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The Moderating Role of Environmental Information Disclosure on the Impact of Environment Protection Investment on Firm Value

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Abstract: The presence of a link between corporate environmental protection investment and firm value is essential for enterprises to have incentives to invest in environmental protection by themselves. How environmental information disclosure affects the relationship between environmental protection investment and firm value is also an issue worth exploring. This paper uses the regression model with the industry and time-fixed effects to examine the relationship between environmental protection investment and firm value of China's A-share heavily and non-heavily polluting enterprises from 2010–2020, as well as the moderating role of environmental information disclosure. The empirical results show that (1) there is a significant U-shaped relationship between environmental protection investment and firm value, and (2) corporate environmental information disclosure has a moderating effect. Specifically, it has an "amplifying" effect on the relationship between environmental protection investment and firm value. If a company's environmental protection investment is insufficient, overly transparent corporate environmental disclosure will exacerbate the decline in firm value. Once environmental protection investment is up to standard, adequate disclosure can contribute to an increase in firm value.

Keywords: environment protection investment; corporate information disclosure; firm value; moderating effect

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1. Introduction

Resource consumption and environmental pollution, which are byproducts of necessary economic activities, have brought a series of difficulties to global environmental governance and the sustainable development of mankind [1–4]. In the past 40 years, China has made remarkable progress in economic development since the implementation of the reform and opening-up policy. However, the accelerated pace of economic growth has also resulted in more severe ecological and environmental issues. According to the 2020 China Ecological Environment Status Bulletin released by the Ministry of Ecology and Environment, 40% of the total of China's prefecture-level cities, totaling 135, fail to meet the air quality standards, with PM2.5, ozone, and PM10 concentrations exceeding their daily thresholds at 6.8%, 4.9%, and 2.6% of times, respectively. The 2020 Global Environmental Performance Index Report jointly published by Yale University and other institutions revealed that China's environmental standing system ranks in the bottom 60 among 180 countries and regions, with severe ecological and environmental problems limiting the sustainable development of China's economy and society.

Enterprises serve as the cornerstone of a country's economic development. Many operational and production activities conducted by enterprises involve the extraction and consumption of resources, which can potentially result in environmental pollution and inflict negative externalities on society as a whole [5–9]. In accordance with the fundamental

principle of "polluter pays," enterprises should be the principal contributors to investment in environmental protection. However, private enterprises tend to shy away from investing in environmental protection due to the long payback period and high investment scale, which limits their ability to gain immediate economic benefits [10]. Traditional theories suggest that external factors such as environmental regulations and multi-stakeholder games pressure enterprises into investing in environmental protection. Therefore, countries worldwide have established regulations and institutions to encourage, lead, and regulate local environmental protection investment. Empirical evidence shows that external pressure indeed spurs some degree of investment in environmental protection [11]. However, the passive investment may not be as impactful as intended and can sometimes lead to avoidance of regulations and external pressures, resulting in a "talk much but do little" situation [12]. It has also been discovered that both mandatory and voluntary Corporate Social Responsibility (CSR) expenditure has an impact on firm value [13,14]. Therefore, if a clear link exists between investment in environmental protection and firm value, it may be easier for stakeholders to demonstrate the profitability of environmental protection investment to enterprises. The 2020 Evaluation Report on Environmental Responsibility Information Disclosure by Listed Companies in China indicated that corporate information disclosure levels have been increasing steadily year after year. In 2020, 1135 of the 4418 listed companies in the A-share market disclosed their social and environmental responsibility reports, accounting for 25.69% of the total, which is an increase of 129 companies from 2019, and a proportional increase of 11.7%. Corporate information disclosure possesses both social and economic dimensions [15]. According to signaling theory, information disclosure can reduce the information asymmetry between firms and external stakeholders, enabling capital markets to allocate resources more efficiently [16]. For listed companies, the decision to disclose information to the public, and the degree of similarity of disclosures, influences the market's evaluation of the company's production, operations, and social responsibility fulfillment, which, in turn, affects the market's assessment of the firm value.

Previous research primarily focused on the driving factors behind investment in environmental protection, particularly the influence of environmental regulations. Externally, this can be attributed to factors such as environmental governance and government regulations. There are three well-known hypotheses in this regard: the pollution paradise hypothesis, the factor endowment hypothesis, and the Porter hypothesis [17]. Internally, governance factors include property rights [18,19], shareholding structure [20], internal controls, and the environmental investment tendencies of directors and supervisors [21]. However, previous studies have overlooked intrinsic mechanisms that drive investment in environmental protection within enterprises. Furthermore, research examining the economic consequences of environmental protection investment in China has focused mainly on heavily polluting industries, with an insufficient exploration of industry heterogeneity [22]. The relationship between environmental protection investment and firm value in China is further complicated by divergent opinions on the impact of corporate environmental information disclosure. Different studies have produced contrasting results, ranging from a significant positive correlation to a significant negative correlation, a non-linear correlation, or no significant correlation at all [23–30]. This polarization of opinions has led to an under-explored issue.

Based on the above discussion, this paper aims to make a valuable contribution in three key areas: (1) this study examines the relationship between environmental protection investment and firm value, shedding light on the true market reflection of Chinese firms' environmental protection investment. This research emphasizes the economic significance of environmental protection investment, while also deepening insights into the industry heterogeneity of environmental protection investment and the transparency of corporate information disclosure in non-heavily polluting industries; (2) we further examine the moderating effect of environmental information disclosure on the relationship between environmental protection investment and firm value, facilitating a clearer understanding of the role of corporate information disclosure in the capital market; (3) this study provides

empirical evidence supporting enterprises to actively invest in environmental protection and enhance the quality of environmental information disclosure, serving as a crucial reference for the development of new government strategies pertinent to the implementation of environmental protection investment at listed and unlisted companies and the publication of sustainability reports encompassing environmental protection investment.

The structure of the rest of this paper is as follows. Related work is reviewed and the theoretical hypotheses are proposed in Section 2. The data and methodology are then presented in Section 3. Section 4 presents the empirical results. Section 5 provides robustness tests. Section 6 concludes and Section 7 discusses the theoretical and practical implications of our study.

2. Related Literature and Hypotheses

2.1. Environmental Protection Investment

Environmental protection investment is an important part of enterprise environmental, social, and governance (ESG) investment. It is a national economic and social development investment and has three particularities [31]. First, the investors in environmental protection investment are mainly enterprises. Second, the benefits of environmental protection investment are not exclusive to the subjects of environmental protection investment. Finally, the benefits of environmental protection investment are comprehensive and are reflected in environmental, economic, and social aspects.

Typically, the market pays more attention to companies with poor environmental management, and environmental performance and investment are always seen as a risk and rarely as an opportunity. The conventional view is that both waste management and pollution prevention expenditure is a drain on a company's resources and an obligation to use unproductive operating funds [32].

However, a growing number of scholars are arguing against the traditional view that pollution prevention and related investments have certain economic benefits.

Firstly, enterprises complete their production and operation activities by consuming certain environmental resources, and the exhaust gases, wastewater and waste generated during the production process become the main component of pollutant emissions. These products are often the result of inefficient consumption and inappropriate use of resources and energy. By investing in green production processes, machinery and equipment, we can effectively improve the efficiency of resource and energy use, helping companies to reduce their production and operating costs and increase their value [31].

Secondly, pollution prevention and the associated redesign of a company's production processes can open up opportunities for companies to change their production methods in directions such as the reuse of recyclable materials, the targeted retrofitting of old machinery and the research and development of production processes [33], which helps to promote continuous technological innovation, objectively increasing the efficiency of the company's production operations and turning innovation opportunities into competitive advantages [34].

Finally, environmental investment also helps to reduce the risk of corporate non-compliance and environmental costs. Companies with a better environmental record are more attractive investment targets for the capital market, as this implies lower compliance costs [35]. Currently, China has increasingly stringent environmental regulations, with the introduction of emission fees on direct pollutant discharges in July 2003, the introduction of the Environmental Protection Law in 2016, and the Environmental Protection Tax Law in 2018, which "transformed emission fees into environmental protection taxes", all of which represent environmental risks and costs faced by enterprises. Enterprises can invest in environmental protection to a certain extent by making upfront investments to reduce pollution emissions, meet relevant national standards, reduce environmental burdens such as environmental protection tax, and avoid environmental penalties.

At present, the academic community pays relatively little attention to the economic consequences of environmental protection investment in China. Shan [22] found that in the short term, environmental protection investment is negatively correlated with the core competitiveness of enterprises, but in the long run, it can significantly improve the core competitiveness of enterprises, which is manifested in two stages; initial hindrance and late gain. Tang [23] took listed enterprises in heavily polluting industries as a research object and found that the impact of environmental protection value on the value of enterprises showed a non-linear curve relationship which first decreased and then increased. Cui [36] also believed that the relationship between environmental protection investment and firm value showed a decline and then increase, and the CEO's overseas experience had a significant moderating effect on the non-linear relationship between the two.

As a result, environmental protection investment may have both a negative and a positive effect on firm value, and there may be a transition period between the two. As the scale of investment in environmental protection increases, the investment in environmental protection begins to include precautionary technological innovation and the installation of cleaner production equipment, which are capitalized in nature and have a more pronounced value-creating effect.

Therefore, we propose the following hypothesis:

H1. *There is a U-shaped relationship between environmental protection investment and firm value.*

H1a. *Heavily polluting enterprises: A U-shaped relationship between environmental protection investment and firm value.*

H1b. *Non-heavily polluting enterprises: A U-shaped relationship between environmental protection investment and firm value.*

2.2. Environmental Information Disclosure

Environmental information disclosure refers to the disclosure of financial and non-financial information related to the environment, such as natural resource consumption and waste discharge, and environmental governance plans and measures, to those who need information [31] to help investors and other stakeholders understand and make decisions.

As environmental issues become increasingly prominent, the implementation of the environmental responsibilities of listed enterprises has received attention from the regulatory and capital markets. How a listed company fulfills its corporate environmental responsibility has gradually become an important consideration for investors in evaluating their firm value. There are many types of environmental information disclosure carriers around the world. Currently, enterprises mainly issue "Sustainability Reports", "Corporate Social Responsibility Reports (CSR)", "Environmental, Social, and Corporate Governance (ESG) reports", "Environmental Reports", and the appendix of the financial report.

Regarding the relationship between environmental information disclosure and firm value, existing studies have found four different results: significant positive correlation, significant negative correlation, a non-linear correlation, and no significant correlation.

The significant positive correlation between corporate environmental information disclosure and firm value means that environmental information disclosure sends positive signals about the company to the capital market, thereby promoting the improvement of firm value. Tang [23] used the content-based evaluation score released by R&L International Public Welfare as a proxy variable for environmental information disclosure and explored a significant positive relationship between the quality of environmental information disclosure and firm value at the 1% level, while adding the level of corporate internal control as a moderating variable, and concluded that the relationship between the quality of environmental information disclosure and firm value is more positive for companies, with relatively weak internal control quality being a significant factor. Li [24] focused on the relationship between carbon information disclosure and firm value, and empirically tested that corporate carbon information disclosure is significantly and positively correlated with firm value through OLS regression and two-stage least squares, and this correlation is

more significant for firms with high carbon emissions. Shen and Feng [25] concluded that environmental information disclosure is significantly and positively correlated with firm size and profitability.

A significant negative correlation means that enterprises with a high degree of corporate environmental information disclosure will not release a positive signal to the market, and the firm value performance will be worse. A company's environmental protection activities will generate environmental protection expenditure, which increases the production costs and management expenses of the enterprise [26]. Bird [27] found that firms' excess returns are negatively related to the lagged-period environmental information disclosure index. In addition, strict environmental regulations increase firms' production and operating costs, and aggressive environmental information disclosure reduces the financial performance of listed energy firms. Lioui [28] argued that investors perceive environmental protection measures disclosed by firms as potential costs or fines.

At the same time, some scholars believe that the relationship between the two is not a simple linear correlation but an inverted U-shaped, U-shaped, S-shaped, or N-shaped correlation [29]. Other studies have shown that there is no significant relationship between the two. For example, Zhu [30] argued that the level of profitability of a company will not prompt enterprises to voluntarily disclose environmental information. Therefore, it is necessary to further explore the relationship between environmental information disclosure and firm value.

According to the information asymmetry theory, companies have internal information that is not available to the public, which may lead to moral hazard and adverse selection problems [37,38], and adequate disclosure of environmental information can alleviate this embarrassing situation. Companies that do not disclose or under-disclose environmental information may be penalized by the market because investors are unable to accurately judge the firm's attitude and behavior toward environmental protection investment and the environmental performance generated by past environmental protection investment, which may be perceived by external stakeholders as a lack of enthusiasm for environmental protection investment that does not yield the desired results, thus weakening the relationship between environmental protection investment and firm value. Even the environmental protection investment of the same enterprises, where there is different transparency of environmental information disclosure, may cause investors to have different reactions, and there may be a moderating effect of environmental information disclosure.

At the same time, firm value includes the market's measure of information risk. The more adequate the environmental information disclosed by the enterprise, the lower the information risk of the enterprise, the lower the investors' return demand [24], and the higher the market's assessment of the firm value. Therefore, the level of environmental information disclosure is likely to lead to an improved relationship between environmental protection investment and firm value, increasing the overall level of the U-shaped curve.

In addition, according to the Signal Theory, sufficient environmental information disclosure helps enterprises establish a "green" environmentally friendly image, which makes it easier to gain market recognition and win a corporate reputation. When enterprises make environmental protection investments, high-transparency environmental information disclosure enables stakeholders to fully understand the enterprise's environmental management system, environmental protection funding plan, environmental engineering progress, and the results achieved, so that the enterprise's environmental protection investment can be recognized and understood by the market. It can weaken the value depletion effect and enhance the value gain effect, making the shape of the curve in the transitional stage between the two smoothers. At the same time, it can also make investors fully aware of the economic and environmental benefits brought by environmental protection investment by enterprises and promote the faster manifestation of the gain effect, thus shifting the inflection point of the curve to the left.

H2. *Corporate environmental information disclosure has a moderating effect on the relationship between environmental protection investment and firm value.*

H2a. *Corporate environmental information disclosure may improve the overall U-shaped relationship between environmental protection investment and firm value.*

H2b. *Corporate environmental information disclosure may make the U-shaped relationship between environmental protection investment and firm value more gradual.*

H2c. *Corporate environmental information disclosure may shift the inflection point of the U-shaped relationship between environmental protection investment and firm value to the left.*

3. Data and Methodology

3.1. Model 1: The Impact of Environmental Protection Investment on Firm Value

3.1.1. Sample and Data

This paper takes all A-share listed enterprises from 2010 to 2020 as the research object and processes the samples as follows. Here, we eliminate (1) all the enterprises treated by ST, *ST; (2) data samples of all listed enterprises in the year of IPO; (3) all research samples of the financial industry; (4) for the samples with missing values, in order to eliminate outliers, the 1% and 99% quantiles of all variables were narrowed to obtain the annual observation values of 2430 sample enterprises. The data were divided into heavily polluting and non-heavily polluting industries, resulting in a total of 2149 effective sample observations from 511 heavily polluting enterprises and 281 effective sample observations from 89 non-heavily polluting enterprises.

The data for environmental protection investment is extracted from the financial statement overheads for pollution emissions, environmental protection and environmental treatment costs related to greening. Data for *Tobin Q* are from the CSMAR database and data for the remaining variables are from the Wind database.

Because non-heavily polluting industries have relatively little environmental pollution and do not face centralized supervision [39], they are less affected by environmental regulation. In this study, according to the Guidelines on Industry Classification of Listed enterprises and Guidelines on Environmental Information Disclosure of Listed enterprises revised by the China Securities Regulatory Commission in 2012, industries are differentiated. A total of 2149 effective sample observations of 511 heavily polluting enterprises and 281 effective observation samples of 89 non-heavily polluting enterprises are obtained. It can be seen from Table 1 that from 2010 to 2020, the number of heavily polluting and non-heavily polluting enterprises participating in environmental protection investment increased from 122 to 336, with a cumulative growth rate of 175%.

Table 1. The number and growth rate of enterprises investing in environmental protection.

Year	Obs.	Proportion of Obs.	Growth Rate
2010	122	5.02%	-
2011	153	6.30%	25.41%
2012	184	7.57%	20.26%
2013	188	7.74%	2.17%
2014	187	7.70%	−0.53%
2015	198	8.15%	5.88%
2016	211	8.68%	6.57%
2017	240	9.88%	13.74%
2018	296	12.18%	23.33%
2019	315	12.96%	6.42%
2020	336	13.83%	6.67%
Total	2430	100.00%	-

3.1.2. Dependent Variables

Generally, there are two methods to measure the firm value, namely, the absolute value of the enterprise obtained by discounting the future cash flow, which represents the intrinsic value of the enterprise, and the relative valuation of the enterprise obtained by

comparing the book value and market value of the firm. Since the purpose of this paper is to explore the capital market's response to enterprises after environmental protection investment, the relative valuation method is more suitable for the content of this paper. At the same time, referring to the variable design in the existing research [23,24,40], *Tobin Q* is selected as the measurement standard and proxy variable of the firm value. At the same time, there are two statistical calibers according to whether the net balance of intangible assets (*NIA*) and the net goodwill (*NG*) are included in total assets (*TA*):

$$TobinQA = \frac{MVE + PS + DEBT}{TA} \quad (1)$$

$$TobinQB = \frac{MVE + PS + DEBT}{TA - NIA - NG} \quad (2)$$

In the above calculation, *MVE* is the market value of the public float, *PS* is the value of the preferred stock, *DEBT* is net debt, *TA* is total assets, *NIA* is the net balance of intangible assets, and *NG* is net goodwill. The data corresponding to these variables can all be found in the balance sheet. More specifically, the net balance of intangible assets can be calculated by deducting the impairment of intangible assets from intangible assets. Net goodwill is the goodwill shown in the balance sheet under the non-current assets line, which can be calculated by deducting the provision for impairment of goodwill from the carrying amount of goodwill.

In this paper, *Tobin QA* is used as the explained variable in the empirical part, and *Tobin QB* is replaced as the explained variable in the subsequent robustness test.

3.1.3. Explanatory Variables

According to Lu [41] and Meng [42], in this study, the logarithm of all expenditure related to environmental protection disclosed in the notes to the financial statements of the enterprise is taken after summing up, including the capitalized part (such as the installation and operation costs of wastewater, waste gas, and waste treatment facilities, the expenditure on environmental protection facilities renovation projects, and the investment in clean production special renovation, etc.). It also includes the expended part (such as environmental monitoring expenditure, environmental management cost, safety assessment and environmental protection assessment fee, greening fee, etc.) as the variable of the environmental protection investment of enterprises.

At the same time, for the robustness of the model, according to the setting of the scale of environmental protection investment by Zhang [43], the environmental protection-related capital expenditure data in the detailed items of the project in the progress of the listed company's annual report were summed and corrected. After being counted, the amount of environmental protection investment of the enterprise is used as a new proxy variable for environmental protection investment for robustness testing.

3.1.4. Control Variables

According to the analysis of the influencing factors of firm value, whether the industry is heavily polluting (*POLLUTE*), the proportion of the largest shareholder (*FIRST*), the asset–liability ratio (*LEV*), the nature of property rights (*STATE*), the growth capacity (*GROW*), the company size (*SIZE*), institutional investor shareholding ratio (*INS*), annual average turnover rate (*YEARTURN*), and the number of shareholders (*LNG*) may affect the analysis of firm value by explanatory variables, so they can be used as control variables [25,43–46].

The industry in which a company is located has an important impact on corporate decision-making, and the environmental protection investment of a company is affected by the characteristics of the industry. The difference in the industry should be controlled during the inspection. According to the existing relevant research and the empirical purpose of this research [36,43,47,48], after the Hausman test, industry-fixed and year-fixed effect models were used for empirical analysis. To test the impact of environmental protection

investment on firm value to avoid the impact of heteroscedasticity, robust standard error regression is used, and the model is constructed as follows:

$$TobinQ_{i,t} = \beta_0 + \beta_1 LN_{INV\,i,t} + \beta_2 LN_{INV\,i,t}^2 + \beta_3\, Controls + \sum_{i=1}^{11} YEAR + \sum_{j=1}^{19} IND + \varepsilon_2 \quad (3)$$

3.1.5. Descriptive Statistics

We conducted the following descriptive analysis on a total of 2430 research samples of 511 heavily polluting enterprises and 89 non-heavily polluting listed enterprises from 2010 to 2020. After logarithmic normalization, the average value of environmental protection investment in the heavily polluting industry is 5.21, the maximum value is 8.99, the minimum value is only 0.12, and the standard deviation is 1.78, indicating that the difference in the amount of environmental protection investment between different enterprises and between different years of the same company is relatively large. The average value of environmental protection investment in non-heavily polluting industries after logarithmic standardization is 4.66, which proves that the environmental protection investment in heavily polluting industries is higher than that in non-heavily polluting industries. Except for the standard deviation of the annual average turnover rate (*YEARTURN*), the standard deviations of other variables are all less than in Table 2, which proves that the overall degree of dispersion of the sample is relatively low, and the reliability of the results obtained by the subsequent regression empirical study is relatively high.

Table 2. Presents the descriptive statistical results for the variables.

Variable	N	Min	Mean	Median	Max	Std. Dev.
PANEL A: Non-heavily polluting industry						
TobinQ	281	0.86	1.72	1.50	7.58	0.89
INV	281	0.12	4.46	4.62	8.69	1.76
SIZE	281	1.57	4.06	4.11	6.96	1.02
LEV	281	0.07	0.47	0.49	0.95	0.21
FIRST	281	0.08	0.39	0.40	0.75	0.16
INS	281	0.01	0.46	0.47	0.89	0.21
YEARTURN	281	0.46	4.98	3.73	23.33	4.07
STATE	281	0.00	0.59	1.00	1.00	0.49
GROW	281	−0.54	0.12	0.08	1.41	0.39
LNG	281	0.50	1.65	1.59	2.93	0.52
PANEL B: Heavily polluting industry						
TobinQ	2149	0.86	1.89	1.52	7.58	1.15
INV	2149	0.12	5.21	5.30	8.99	1.78
SIZE	2149	1.57	4.00	3.88	6.96	1.23
LEV	2149	0.07	0.45	0.44	0.95	0.20
FIRST	2149	0.08	0.36	0.34	0.75	0.15
INS	2149	0.00	0.43	0.44	0.89	0.23
YEARTURN	2149	0.46	5.50	4.25	23.33	4.35
STATE	2149	0.00	0.45	0.00	1.00	0.50
GROW	2149	−0.54	0.13	0.09	1.41	0.29
LNG	2149	0.50	1.64	1.59	3.30	0.66
TobinQ	2149	0.86	1.89	1.52	7.58	1.15

Table 2. *Cont.*

Variable	N	Min	Mean	Median	Max	Std. Dev.
TOTAL						
TobinQ	2430	0.86	1.87	1.52	7.58	1.12
INV	2430	0.12	5.12	5.21	8.99	1.79
SIZE	2430	1.57	4.00	3.90	6.96	1.21
LEV	2430	0.07	0.45	0.44	0.95	0.20
FIRST	2430	0.08	0.36	0.35	0.75	0.15
INS	2430	0.00	0.43	0.44	0.89	0.22
YEARTURN	2430	0.46	5.44	4.21	23.33	4.32
STATE	2430	0.00	0.46	0.00	1.00	0.50
GROW	2430	−0.54	0.13	0.08	1.41	0.30
LNG	2430	0.50	1.64	1.59	3.30	0.64

3.2. Model 2: The Moderating Effect of Environmental Information Disclosure

3.2.1. Sample and Data

Compared with non-heavily polluting industries, heavily polluting industries often have the characteristics of higher energy consumption, heavy pollution, and more emissions [30]. The overall situation and proportion of environmental information disclosure are better than those of non-heavily polluting industries [49], and environmental information disclosure is more comprehensive. Therefore, we selected all the A-share listed enterprises in the heavily polluting industry in China from 2010 to 2020 as the original sample, and the data are processed as follows: (1) all ST and *ST enterprises are excluded; (2) the data sample of all listed enterprises in the year of IPO is excluded; (3) to eliminate outliers, the 1% and 99% quantiles of all variables are narrowed, and finally, 2149 valid sample data from 482 listed enterprises are obtained.

3.2.2. Dependent Variables

With reference to variable selection in Section 3.1.2, *Tobin Q* is selected as the measurement standard and proxy variable of firm value, and the calculation method is the ratio of the total market value of the enterprise divided by the replacement cost of assets.

3.2.3. Explanatory Variables

With reference to the variable selection in Section 3.1.3, all the expenditures related to environmental protection disclosed in the notes to the financial statements of the heavily polluting enterprises are summed up and taken as the logarithm, including both the capitalized part and the expensed part, as the variable of the enterprise's environmental protection investment.

3.2.4. Moderating Variables

When designing environmental information disclosure indicators, it is necessary to consider both the actual disclosure situation of the enterprise and the needs of shareholders, creditors, and the supervision of environmental information. The indicator design of this paper draws on the indicator design of Clarkson [50], Wu [51], and Ren [52] and makes some improvements on the basis of the indicator design. From the perspectives of compensation, cost, and capitalization, corporate environmental information disclosure is divided into four parts: environmental management disclosure (*MD*), environmental supervision and certification disclosure (*SD*), environmental liability disclosure (*LD*), and environmental performance and governance disclosure (*PD*), with a total of 27 parts. Detailed indicators are used to comprehensively measure corporate environmental information disclosure, which can be seen in Table 3. The data source was the CSMAR database.

$$EDI = \sum \frac{EDI_i}{TEDI} \quad (4)$$

$$MD = \sum \frac{MD_i}{TMD} \tag{5}$$

$$SD = \sum \frac{SD_i}{TSD} \tag{6}$$

$$LD = \sum \frac{LD_i}{TLD} \tag{7}$$

$$PD = \sum \frac{PD_i}{TPD} \tag{8}$$

Table 3. Construction of Environmental Information Disclosure Index.

Construction	Indicator	Description
Environmental Management Disclosure (*MD*)	Environmental Concept	Disclose the company's environmental protection concept, environmental policy, environmental management structure, whether the economic development is recyclable, green development, etc., with a value of 1, otherwise 0.
	Environmental Target	Disclose the completion of the company's existing environmental protection goals and future environmental protection goals, assign a value of 1, otherwise 0.
	Environmental Protection Management System	Disclose that the company has established a series of management systems, systems, regulations, responsibilities, and other relevant environmental management systems, with a value of 1, otherwise 0.
	Environmental Education and Training	Disclose the company's participation in environmental-related education and training, assign a value of 1, otherwise 0.
	Special Action on Environmental Protection	Disclose the company's participation in environmental protection special activities, environmental protection, and other social public welfare activities, assign a value of 1, otherwise 0.
	Emergency Mechanism for Environmental Events	Disclose the company's establishment of an emergency mechanism for major environment-related emergencies, the emergency measures taken and the treatment of pollutants, etc., assign a value of 1, otherwise 0.
	Environmental Honors or Awards	Disclose the company's environmental honors or awards with a value of 1, otherwise 0.
	"Three Synchronizations" System	Disclose the company's implementation of the "Three Synchronizations" System, assign a value of 1, otherwise 0

Table 3. *Cont.*

Construction	Indicator	Description
Environmental Supervision and Certification Disclosure (*SD*)	Key Pollution Monitoring Unit	The disclosure company is the key monitoring unit, with a value of 1, otherwise 0.
	Pollutant Discharge under Certain Standards	The value of the pollutant emission standard is 1, otherwise, it is 0.
	Sudden Environmental Accident	If there is a sudden major environmental pollution event, the value is 1, otherwise, it is 0.
	Environmental Violations	If environmental violations have occurred, the value is 1, otherwise 0.
	Environmental Petition Cases	If there is an environmental petition event, the value is 1, otherwise, it is 0.
	Whether it has passed ISO14001 certification	Pass ISO14001, assign a value of 1, otherwise 0.
	Whether it has passed ISO9001 certification	Pass ISO19001, assign a value of 1, otherwise 0.
Entry Environmental Liability Disclosure (*LD*)	Quantity of Wastewater Effluent	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	COD Emissions	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Sulfur Dioxide Emissions	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	CO_2 Emissions	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Soot and Dust Emissions	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Production of Industrial Solid Waste	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
Environmental Performance and Governance Disclosure (*PD*)	Treatment of Emission Reduction in Waste Gas	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Emission Reduction and Treatment of Wastewater	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Dust and Smoke Control Situation	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Utilization and Disposal of Solid Waste	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	Noise, Light Pollution and Radiation Control	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).
	The Implementation of Cleaner Production	0 = no description; 1 = qualitative description; 2 = Quantitative description (monetary/numerical description).

TEDI is the highest score for corporate environmental information disclosure (39 points); *TMD* is the highest score for environmental management disclosure project (8 points); *TSD* is the highest score for environmental supervision and certification disclosure project (7 points); *TLD* is the highest score for environmental liability disclosure project (12 points); *TPD* repre-

sents disclosure projects for environmental performance and governance disclosure and can receive a maximum score of 12 points.

3.2.5. Control Variables

In addition to those mentioned in 3.1.4, for the moderating effect test model with quadratic terms, we refer to the model settings of Tang [24], Law [53], Li [54], and Zhang [55], using firm value as the dependent variable and using enterprise environmental protection as the dependent variable. Investment, the corporate environmental information disclosure index, and their interaction terms are used as explanatory variables, and some control variables are added, including company size, asset–liability ratio, institutional investor's shareholding ratio, property rights, year factor, industry factor, etc. For heteroscedasticity, robust standard error regression is used to construct a panel data Formula (9) to test the impact of environmental protection investment and the environmental information disclosure index on firm value.

$$TobinQ_{i,t} = \gamma_0 + \gamma_1 LN_{INV\,i,t} + \gamma_2 LN_{INV\,i,t}^2 + \gamma_3 EDI_{i,t} + \gamma_4 LN_{INV\,i,t} * EDI_{i,t} + \gamma_5 LN_{INV\,i,t}^2 * EDI_{i,t} + \gamma_6\, Controls + \sum_{i=1}^{10} YEAR + \sum_{j=1}^{16} IND + \varepsilon_3 \quad (9)$$

At the same time, we also further examine the four main components of the corporate environmental information disclosure index (*MD*, *SD*, *LD*, and *PD*) and the moderating effect of the relationship between environmental protection headlines and the corporate environmental information disclosure index (Formulas (10)–(13)).

$$TobinQ_{i,t} = a_0 + a_1 LN_{INV\,i,t} + a_2 LN_{INV\,i,t}^2 + a_3 MD_{i,t} + a_4 LN_{INV\,i,t} * MD_{i,t} + a_5 LN_{INV\,i,t}^2 * MD_{i,t} + a_6\, Controls + \sum_{i=1}^{10} YEAR + \sum_{j=1}^{16} IND + \varepsilon_4 \quad (10)$$

$$TobinQ_{i,t} = b_0 + b_1 LN\_INV_{i,t} + b_2 LN\_INV_{i,t}^2 + b_3 SD_{i,t} + b_4 LN\_INV_{i,t} * SD_{i,t} + b_5 LN\_INV_{i,t}^2 * SD_{i,t} + b_6\, Controls + \sum_{i=1}^{10} YEAR + \sum_{j=1}^{16} IND + \varepsilon_5 \quad (11)$$

$$TobinQ_{i,t} = c_0 + \gamma_1 LN_{INV\,i,t} + c_2 LN_{INV\,i,t}^2 + c_3 LD_{i,t} + c_4 LN_{INV\,i,t} * LD_{i,t} + c_5 LN_{INV\,i,t}^2 * LD_{i,t} + c_6\, Controls + \sum_{i=1}^{10} YEAR + \sum_{j=1}^{16} IND + \varepsilon_6 \quad (12)$$

$$TobinQ_{i,t} = d_0 + d_1 LN_{INV\,i,t} + d_2 LN_{INV\,i,t}^2 + d_3 PD_{i,t} + d_4 LN_{INV\,i,t} * PD_{i,t} + d_5 LN_{INV\,i,t}^2 * PD_{i,t} + d_6\, Controls + \sum_{i=1}^{10} YEAR + \sum_{j=1}^{16} IND + \varepsilon_7 \quad (13)$$

3.2.6. Descriptive Statistics

Table 4 shows the basic information of the main research variables in this section. It can be seen that the mean value of *DIS*, the dummy variable of environmental information disclosure, is 0.94, and the median is 1, which proves that most of the listed heavily polluting enterprises are still inclined to disclose environmental information, and only about 6% of the heavily polluting enterprises choose not to disclose environmental information. However, from the perspective of *EDI*, the enterprise environmental information disclosure index, although most Chinese enterprises choose to disclose environmental information, the amount of disclosure is different, and there is a great difference in the transparency of environmental information among enterprises. The mean (median) is 0.23 (0.21), and there is a big gap between the maximum and 0.85. This reflects that the degree of environmental information disclosure of heavily polluting enterprises is quite different.

Table 4. Presents the descriptive statistical results for the variable.

Variable	N	Min	Mean	Median	Max	Std. Dev.
Tobin QA	1848	0.87	1.88	1.51	7.61	1.13
LN_INV	1848	0.09	5.16	5.25	8.99	1.79
DIS	1848	0.00	0.94	1.00	1.00	0.23
EDI	1743	0.00	0.23	0.21	0.85	0.19
LD	1743	0.00	0.18	0.08	0.92	0.22
MD	1743	0.00	0.25	0.12	1.00	0.25
SD	1741	0.00	0.27	0.29	0.71	0.14
PD	1743	0.00	0.25	0.25	1.00	0.25
SIZE	1848	1.55	3.97	3.86	6.84	1.22
LEV	1848	0.07	0.45	0.44	0.95	0.20
FIRST	1848	0.08	0.36	0.34	0.75	0.15
INS	1848	0.00	0.42	0.44	0.88	0.22
YEARTURN	1848	0.50	5.33	4.11	23.37	4.23
STATE	1848	0.00	0.46	0.00	1.00	0.50
GROW	1848	−0.52	0.14	0.09	1.47	0.29
LNG	1848	0.50	1.64	1.59	3.30	0.66

The explanation of the abbreviation of the variables of Table 4; *LN_INV*: environmental protection investment; *DIS*: the dummy variable of environmental information disclosure; *EDI*: environmental information disclosure index; *LD*: environmental liability disclosure; *MD*: environmental management disclosure; *SD*: environmental supervision and certification disclosure; *PD*: environmental performance and governance disclosure; *SIZE*: the company size; *LEV*: the asset–liability ratio; *FIRST*: the proportion of the largest shareholder; *INS*: institutional investor shareholding ratio; *YEARTURN*: annual average turnover rate; *STATE*: the nature of property rights; *GROW*: the growth capacity; *LNG*: the number of shareholders.

4. Empirical Results and Discussion

4.1. The Impact of Environmental Protection Investment on Firm Value

Table 5 shows the result of the heteroscedasticity-robust regression analysis based on Model 1. First, for regression (1) and (3), *LN_INV* is not significantly correlated with firm value by *Tobin Q* if only the primary term of the logarithm of environmental protection investment is included in the regression. However, when the primary term and the secondary term LN_INV^2 of *LN_INV* are included in the regression, both are significantly correlated with firm value by *Tobin Q*. At the same time, the adjusted R-sq of regression (2) and regression (4) was significantly higher than that of regression (1) and regression (3), which proved that the explanatory power of the model was enhanced after the addition of quadratic terms. Therefore, the specific curve shape of the nonlinear relationship was further determined.

With reference to the determination of the U-shaped curve by Lind [56], the regression results (2) and (4) were first analyzed.

Targeting heavily polluting industries and non-heavily polluting industries *LN_INV*, the coefficients of are all significantly negative at the 1% level, and the square term is LN_INV^2. The regression coefficients of are all significantly negative at the 1% level, which satisfies the first condition of a positive U-shaped curve. Under the assumption that the curve has only one extreme value, the second condition of the U-shaped curve is that the slope is negative at the minimum value range of the independent variable, and positive at the maximum value range of the independent variable:

$$\hat{\beta}_1 + 2 * \hat{\beta}_2 LN_{INV\,min} < 0 < \hat{\beta}_1 + 2 * \hat{\beta}_2 LN_{INV\,max} \quad (14)$$

The minimum and maximum values of the descriptive statistics of *LN_INV* and the estimated values of coefficients of regression results (2) and regression results (4) are put into Formula (14), successively. For heavily polluting industries, when the minimum *LN_INV* is 0.12, the slope is $-0.19 < 0$, and when the maximum *LN_INV* is 8.99, the slope corresponding to this point is $0.191 > 0$, which satisfies the second condition for a U-shaped curve. For non-heavily polluting industries, when *LN_INV* is set to the minimum value 0.12,

the slope is −0.364 < 0, and when the maximum *LN_INV* is 8.69, the slope corresponding to this point is 0.486 > 0, which also satisfies the second condition for a U-shaped curve.

Table 5. The impact of environmental protection investment on firm value.

	Heavily Polluting Industry		Non-Heavily Polluting Industry	
	(1) *Tobin Q*	(2) *Tobin Q*	(3) *Tobin Q*	(4) *Tobin Q*
LN_INV	−0.005	−0.200 ***	0.030	−0.376 ***
	(−0.34)	(−3.77)	(1.01)	(−3.15)
LN_INV^2		0.021 ***		0.050 ***
		(4.11)		(3.80)
SIZE	−0.682 ***	−0.705 ***	−0.325 ***	−0.361 ***
	(−16.86)	(−17.04)	(−4.26)	(−4.73)
LEV	−0.0263	−0.0107	−0.659 ***	−0.619 ***
	(−0.16)	(−0.07)	(−2.83)	(−3.00)
FIRST	−0.530 ***	−0.554 ***	−0.281	−0.293
	(−3.54)	(−3.69)	(−0.59)	(−0.69)
INS	1.991 ***	1.971 ***	0.495	0.554
	(14.36)	(14.19)	(1.12)	(1.36)
YEARTURN	0.010 *	0.010	0.002	0.006
	(1.69)	(1.61)	(0.16)	(0.53)
STATE	−0.285 ***	−0.270 ***	−0.164	−0.191 **
	(−6.30)	(−5.97)	(−1.59)	(−2.10)
GROW	0.337 ***	0.348 ***	−0.005	0.042
	(3.94)	(4.15)	(−0.04)	(0.35)
LNG	0.467 ***	0.466 ***	0.310 ***	0.240 **
	(8.90)	(8.97)	(2.79)	(2.16)
YEAR	Control			
IND	Control			
cons	3.453 ***	3.967 ***	3.563 ***	4.545 ***
	(23.36)	(18.93)	(7.67)	(7.32)
N	2149	2149	281	281
R^2	0.408	0.414	0.442	0.498
F	43.48	42.36	-	-

t statistics in parenthesis * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

The third condition is to judge whether inflection point values lie within the scope of *LN_INV*; when $\hat{\beta}_1 + 2 * \hat{\beta}_2 LN_{INV\,i,t} = 0$, the heavily polluting industry *LN_INV* value is 4.85, and the value of heavily polluting industry is 3.79, all within the scope of *LN_INV*. However, Lind and Mehlum [56] pointed out that it may not be enough to confirm that the curve is U-shaped even if the above three conditions are met, because there is a certain possibility that the inflection point will exceed the value range when it approaches the boundary of the value range of explanatory variables. Therefore, Lind proposed a sufficient and necessary U-shaped test method and gave confidence intervals for extreme points. As can be seen from Table 6, the extreme value points tested by Lind and Mehlum's U-shaped test are 4.841 and 3.794, respectively, the 99% confidence intervals of the extreme value points are within the value range, and the null hypothesis can be rejected at the statistical level of 1%. Therefore, it can be determined that no matter whether the industry is heavily polluting or non-heavily polluting, there is a positive U-shaped relationship between environmental protection investment and firm value (Figure 1). In addition, it is worth noting that from the descriptive statistics in Tables 3 and 4, the mean and median *LN_INV* of environmental protection investment in heavily polluting industries are 5.21 and 5.3, respectively, and the mean and median of c of non-heavily polluting industries are 4.46 and 4.62, respectively, both of which are greater than the value of *LN_INV* corresponding to the inflection point of the U-shaped curve. It is proved that environmental protection investment has already exceeded the impairment stage and entered the value-added stage for both heavily polluting enterprises and non-heavily polluting enterprises.

Table 6. U-curve test.

Dependent Variable: *Tobin QA*		Heavily Polluting	Non-Heavily Polluting
LN_INV	$\hat{\beta}_1$	−0.200 ***	−0.376 ***
		(−3.77)	(−3.15)
LN_INV^2	$\hat{\beta}_2$	0.0206 ***	0.0496 ***
		(4.11)	(3.80)
slope at X_l	$\hat{\beta}_1 + 2\hat{\beta}_2 X_l$	−0.195	−0.364
		0.000	0.001
slope at X_h	$\hat{\beta}_1 + 2\hat{\beta}_2 X_h$	0.0171	0.515
		0.000	0.000
Extreme point	$-\frac{\hat{\beta}_1}{2\hat{\beta}_2}$	4.841	3.794
confidence interval (99%)		[3.533, 5.825]	[1.907, 4.562]

Robust standard errors in parenthesis and *p*-values in square brackets, *t* statistics in parentheses *** $p < 0.01$.

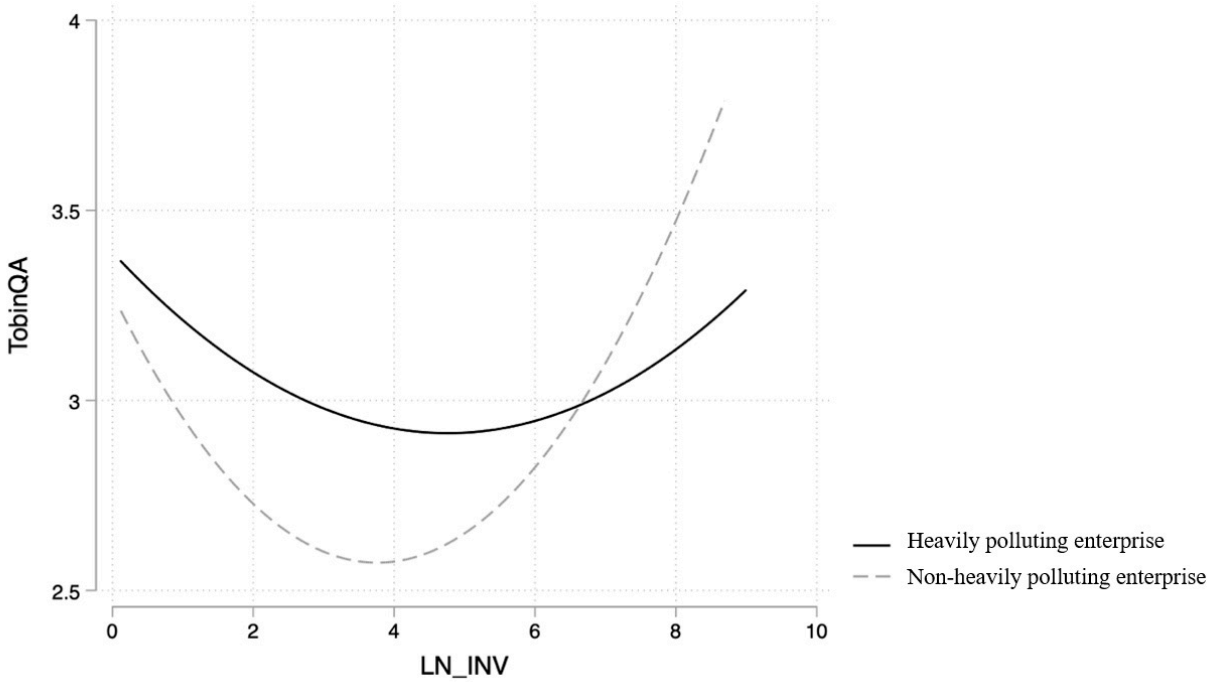

Figure 1. U–shaped relationship between environmental protection investment and firm value.

When heavily polluting industries and non-heavily polluting industries were compared, it was found that the adjusted R^2 (0.442 and 0.498) of the non-heavily polluting industry model were significantly higher than the adjusted R^2 (0.408 and 0.414) of the heavily polluting industry model, and the non-heavily polluting industry model had better explanatory power. Meanwhile, the inflection points of non-heavily polluting enterprises (LN_INV = 3.797) are also smaller than the inflection points of the U-shaped curve of heavily polluting enterprises (LN_INV = 4.841), which indicates that the gain effect of environmental protection investment in non-heavily polluting enterprises on firm value appears earlier than that of heavily polluting enterprises, possibly because heavily polluting enterprises bear more mandatory environmental protection pressure. In contrast, the environmental protection investment in non-heavily polluting industries has almost no external mandatory force requirements, and is spontaneous behavior of the enterprises. They are "purer" and take the initiative to undertake environmental social responsibilities which can be better identified by the market.

From the perspective of control variables, there is a significant correlation between enterprise *SIZE* and firm value at the 1% level. Corporate asset-liability ratio (*LEV*) is negatively correlated with firm value at 1% in non-polluting industries, but not in heavily

polluting industries. The shareholding ratio of the largest shareholder *FIRST* significantly affects the firm value of the heavily polluting enterprises at the level of 1%, and shows that the higher the shareholding ratio of the largest shareholder, the lower the firm value, but there is no significant correlation in the non-heavily polluting industries. The shareholding ratio of institutional investors in *INS* is significantly positively correlated with the firm value of heavily polluting industries, which may be because institutional investors have a high degree of participation in enterprise management. In the case of heavily polluting industries facing strong external control, participation of institutional investors can enable heavily polluting enterprises to avoid corresponding policy risks and obtain a higher firm value. The property right of enterprises has a significant negative impact on firm value in both heavily polluting industries and non-polluting industries. In other words, the nature of state-owned enterprises is relative to non-state-owned enterprises, which will reduce firm value, which may reflect that the market-oriented reform process of state-owned enterprises has not been fully recognized by the market to some extent. The growth capacity of heavily polluting enterprises also has a significant positive correlation with the 1% level of firm value. In addition, on the whole, the number of shareholders *LNG* is also positively correlated with firm value.

4.2. The Moderating Effect of Environmental Information Disclosure

Formulas (10)–(13), respectively, examined the total regulatory effect of environmental information disclosure quality and the respective regulatory effects of the environmental liability disclosure index *LD*, environmental management disclosure index *MD*, environmental regulation disclosure index *SD*, and environmental performance and governance disclosure index *PD*. As can be seen from Table 7, *EDI* the coefficient of the environmental information disclosure index is −2.338, which is significant at the 1% level, and *LN_INV*EDI* the coefficient of cross-product of the environmental information disclosure index and environmental protection investment is 0.646, which is significant at the 5% level. The interaction term LN_INV^2*EDI between the environmental information disclosure index and the square of environmental protection investment is significant at the 10% level. Hypothesis H2 is empirically tested, that is, the environmental information disclosure index has a significant moderating effect on the relationship between environmental protection investment and firm value.

Table 7. Moderating effect of EDI.

	***Tobin QA* (*EDI*)**	***Tobin QA* (*LD*)**	***Tobin QA* (*MD*)**	***Tobin QA* (*SD*)**	***Tobin QA* (*PD*)**
LN_INV	−0.260 ***	−0.233 ***	−0.232 ***	−0.373 ***	−0.201 **
	(−2.77)	(−3.07)	(−2.97)	(−3.18)	(−2.26)
LN_INV^2	0.0234 ***	0.0230 ***	0.0217 ***	0.0353 ***	0.0179 **
	(2.61)	(3.16)	(2.90)	(3.30)	(2.09)
EDI	−2.338 ***				
	(−2.84)				
*LN_INV*EDI*	0.646 **				
	(2.29)				
LN_INV^2*EDI	−0.0412 *				
	(−1.73)				
LD		−1.525 **			
		(−2.28)			
*LN_INV*LD*		0.465 **			
		(2.05)			

Table 7. *Cont.*

	***Tobin QA* (*EDI*)**	***Tobin QA* (*LD*)**	***Tobin QA* (*MD*)**	***Tobin QA* (*SD*)**	***Tobin QA* (*PD*)**
*LN_INV²*LD*		−0.0328 *			
		(−1.72)			
MD			−1.707 ***		
			(−2.64)		
*LN_INV*MD*			0.499 **		
			(2.29)		
*LN_INV²*MD*			−0.0333 *		
			(−1.85)		
SD				−2.755 ***	
				(−2.78)	
*LN_INV*SD*				0.834 **	
				(2.37)	
*LN_INV²*SD*				−0.0675 **	
				(−2.22)	
PD					−1.303 **
					(−2.10)
*LN_INV*PD*					0.306
					(1.41)
*LN_INV²*PD*					−0.0141
					(−0.75)
SIZE	−0.771 ***	−0.773 ***	−0.770 ***	−0.774 ***	−0.773 ***
	(−17.01)	(−16.93)	(−16.97)	(−17.01)	(−17.01)
LEV	0.204	0.195	0.186	0.190	0.209
	(1.18)	(1.13)	(1.08)	(1.11)	(1.20)
FIRST	−0.553 ***	−0.572 ***	−0.540 ***	−0.495 ***	−0.561 ***
	(−3.61)	(−3.72)	(−3.56)	(−3.26)	(−3.65)
INS	1.806 ***	1.813 ***	1.808 ***	1.780 ***	1.802 ***
	(13.52)	(13.54)	(13.51)	(13.26)	(13.46)
YEARTURN	−0.00156	−0.00138	−0.00147	−0.00349	−0.00188
	(−0.27)	(−0.24)	(−0.25)	(−0.59)	(−0.33)
STATE	−0.204 ***	−0.208 ***	−0.212 ***	−0.217 ***	−0.203 ***
	(−4.15)	(−4.20)	(−4.34)	(−4.53)	(−4.18)
GROW	0.238 ***	0.243 ***	0.240 ***	0.239 ***	0.240 ***
	(2.77)	(2.82)	(2.81)	(2.81)	(2.79)
LNG	0.489 ***	0.490 ***	0.490 ***	0.497 ***	0.488 ***
	(8.75)	(8.70)	(8.78)	(8.89)	(8.74)
YEAR			Control		
IND			Control		
cons	3.814 ***	3.689 ***	3.704 ***	3.678 ***	3.678 ***
	(12.91)	(14.11)	(13.91)	(10.89)	(13.04)
N	1743	1743	1743	1741	1743
R^2	0.470	0.468	0.469	0.471	0.470
F	34.31	33.72	33.54	33.10	34.25

t statistics in parentheses * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

From the perspective of segmentation, the cross-product terms of the environmental liability disclosure index *LD*, environmental management disclosure index *MD* and environmental regulation disclosure index *SD* with the square of environmental protection investment and environmental protection investment are all significant at the significance level of less than 10%. The three parts of the environmental liability disclosure index *LD*, environmental management disclosure index *MD* and environmental regulation disclosure index *SD* all play significant regulatory roles. However, there is no significant relationship between *PD*, the disclosure index of environmental performance and governance, and the primary and secondary cross-crossing items of enterprises' environmental protection investment. This may be because the environmental performance and governance index mainly discloses the treatment and disposal of waste gas, waste water, dust, solid waste and other items, which belong to the voluntary disclosure of enterprises without strict and unified standards. Therefore, each enterprise may disclose in different formats and contents, which makes it more difficult for investors to make horizontal and vertical comparisons, which is not conducive to market screening of excellent environmental protection investment projects and enterprises, and therefore weakens the regulating effect of the environmental performance and governance disclosure index on the relationship between environmental protection investment and firm value.

Next, we analyze the influence of corporate environmental information disclosure on the U-shaped relationship between environmental protection investment and firm value. Referring to Zhu [57] on the adjustment effect on the U-shaped relationship, the changes in the shape, inflection point and overall level of the curve were analyzed (as shown in Figure 2).

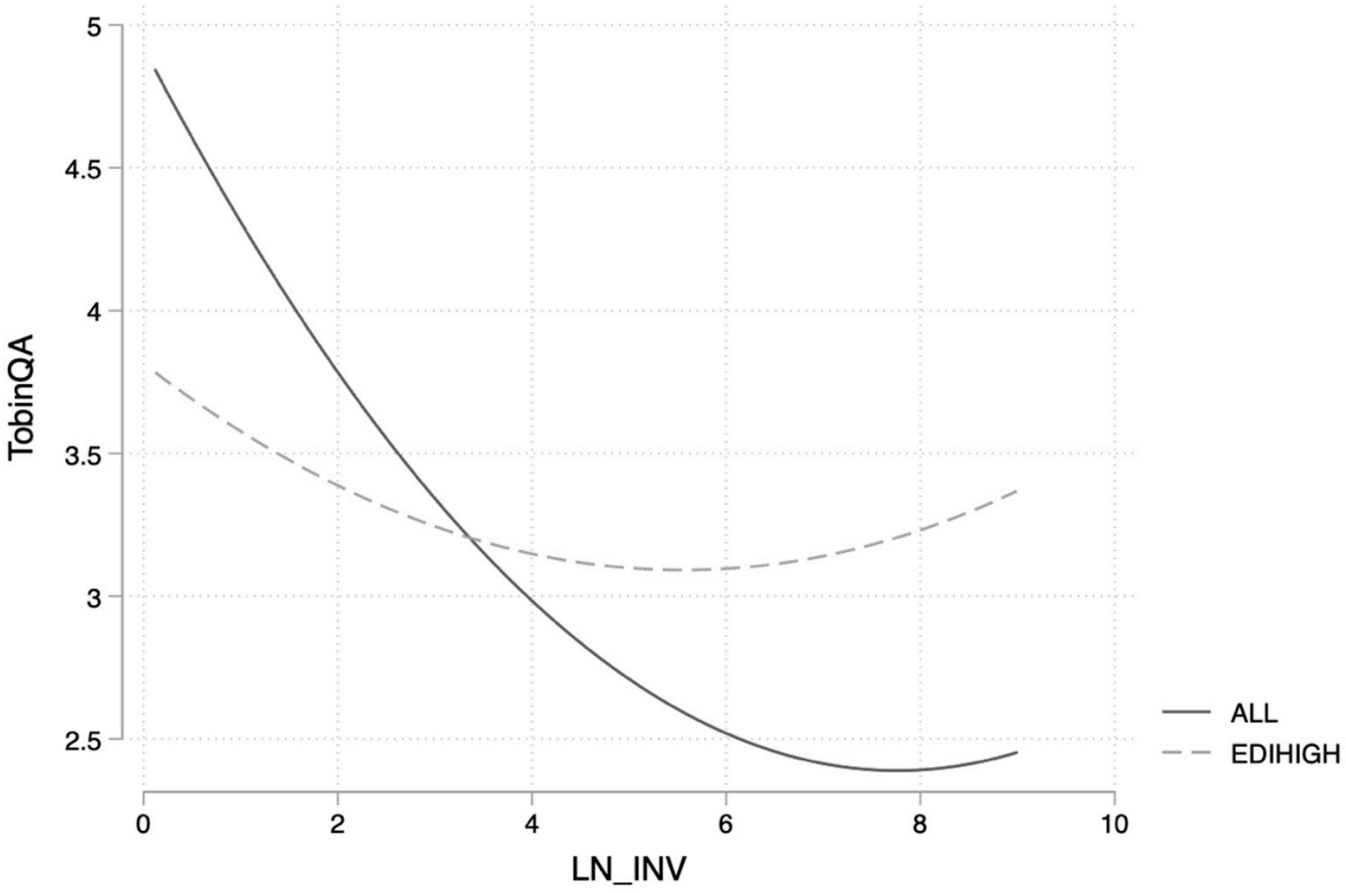

Figure 2. The moderating effect of environmental information disclosure.

First of all, for the change of curve shape, the research model in this paper is about the quadratic function of the independent variable *LN_INV*. Whether the curve is flat or steep can be determined by the curvature of the vertex, and the curvature of the point is the derivative of the quadratic function at the vertex. After the control variable is omitted, formula (9) in this paper can be simplified to quadratic function Formula (15), and the curvature R of the vertex is obtained by calculating the second derivative of Formula (15) (see Formula (16)). The curvature R of the vertex of a U-shaped curve should be greater than 0, and the greater the R-value, the steeper the curve, and the smaller the R-value, the smoother the curve. Further analysis can be obtained by partial derivation of *R* with respect to *EDI* (Formula (17)), and the influence of variable *EDI* on the vertex curvature *R* of the U-shaped curve is mainly reflected in the symbol of γ_5. If $\gamma_5 > 0$, the curvature *R* increases with the increase in *EDI*, that is, the curve shape becomes steeper and more concentrated. Conversely, if $\gamma_5 < 0$, then with the increase in *EDI*, curvature *R* becomes smaller, that is, the shape of the curve becomes smoother. It can be seen from Table 7 that γ_5 is -0.0412, which is significantly negative at the 10% level, indicating that the higher the score of the enterprise environmental information disclosure index, the smoother the curve shape, and H2b is assumed to be supported.

$$TobinQ = \gamma_0 + \gamma_1 LN\_INV + \gamma_2 LN\_INV^2 + \gamma_3 EDI + \gamma_4 LN\_INV * EDI + \gamma_5 LN\_INV^2 * EDI + \varepsilon_3 \quad (15)$$

$$R = 2(\gamma_2 + \gamma_5 EDI) \quad (16)$$

$$\frac{\partial R}{\partial EDI} = 2\gamma_5 \quad (17)$$

Secondly, the influence of the adjustment variable on the inflection point of the curve is considered. When the first derivative is zero, the independent variable LN_INV^* is the inflection point of the curve (Formula (18)). In order to study the influence of moderating variables on LN_INV^*, we can take the partial derivative of LN_INV^* with respect to *EDI* (Formula (19)). From Formula 19, it can be seen that the denominator is always greater than 0, so the effect of *EDI* on the symmetry axis of the curve is only determined by $\gamma_1\gamma_{5-}\gamma_2\gamma_4$. Regression (1) in Table 7 shows that the value of $\gamma_1\gamma_{5-}\gamma_2\gamma_4$ is -0.026, which is less than 0. It proves that when the *EDI* disclosure index is higher, the inflection points of environmental protection investment and firm value shift to the left, proving that sufficient corporate environmental information disclosure can indeed reduce the detrimental effect of environmental protection investment on firm value, and the promotion of environmental protection investment is fully considered in the firm value, which validates Hypothesis H2c.

$$LN_{INV}{}^* = -\frac{\gamma_1 + \gamma_4 EDI}{2(\gamma_2 + \gamma_5 EDI)} \quad (18)$$

$$\frac{\partial LN_{INV}{}^*}{\partial EDI} = \frac{\gamma_1\gamma_{5-}\gamma_2\gamma_4}{2(\gamma_2 + \gamma_5 EDI)^2} \quad (19)$$

$$\begin{aligned} TobinQ_{EDIH} \quad & -TobinQ_{EDIL} \\ & = \left(\gamma_1 LN_{INV} + \gamma_2 LN_{INV}{}^2 + \gamma_3 EDI_H + \gamma_4 LN_{INV} * EDI_H + \gamma_5 LN_{INV}{}^2 * EDI_H\right) \\ & -\left(\gamma_1 LN_{INV} + \gamma_2 LN_{INV}{}^2 + \gamma_3 EDI_L + \gamma_4 LN_{INV} * EDI_L + \gamma_5 LN_{INV}{}^2 * EDI_L\right) \\ & = (EDI_H - EDI_L)\left(\gamma_3 + \gamma_4 LN_{INV} + \gamma_5 LN_{INV}{}^2\right) \end{aligned} \quad (20)$$

Finally, the influence of moderating variables on the overall level of the curve is analyzed. In order to verify whether high-quality corporate environmental information disclosure improves environmental protection investment and firm value, the firm value corresponding to high-quality environmental information disclosure is denoted as $TobinQ_{EDIH}$, and that of low-quality environmental information is denoted as $TobinQ_{EDIL}$. If the difference between the two is always greater than 0, it can be proved that high-quality environmental information disclosure improves the overall level of investment and firm-value

curve of environmental protection enterprises. According to Formula (20) and Table 7, when *LN_INV* is in the range (5.67, 8.99], $TobinQ_{EDIH} - TobinQ_{EDIL}$ is always greater than 0, which means that only when environmental protection investment exceeds a certain critical value can sufficient environmental information disclosure significantly improve the curve between environmental protection investment and firm value.

In addition, the mean and median *LN_INV* of heavily polluting industries are 5.16 and 5.25, respectively, both of which are less than 5.67, which proves that the environmental protection investment value of most heavily polluting enterprises has not reached the critical value to enhance firm value through adequate environmental information disclosure, which explains why the initiative of environmental information disclosure of Chinese heavily polluting enterprises is not high. It is still very dependent on outside environmental regulations. However, at the same time we can also see that there are still some enterprises in China which have reached and exceeded the threshold of environmental protection investment, enjoying the dividend of sufficient environmental information disclosure to enhance the value of these enterprises.

5. Robustness Tests

This article uses the following methods for testing to ensure robust results.

First, as shown in Section 3.1.2, there are two ways to calculate the *Tobin Q* value, depending on whether net intangible assets and net goodwill are taken into account. The *Tobin QB* value does not include the net intangible assets and net goodwill in the book value of the enterprise. In the process of environmental protection investment, enterprises may apply for intangible assets such as patents or proprietary technologies. In the transformation of old machinery, the purchase and installation of environmental protection equipment may also have an impact on tangible assets. At the same time, enterprises may obtain green honors by constantly upgrading existing products and services, thus increasing the value of original trademarks or goodwill [42]. Therefore, *Tobin QA* is replaced by *Tobin QB* to consider the impact of enterprise environmental protection investment on firm value after excluding the impact of net intangible assets and goodwill. Tables A1 and A2 in Appendix A list Model 1: The Impact of Environmental Protection Investment on Firm Value and Model 2: The Moderating Effect of Environmental Information Disclosure.

The significance and coefficient of Model 1 have not changed fundamentally, and the relationship between environmental protection investment and firm value is still U-shaped. In Model 2, the overall significance of the environmental information disclosure index did not change significantly. As for the specific four components of the environmental information disclosure index, the results were the same as the main regression. The environmental liability disclosure index, environmental management disclosure index and environmental regulation disclosure index had significant moderating effects, but the environmental performance and governance disclosure index had no significant moderating effects.

Secondly, the impact of enterprise environmental protection investment on firm value may have a lag effect. On the one hand, the impact of CSR on financial performance has a significant lag effect [58], and environmental protection input is one of the practical actions to fulfill CSR. On the other hand, due to the lag of financial reports and corporate social responsibility reports, the market may not be able to immediately identify the current investment in environmental protection of enterprises. Meanwhile, upgrading production equipment and installing pollution removal equipment are all long-term investments, and it is difficult to see significant returns in the short term [59], which leads to the market lowering the evaluation of firm value in the short term. Therefore, this paper selects the average value of environmental protection input of one-period lag and two-period lag, respectively, to carry out the regression of firm value, as shown in Table A3 in Appendix A. The results show that the environmental protection input with a lag of one phase shows a significant U-shaped relationship with firm value at the 1% level, which is consistent with the basic regression results. Meanwhile, the adjusted R^2 of heavily polluting industry is basically consistent with the basic regression, while the adjusted R^2

of non-heavily polluting industry has a significant increase, rising from 0.498 to 0.558. The use of the one-period lag variable improves the explanatory power of the model. However, when the two-period lag variable is used, environmental protection investment is no longer significantly correlated with firm value, possibly because enterprise environmental protection investment is more of a signal to the market, the strength of which weakens with the extension of time, so in the long run, environmental protection investment is not significantly correlated with firm value.

6. Conclusions

The purpose of this research is to examine the relationship between environmental protection investment and the firm value of heavily polluting and non-heavily polluting A-share enterprises, considering the moderating effect of environmental information disclosure. To achieve this objective, regression models with industry and time-fixed effects are employed. The findings of this study reveal a significant U-shaped relationship between environmental protection investment and firm value, suggesting that low levels of investment may have a negative effect on firm value while exceeding a certain threshold leads to a positive effect on firm value. Notably, in China, a majority of the environmental protection investment in enterprises exceeds the critical value, resulting in a positive effect on firm value, which is different from the findings of Tang's study [59].

For the first time, this paper investigates the impact of environmental protection investment on non-heavily polluting enterprises in China. Interestingly, it is found that the impact of environmental protection investment in non-heavily polluting enterprises on firm value also shows a U-shaped relationship, and the model significance is better than that of heavily polluting enterprises. Non-heavily polluting enterprises are less subject to environmental control than polluting enterprises, and their investment in environmental protection is more voluntary, which may be more conducive for the market to identify the level of environmental responsibility of enterprises and give valuation rewards to enterprises that have taken environmental responsibility. This conclusion has enriched the research on the effect of environmental protection investment on firm value, and is helpful to internally motivate enterprises to make environmental protection investment and has filled the research gap on non-heavily polluting enterprises.

The study has also found that the level of corporate environmental information disclosure has a significant moderating effect on the U-shaped relationship between environmental protection investment and firm value. Specifically, a higher level of transparency in corporate information disclosure allows investors to better understand the environmental efforts undertaken by the enterprises. As a result, the inflection point on the curve shifts to the left, which means that a lower level of environmental protection investment can still lead to an increase in firm value due to the investors' perceptions of the companies' commitment to environmental responsibilities. In addition, if the environmental protection investment is insufficient, the overly-transparent disclosure of environmental information may imply the fulfillment of environmental and social responsibility and ultimately have a detrimental effect on firm value.

Thus, by providing academic evidence on the impact of corporate information disclosure, we can conclude that improving the standards and quality of corporate information disclosure could reduce the information asymmetry, optimize market efficiency, reduce government supervision costs, and encourage companies to assume environmental responsibility while demonstrating their environmental development and investing in internal environmental management systems and information disclosure processes.

7. Discussion

This study makes notable contributions to the theoretical research on the economic consequences of environmental protection investment. By examining the impact of industry heterogeneity on the relationship between environmental protection investment and firm value, this study fills the research gap on the economic consequences of environmental

protection investment in non-heavily polluting industries. In addition, the article clarifies how corporate information disclosure moderates the impact of environmental protection investment on firm value, providing further insight into the mechanisms through which corporate information disclosure affects firm value.

Practically, this study provides empirical evidence for firms to increase environmental protection investment and improve the quality of environmental information disclosure. It also provides valuable guidance for the government in formulating new environmental investment policies for both listed and non-listed companies, and in publishing sustainable development reports that include environmental investment content.

However, the study has limitations, such as the use of a simple linear method to measure the corporate information disclosure index. This study did not provide different weights for different indicators. Future research may consider establishing a comprehensive corporate environmental information disclosure index system, including text analysis methods to assign different weights to different indicators to enhance reliability and comparability. Additionally, expanding the research to an inter-provincial perspective can improve the comparability of environmental data to examine the impact of environmental management and performance on firm value and the economy. Lastly, future research can deepen the study of industry heterogeneity by examining the adoption of environmental responsibility among different industries to gain further insights.

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Appendix A

Table A1. Robustness test of Tobin QB in Model 1.

	Heavily Polluting Industry		**Non-Heavily Polluting Industry**	
	(1) ***Tobin Q***	**(2)** ***Tobin Q***	**(3)** ***Tobin Q***	**(4)** ***Tobin Q***
LN_INV	−0.0117	−0.213 ***	0.0360	−0.483 ***
	(−0.74)	(−3.60)	(1.01)	(−3.40)
LN_INV^2		0.0213 ***		0.0635 ***
		(3.80)		(4.18)
SIZE	−0.722 ***	−0.745 ***	−0.447 ***	−0.492 ***
	(−16.10)	(−16.26)	(−4.54)	(−5.13)
LEV	−0.0346	−0.0186	−0.0968	−0.0445
	(−0.19)	(−0.10)	(−0.26)	(−0.13)
FIRST	−0.811 ***	−0.836 ***	−0.602	−0.618
	(−4.77)	(−4.90)	(−1.05)	(−1.20)
INS	2.137 ***	2.117 ***	0.634	0.710
	(13.89)	(13.74)	(1.23)	(1.49)
YEARTURN	0.0121 *	0.0115 *	−0.0135	−0.00869
	(1.80)	(1.72)	(−0.72)	(−0.51)
STATE	−0.349 ***	−0.334 ***	−0.405 ***	−0.439 ***
	(−6.98)	(−6.66)	(−2.78)	(−3.37)

Table A1. *Cont.*

	Heavily Polluting Industry		Non-Heavily Polluting Industry	
	(1) ***Tobin Q***	**(2)** ***Tobin Q***	**(3)** ***Tobin Q***	**(4)** ***Tobin Q***
GROW	0.475 ***	0.487 ***	0.0146	0.0749
	(5.00)	(5.22)	(0.10)	(0.52)
LNG	0.476 ***	0.475 ***	0.357 **	0.267 *
	(8.03)	(8.10)	(2.42)	(1.82)
YEAR		Control		
IND		Control		
cons	3.386 ***	3.900 ***	4.093 ***	5.518 ***
	(24.19)	(18.59)	(4.04)	(4.93)
N	2149	2149	281	281
R^2	0.400	0.405	0.402	0.465
F	46.18	44.92	-	-

t statistics in parentheses * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

Table A2. Robustness test of Tobin QB in Model 2: Moderating effect of EDI.

	***Tobin QA* (*EDI*)**	***Tobin QA* (*LD*)**	***Tobin QA* (*MD*)**	***Tobin QA* (*SD*)**	***Tobin QA* (*PD*)**
LN_INV	−0.388 **	−0.363 ***	−0.355 **	−0.658 ***	−0.253
	(−2.22)	(−2.61)	(−2.44)	(−2.76)	(−1.57)
LN_INV^2	0.0241	0.0300 **	0.0273 **	0.0537 ***	0.0132
	(1.46)	(2.35)	(2.04)	(2.71)	(0.80)
EDI	−6.617 **				
	(−2.57)				
*LN_INV*EDI*	1.507 **				
	(2.34)				
LN_INV^2*EDI*	−0.0649				
	(−1.50)				
LD		−4.768 **			
		(−2.51)			
*LN_INV*LD*		1.196 **			
		(2.46)			
LN_INV^2*LD*		−0.0614 *			
		(−1.91)			
MD			−4.010 **		
			(−2.48)		
*LN_INV*MD*			1.030 **		
			(2.26)		
LN_INV^2*MD*			−0.0538 *		
			(−1.67)		
SD				−6.787 ***	
				(−2.66)	
*LN_INV*SD*				1.659 **	
				(2.44)	
LN_INV^2*SD*				−0.106 **	
				(−2.03)	
PD					−3.877 **
					(−2.31)
*LN_INV*PD*					0.687 *
					(1.65)
LN_INV^2*PD*					−0.00667
					(−0.20)
SIZE	−1.257 ***	−1.262 ***	−1.256 ***	−1.261 ***	−1.264 ***
	(−5.76)	(−5.75)	(−5.72)	(−5.77)	(−5.72)
LEV	2.228 **	2.206 **	2.150 **	2.154 **	2.263 **
	(2.20)	(2.19)	(2.19)	(2.20)	(2.20)

Table A2. *Cont.*

	***Tobin QA* (*EDI*)**	***Tobin QA* (*LD*)**	***Tobin QA* (*MD*)**	***Tobin QA* (*SD*)**	***Tobin QA* (*PD*)**
FIRST	−1.532 ***	−1.613 ***	−1.478 ***	−1.359 ***	−1.549 ***
	(−2.87)	(−2.87)	(−2.88)	(−2.85)	(−2.88)
INS	2.806 ***	2.833 ***	2.806 ***	2.738 ***	2.798 ***
	(6.12)	(6.04)	(6.14)	(6.21)	(6.13)
YEARTURN	−0.0118	−0.0110	−0.0119	−0.0173	−0.0127
	(−0.66)	(−0.62)	(−0.66)	(−0.88)	(−0.69)
STATE	−0.455 ***	−0.466 ***	−0.489 ***	−0.497 ***	−0.457 ***
	(−4.05)	(−4.08)	(−3.96)	(−4.05)	(−4.03)
GROW	0.270	0.285	0.283	0.279	0.274
	(1.24)	(1.32)	(1.32)	(1.29)	(1.26)
LNG	0.564 ***	0.565 ***	0.572 ***	0.590 ***	0.562 ***
	(5.11)	(5.10)	(5.22)	(5.50)	(5.12)
YEAR			Control		
IND			Control		
cons	5.743 ***	5.463 ***	5.436 ***	5.506 ***	5.401 ***
	(5.53)	(5.90)	(5.88)	(4.87)	(5.70)
N	1743	1743	1743	1741	1743
R^2	0.151	0.149	0.149	0.151	0.151
F	21.78	21.57	20.67	20.66	21.61

t statistics in parentheses * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

Table A3. Robustness test of considering lagged effect.

	One-Period Lag		**Two-Period Lag**	
	Heavily	**Non-Heavily**	**Heavily**	**Non-Heavily**
L.LN_INV	−0.198 ***	−0.454 **		
	(−3.04)	(−2.37)		
L_LN_INV2	0.0217 ***	0.0573 ***		
	(3.54)	(2.82)		
L2.LN_INV			−0.0269	−0.0639
			(−0.71)	(−0.55)
L2_LN_INV2			0.00424	0.0148
			(1.26)	(1.27)
avgLN_INV				
avgLN_INV2				
SIZE	−0.678 ***	−0.301 ***	−0.615 ***	−0.288 **
	(−14.20)	(−3.24)	(−10.63)	(−2.28)
LEV	−0.00498	−0.516 ***	−0.232	−0.382
	(−0.03)	(−2.89)	(−1.02)	(−1.61)
FIRST	−0.525 ***	0.520	−0.423 *	1.946 **
	(−2.99)	(1.22)	(−1.89)	(2.33)
INS	1.879 ***	0.191	1.731 ***	−1.014
	(11.42)	(0.41)	(8.73)	(−1.02)
YEARTURN	0.0223 ***	0.0104	0.0262 ***	0.00377
	(2.76)	(0.86)	(2.70)	(0.22)
STATE	−0.288 ***	−0.225 **	−0.363 ***	−0.226
	(−5.90)	(−2.33)	(−6.40)	(−1.63)
GROW	0.407 ***	0.115	0.530 ***	0.161
	(4.12)	(0.87)	(4.46)	(0.91)
LNG	0.411 ***	0.348 ***	0.392 ***	0.480 ***
	(6.93)	(2.97)	(5.28)	(2.76)
YEAR		Control		
IND		Control		
cons	3.465 ***	3.142 ***	3.346 ***	1.949 **
N	1603	202	1176	149
N	0.402	0.558	0.396	0.470
R^2	33.08	10.34	26.58	7.466

t statistics in parentheses * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

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