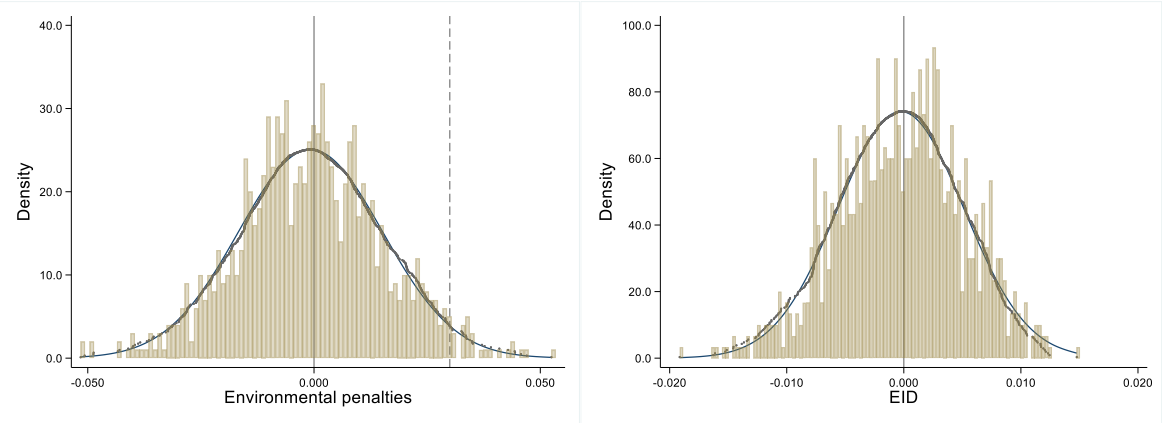

Fig. A2. Placebo tests of environmental penalties and EID