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Assessing the Impact of Environmental Protection Tax Law on the Market Valuation of High-Pollution Companies: A Quasi-Natural Experiment Approach in China

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Abstract: Based on the financial panel data of Chinese A-share listed companies from 2015 to 2022, this paper takes the "Fee-to-Tax" reform in environmental protection in 2018 as a quasi-natural experiment and employs the Propensity Score Matching-Difference-in-Differences (PSM-DID) model to explore the impact of the environmental protection tax on the valuation of heavily polluting enterprises. The research results show that the environmental protection tax can significantly promote the valuation increase of heavily polluting enterprises and has passed a series of robustness tests. In addition, the analysis of regional heterogeneity and enterprise ownership heterogeneity further reveals the differences between regions and enterprise ownership. The environmental protection tax has a significant positive impact on the valuation of heavily polluting enterprises in Eastern China and non-state-owned heavily polluting enterprises. It is also further found that the environmental protection tax policy improves the valuation of heavily polluting enterprises through the paths of environmental information disclosure, green technology innovation, and intelligent transformation. In light of these findings, this paper proposes relevant policy recommendations to provide reference for accelerating enterprise transformation and upgrading and promoting steady economic growth.

Keywords: Environmental protection tax; Enterprise valuation; Propensity Score Matching-Difference-in-Differences (PSM-DID) model; Heavily polluting enterprises

1 Introduction

Since the reform and opening-up, China's economy has developed rapidly, but this has also concealed a series of environmental degradation problems. Therefore, environmental protection has attracted widespread attention. Environmental issues are inseparable from the sustainable development of society. With the rapid development of the economy and society, the continuous consumption of resources, the continuous deterioration of the environment, and the gradual emergence of ecological imbalances, the carrying capacity of the environment is gradually approaching its limit. The Chinese government has always emphasized the concept that "lucid waters and lush mountains are invaluable assets," and building an ecological civilization system is not only an important strategy for China but also a measure that meets the expectations of the people. Therefore, the state and citizens have paid more attention to the impact of enterprises' daily production and business activities on the ecological environment and the disclosure of environmental behavior-related information by enterprises. Enterprise valuation is not only the goal pursued by enterprises, but it is also closely related to the transformation and upgrading of enterprise industrial structure and stable development. In addition, enterprise valuation is also one of the indicators widely used internationally to evaluate company performance. In the context of global economic integration, if enterprises want to gain an advantage in the fierce market competition, they must optimize their industrial structure to maximize corporate value.

The Porter Hypothesis suggests that appropriate environmental regulations will stimulate technological innovation [1]. The environmental protection tax is a policy that has received much attention in recent years. Research evidence from foreign scholars such as Klenert et al. [2], Freire-González [3], and Alexeev et al. [4] shows that environmental tax policies not only play a positive role in environmental conservation but also have a positive impact on economic growth. This means that while achieving environmental dividends, environmental tax policies can also

bring economic benefits. At the same time, Chiroleu-Assouline and Fodha [5] believe that the environmental tax, as a market-based and economically incentivized environmental regulation tool, has a positive role in promoting the coordinated development of the economy, society, and nature. With the increasing severity of global environmental issues, how to promote the green transformation of HPC through the reform and improvement of the EPT system has become a focus of attention in both the academic and business communities. Here are some studies on EPT in the academic community: Liu et al. [6] found that the implementation of environmental protection taxes can improve the Environmental-Social-Governance (ESG) performance of severely polluting companies. In addition, heterogeneity analysis in terms of tax incentives, total operating costs, and monopoly power suggests that severely polluting companies with higher tax incentives, higher total operating costs, or weaker monopoly power are more likely to improve their performance on ESG issues after the introduction of environmental taxes. Liu et al. [7] found that after the implementation of the environmental protection tax, enterprises' environmental investments increased significantly. Further analysis found that for state-owned enterprises and enterprises that receive high media attention, the positive impact is more significant, but there is no significant difference between enterprises in regions with different levels of economic development. A study by Xie et al. [8] showed that the execution of environmental taxes significantly reduced the investment efficiency of companies. Yu et al. [9] found that the reform of the EPT had a notable positive impact on the capacity utilization rate of companies, indicating that this positive effect gradually increased over time. He et al. [10] proved that the EPT promotes the total factor productivity of heavy polluters. The dynamic effect analysis shows that the positive effect of the EPT on total factor productivity will increase over time. Guan et al. [11] found that there is a significant positive spatial correlation in the upgrading of provincial industrial structures in China, and the environmental protection tax has a significant positive spatial spillover effect on the upgrading of industrial structures. Long et al. [12] found that the imposition of environmental taxes significantly reduced the performance of heavily polluting enterprises. Studies by Yin et al. [13] and Li et al. [14] examined the impact of environmental protection taxes on pollutant emissions, finding that the environmental protection tax has a significant negative impact on industrial sulfur dioxide (SO_2) and industrial soot (dust) emissions.

By reviewing the literature related to environmental protection taxes, it is found that current research on environmental protection tax policies mainly focuses on environmental investment, total factor productivity of enterprises, industrial upgrading, pollutant emissions, and tax policy optimization, etc., with less research on environmental protection taxes from the perspective of enterprise valuation. As a macro-level policy, to understand the implementation effect of environmental protection taxes, it is necessary to judge through the changes of micro-subjects. Therefore, the change in the valuation of enterprises, especially the valuation of heavily polluting enterprises, can reflect to a certain extent the implementation effect and implementation degree of environmental protection tax policies. Therefore, this paper takes this as an entry point, then, based on the data of Chinese A-share listed companies from 2015 to 2022, this study takes the "Fee-to-Tax" reform in environmental protection in 2018 as a quasi-natural experiment, and uses the PSM-DID method to analyze the policy effect of environmental protection tax on the valuation of heavily polluting enterprises, moreover, it conducts empirical research and tries to provide a new perspective for exploring the implementation effect of environmental protection tax policies and research on enterprise valuation.

2 Theoretical Analysis and Research Hypothesis

2.1 Fundamental Theoretical Analysis

The environmental protection tax policy, as an important economic tool, aims to guide enterprises to reduce environmental pollution and protect the ecological environment through the leverage of taxation. The implementation of this policy will impact the value of heavily polluting enterprises. This paper will discuss the impact of environmental protection tax policy on the valuation of heavily polluting enterprises from the following aspects.

Firstly, from the perspective of environmental investment, research by Liu et al. [15] shows that the implementation of the environmental protection tax policy can significantly increase enterprises' investment in environmental protection. Lee et al. [16] argue that environmental investment also provides financial support for enterprises' green technology innovation, and effective environmental investment is conducive to green technological innovation in enterprises. Enterprises, through green technology innovation and the adoption of more environmentally friendly technologies and equipment in the production process, can improve production efficiency, product quality, resource utilization efficiency, and reduce pollution emissions. This will help enterprises form a competitive advantage, thereby enhancing their valuation. Secondly, from the perspective of environmental responsibility, the implementation of the environmental protection tax policy will increase the costs for enterprises. To reduce these costs, enterprises will better fulfill their environmental responsibilities. With the increasing attention of consumers and investors to environmental protection, higher fulfillment of corporate environmental responsibilities can demonstrate their environmental awareness and sense of responsibility to the public, enhancing the social image and reputation of the enterprise. According to the signaling theory, a good corporate reputation can attract more investors and consumers, thereby increasing the enterprise valuation. Thirdly, from the perspective of risk management, the implementation of

the environmental protection tax policy will increase government monitoring of pollution emissions. Governments, by levying environmental protection taxes, make heavily polluting enterprises bear the corresponding environmental costs, increasing the economic burden on enterprises [17]. This cost pressure encourages enterprises to pay more attention to environmental management, adopt effective environmental protection measures, reduce pollution emissions, and improve the standardization and transparency of the enterprise, thereby reducing the risk of legal disputes, fines, and reputation loss due to environmental issues. This risk management effect can enhance the robustness and long-term sustainability of enterprises. According to the risk-return theory, lower environmental risks will bring lower potential costs and higher enterprise valuation to the enterprise [18–20].

Based on the above analysis, this paper proposes the following hypothesis:

Hypothesis 1: The environmental protection tax can increase the valuation of heavily polluting enterprises.

2.2 Analysis of the Mechanism of Environmental Protection Tax on the Valuation of Heavily Polluting Enterprises

(1) Environmental Information Disclosure Effect

With the implementation of the environmental protection tax policy, enterprises, in response to the government's call and to reduce tax burden, will increase their investment in environmental protection. This includes the acquisition of environmental protection facilities, research and development of environmental technologies, and purchasing environmental services. These investments may be directly reflected in the enterprise's financial statements or through other environmental-related indicators. The increase in environmental investments makes the employees and leaders of heavily polluting enterprises more focused on environmental issues. They start to realize the importance of environmental protection, integrate environmental concepts into the company's strategic planning and daily operations, and recognize the impact of environmental information disclosure on the company's image and competitiveness. As environmental awareness increases, heavily polluting enterprises begin to establish and improve their own environmental management systems. This includes formulating environmental policies and systems, establishing environmental departments, and strengthening environmental monitoring. These measures can improve the enterprise's level of environmental management, allowing it to more effectively manage its affairs in environmental protection. With increased environmental investment, raised awareness, and improved environmental management, it means that the enterprise's efforts and achievements in environmental protection will become more significant. To showcase these results, the level of environmental information disclosure of heavily polluting enterprises will also be enhanced. They begin to actively disclose their efforts and achievements in environmental protection, demonstrating their responsibility and commitment to the environment, winning recognition from consumers, investors, and society. As environmental consciousness gradually becomes accepted by the public, consumers tend to choose environmentally friendly products. Therefore, enterprises will highly value environmental protection and timely disclose relevant environmental information to the public. This helps to gain a "green competitive advantage" and enhances the social recognition of the enterprise among consumers. Based on this, it can be seen that the implementation of environmental protection tax policy can improve the level of environmental information disclosure of heavily polluting enterprises. In the context of building an ecological civilization, by improving the level of environmental information disclosure, this behavior can help investors better understand the operation of the enterprise, dispel investor-related doubts, reduce the information asymmetry between the enterprise and the outside world, not only strengthen their investment confidence but also enhance the brand image and reputation of the enterprise among investors and partners, creating more development opportunities for the enterprise. This way, the enterprise can attract capital inflows at a lower cost, increase revenue, and thereby improve the valuation of the enterprise.

After the above analysis, this paper proposes the second hypothesis:

Hypothesis 2: The environmental protection tax enhances the valuation of heavily polluting enterprises by encouraging them to strengthen environmental information disclosure.

(2) Green Technology Innovation Effect

The implementation of the environmental protection tax policy can act as a signal to enterprises, indicating the government's emphasis and determination on environmental protection, while also enhancing society's attention to environmental issues. This leads to consumers and investors increasingly focusing on corporate environmental behavior. Such signals can influence corporate business strategies and investment decisions. In response to government environmental policies, to address public opinion pressures and meet public expectations for environmental protection, heavily polluting enterprises are compelled to adjust their business strategies. This, in turn, prompts them to adopt environmental measures, increase investment in green technology innovation, and improve their environmental performance to meet government and societal environmental requirements, demonstrating their concern and commitment to environmental protection. By improving the level of green technology innovation, heavily polluting enterprises can send positive signals to the market. These signals indicate that the enterprise is committed to environmental protection and sustainable development and is willing to assume corresponding social responsibilities. Investors and consumers will assess and choose enterprises based on these signals. When an enterprise demonstrates

a higher level of green technological innovation, investors and consumers will perceive the enterprise as having better prospects for development and sustainability, increasing its recognition in the market, and thereby enhancing the valuation of heavily polluting enterprises.

Based on the above analysis, this paper proposes the third hypothesis:

Hypothesis 3: The environmental protection tax enhances the valuation of heavily polluting enterprises by encouraging green technology innovation.

(3) Intelligent Transformation Effect

The implementation of the environmental protection tax policy increases the environmental tax burden on heavily polluting enterprises, thereby increasing their production costs. In order to reduce costs and increase profits, enterprises will intensify efforts in intelligent transformation. On the one hand, intelligent transformation can improve the production efficiency of enterprises, reduce the energy consumption and pollutant emissions per unit of product, and thus reduce the payment of environmental taxes. On the other hand, intelligent transformation can optimize the production process and resource utilization of enterprises, making them more compliant with environmental standards and requirements, and thus enjoy tax incentives or exemptions. All these can reduce the tax burden of enterprises. Therefore, the implementation of the environmental protection tax will promote the intelligent transformation of heavily polluting enterprises to reduce production costs and enhance competitiveness. Through intelligent transformation, heavily polluting enterprises, integrating technologies such as artificial intelligence, big data, and the Internet of Things, and using more intelligent equipment, can monitor, analyze, and predict data in the production process in real time. They can achieve real-time information sharing and collaborative operations with partners such as suppliers and logistics service providers. This enables a more precise understanding of market demand, raw material supply, and energy consumption, allowing for a faster response to market changes and customer needs. Moreover, it helps improve efficiency in various supply chain segments like raw material procurement, inventory management, and logistics distribution. This assists enterprises in making more scientific and accurate decisions, aiming for optimal resource allocation and efficient utilization. This ability to optimize resource allocation helps reduce operational costs, increase production capacity, and boost profits, thereby enhancing the market valuation of the enterprise.

Based on the above analysis, this paper proposes the fourth hypothesis:

Hypothesis 4: The environmental protection tax enhances the valuation of heavily polluting enterprises by encouraging intelligent transformation.

3 Empirical Design

3.1 Data Source and Sample Selection

This study uses panel data of A-share listed companies from 2015 to 2022 as the initial sample. Referring to the *Environmental Information Disclosure Guidance for Listed Companies* and the *Listed Company Industry Classification Guidelines*, enterprises in 16 categories including thermal power, steel, cement, electrolytic aluminum, coal, metallurgy, chemical, petrochemical, building materials, papermaking, brewing, pharmaceuticals, fermentation, textiles, tanning, and mining are defined as heavily polluting enterprises. These enterprises are taken as the experimental group, and the rest as the control group. The initial data are filtered according to the following criteria: (1) Exclude all financial listed companies; (2) Exclude companies that have been specially treated (ST, *ST, and PT); (3) Exclude companies listed after 2014; (4) Perform 1% and 99% winsorization on continuous variables; (5) Exclude companies with severe missing data samples; (6) Exclude companies whose industry changed during the research period. After these steps, 1935 companies and 13935 observations were selected. The data for the intelligent transformation index comes from the annual reports of listed companies, and other data mainly come from the CSMAR database, processed mainly through Stata 15.

(1) Dependent Variable

The Tobin's Q value (TobinQ), namely the ratio of company market value to total assets, is selected as the measure of company valuation.

(2) Core Explanatory Variable

Treat*Time in Eq. (2) is the core explanatory variable, represented by DID.

(3) Mechanism Variables

Environmental Information Disclosure (EID): Existing studies typically use a scoring method to measure the level of environmental information disclosure of listed companies. Based on data from the CSMAR database, this paper classifies environmental information disclosure items into 25 categories. Scores are assigned to different items based on their category, and each company's score for each item in a given year is totaled to obtain the Environmental Information Disclosure Quality Index (EID). The scoring rule is: 2 points for disclosed environmental management, information disclosure carriers, and environmental regulation and certification items; otherwise 0 points. 2 points for quantitative and qualitative description of environmental performance and liability disclosure, 1 point for only qualitative description, and 0 for no disclosure. The total score for EID ranges from 0 to 50.

Green Technology Innovation (EnvrPat): Measured by the number of green patent applications of listed companies, including both green invention and utility patents. The sum of these patents is log-transformed to obtain the Green Technology Innovation Index.

Intelligent Transformation (Intel): This study uses keywords such as intelligent, digital, data intelligence, networking, internet+, intelligent terminals, intelligent recognition, robotics, intelligent manufacturing, informatization, automation, cloud computing, cloud platforms, IoT, smart manufacturing, intelligent enterprises, Industry 4.0, cyber-physical systems, big data, sensing technology, data visualization, human-machine interaction, sensors, cloud manufacturing, proactive manufacturing, industrial internet, controllers, and data mining as indicators of intelligent transformation. Text analysis is conducted using Python to mine the annual report texts of listed companies from 2015-2022. The frequency of each intelligent transformation keyword is calculated, and the sum for each company is log-transformed to obtain the Intelligent Transformation Index.

(4) Control Variables

Since the following variables all impact enterprise valuation, they are included as control variables in the model: Company age (Age), measured by the current year minus the listing year; Proportion of independent directors (Indep), measured by the ratio of the number of independent directors to the total board size; Asset size (Size), measured by the natural logarithm of total assets; Return on assets (Roa), measured by the ratio of net profit to the average balance of total assets; Leverage ratio (Lev), measured by the ratio of total liabilities to total assets; Revenue growth rate (Growth), measured by the ratio of the current period's revenue minus the previous period's revenue to the previous period's revenue; Proportion of shares held by the largest shareholder (Share), measured by the proportion of shares held by the largest shareholder; Book-to-market ratio (Bm), measured by the ratio of total assets to market value. The main variable definitions and descriptive statistics are shown in Table 1.

Table 1. Variable descriptions and descriptive statistics

Variable Type	Variable Symbol	Number of Samples	Minimum Value	Maximum Value	Mean	Standard Deviation
Dependent Variable	TobinQ	13,935	0.812	8.804	2.04	1.396
Explanatory Variable	DID	13,935	0	1	0.168	0.374
Mechanism Variable	EID	13,935	0	48	11.364	9.78
	EnvrPat	13,935	0	6.616	0.379	0.838
	Intel	13,935	0	7.266	2.543	1.319
Control Variable	Lev	13,935	0.656	0.894	0.444	0.198
	Growth	13,935	-0.572	1.8	0.128	0.33
	Size	13,935	20.11	26.60	22.65	1.316
	Age	13,935	2	28	14.00	6.997
	Roa	13,935	-0.231	0.211	0.328	0.063
	Share	13,935	8.923	70.535	33.279	14.362
	Indep	13,935	33.33	57.14	37.65	5.492
	Bm	13,935	0.114	1.232	0.642	0.275

3.2 Modelling

3.2.1 PSM

The core question of this paper is whether the implementation of the environmental protection tax policy can enhance the valuation of heavily polluting enterprises. This paper estimates the impact of the environmental protection tax policy on the valuation of heavily polluting enterprises by studying the valuation changes of heavily polluting (treatment group) and non-heavily polluting (control group) enterprises. However, when constructing the model, two issues need to be considered: ① The change in the valuation of heavily polluting enterprises might not result from the policy impact but could be the result of "self-selection," leading to sample selection bias. ② The valuation change differences between the two groups of samples might be caused by unobservable factors or other factors, leading to heterogeneity bias. To reduce the impact of these two endogeneity problems on model estimation, this paper first adopts the PSM method proposed by Rosenbaum and Rubin [21]. The steps are as follows: first, construct a Logit model to calculate the probability of each enterprise, i.e., the propensity score. Then match enterprises with similar propensity scores, that is, find an enterprise in the control group sample that is as similar as possible to the treatment group sample in terms of observable variables. When the observable variables, except for the enterprise valuation measurement indicators, are similar, it is possible to compare the treatment group with the control group. On this

basis, this paper uses the matched samples through the PSM method for regression analysis using the DID method to estimate the impact of the implementation of the environmental protection tax policy on the valuation of heavily polluting enterprises. This can reduce the impact of biases due to sample selection and heterogeneity, thus enhancing the scientific and reliability of the estimation results. The construction of the PSM model is as follows:

$$p_i(x) = pr\left(d_i = 1 \mid x_i\right) = f\left[h\left(x_i\right)\right] \tag{1}$$

where, $p_i(x)$ is the propensity score value, d_i is a dummy variable (treatment group=1); x_i represents the set of variables of enterprise i participating in the matching; $h\left(x_i\right)$ is the linear function of the variable x_i of enterprise i; $f\left[h\left(x_i\right)\right]$ is the Logit function. Through the model in Eq. (1), multiple variables are dimensionally reduced to obtain the probability value of enterprise i, and this is used as a reference to match enterprises similar to the treatment group from non-heavily polluted enterprises as the control group for subsequent analysis.

3.2.2 PSM-DID model

Compared to the Ordinary Least Squares (OLS) regression model, the DID model is more suitable for policy effect evaluation studies. For instance, it is used to analyze the effects of policies like green credit policy, carbon emission trading rights pilot policy, and green finance reform and innovation pilot policy, assessing the impacts brought by these policy effects. Therefore, based on the matched samples, a DID model is constructed for regression to test the impact of the implementation of the environmental protection tax on the valuation of heavily polluting enterprises. The model is constructed as follows:

$$\text{TobinQ}_{it} = \beta_0 + \beta_1 * \text{ Treat}_{it} * \text{ Time}_{it} + \sum_j \beta_j * \text{ control } + \delta_i + \gamma_{\mathrm{t}} + \varepsilon_{it} \tag{2}$$

where, the dependent variable represents the company valuation, denoted by TobinQ_{it}, which is the Tobin's Q value of company i in year t; β_0 is the constant term, β_1 is the coefficient of the core explanatory variable, measuring the impact of the implementation of the environmental protection tax on the valuation of heavily polluting enterprises. If $\beta_1 < 0$, it indicates a decrease in enterprise valuation, and if $\beta_1 > 0$, it indicates an increase. Treat_{it} is a group dummy variable indicating whether enterprise i is a heavily polluting enterprise (1 if yes, 0 otherwise); Time_{it} is a policy dummy variable indicating whether the environmental protection tax policy was implemented in year t (0 before 2018, 1 in 2018 and afterwards); Treat*Time is the core explanatory variable represented by DID, with 1 for heavily polluting enterprises after 2018, and 0 for all other samples. 'control' includes control variables like company age, asset size, and leverage ratio, δ_i is the individual fixed effect, γ_t is the time fixed effect, and ε_{it} is the random disturbance term.

At the same time, based on the matched samples, a mediation effect model is constructed for mechanism testing. To avoid endogeneity and unclear channel identification problems in the traditional three-step test of mediation effects, this paper only uses the second step of the three-step mediation effect test to examine the mechanisms through which the environmental protection tax affects environmental information disclosure, green technology innovation, and intelligent transformation. The roles of environmental information disclosure, green technology innovation, and intelligent transformation on the valuation of heavily polluting enterprises are mainly based on literature and logical reasoning, and the following three mechanism test models are constructed:

$$\text{EID}_{it} = \alpha_0 + \alpha_1 * \text{ Treat}_{it} * \text{ Time}_{it} + \sum_j \alpha_j * \text{ control } + \delta_i + \gamma_t + \varepsilon_{it} \tag{3}$$

$$\text{EnvrPat}_{it} = \lambda_0 + \lambda_1 * \text{ Treat}_{it} * \text{ Time}_{it} + \sum_j \lambda_j * \text{ control } + \delta_i + \gamma_t + \varepsilon_{it} \tag{4}$$

$$\text{Intel}_{it} = \theta_0 + \theta_1 * \text{ Treat}_{it} * \text{ Time}_{it} + \sum_j \theta_j * \text{ control} + \delta_i + \gamma_t + \varepsilon_{it} \tag{5}$$

Eqs. (3)-(5) are mechanism test models used to examine the impact of the environmental protection tax policy on the valuation of heavily polluting enterprises through environmental information disclosure, green technology innovation, and intelligent transformation. EID_{it}, EnvrPat_{it}, and Intel_{it} are mechanism variables, representing the environmental information disclosure quality, green technology innovation level, and degree of intelligent transformation of company i in year t, respectively. The settings of other variables are the same as in Eq. (2).

4 Empirical Results Analysis

4.1 PSM Results

Based on Eq. (1), the k-nearest neighbor matching method (k=3) was used to match samples with similar propensity scores, resulting in a control group with characteristics similar to the treatment group. Then, a balance test was conducted. As shown in Table 2, after matching, the standardized bias of variables decreased and all were less than 10%. Besides, except for the Revenue Growth Rate (Growth), the differences in variables between the treatment and control groups before matching were mostly significant. However, after matching, except for the Return on Assets (Roa), the t-test results did not reject the null hypothesis, indicating that the variables of the two groups were essentially balanced, meaning there was no systematic difference between the treatment and control groups. Additionally, as seen from Figure 1, most of the samples after matching fall within the same support domain, with only a few outside the common value range, suggesting that the matching method meets the common support assumption.

Table 2. Balance test of PSM

Variable	Before/After Matching	Mean		Standardized Bias /%	Change in Standardized Bias /%	T-test	
		Treatment Group	Control Group			t	p > |t|
Lev	Before	0.4492	0.4417	3.8	33.0	1.97	0.049
	After	0.4492	0.4542	-2.6		-1.10	0.27
Growth	Before	0.1354	0.1253	3.1	14.0	1.59	0.112
	After	0.135	0.1263	2.7		1.15	0.249
Size	Before	22.84	22.586	19.0	96.2	10.09	0.000
	After	22.84	22.83	0.7		0.31	0.758
Age	Before	14.544	13.799	10.9	86.7	5.55	0.000
	After	14.54	14.639	-1.5		-0.62	0.534
Roa	Before	0.0361	0.0316	7.1	13.9	3.69	0.000
	After	0.036	0.0322	6.1		2.80	0.005
share	Before	34.293	32.915	9.5	70.9	5.00	0.000
	After	34.291	33.89	2.8		1.19	0.236
Indep	Before	37.288	37.78	-9.1	89.8	-4.68	0.000
	After	37.287	37.337	-0.9		-0.41	0.681
Bm	Before	0.7084	0.6187	32.9	91.5	17.16	0.000
	After	0.7082	0.7158	-2.8		-1.18	0.238

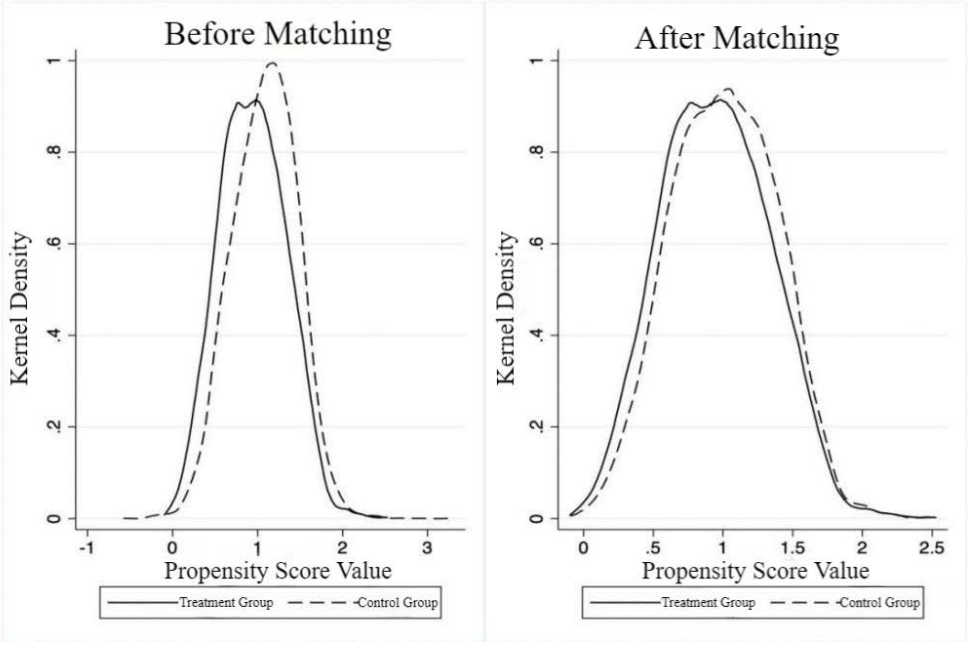

Figure 1. Distribution of propensity scores in treatment and control groups before and after PSM matching

4.2 Baseline Regression

Firstly, without using PSM to match samples, the DID method was applied for regression. The regression results are shown in columns (1) and (2) of Table 3. Both columns (1) and (2) include individual and time fixed effects, but column (1) represents the regression without control variables, where the core explanatory variable DID's regression coefficient is 0.1810, significant at 1%; column (2) includes all control variables, with the DID coefficient being 0.1792, also significant at 1%. Subsequently, based on the propensity score matching, the policy effect of the environmental protection tax was evaluated using the DID method, and the baseline regression results are shown in columns (3) and (4) of Table 3. Both columns (3) and (4) include individual and time fixed effects, but column (3) represents the regression without control variables, with the core explanatory variable DID's regression coefficient being 0.1144, significant at 5%; column (4) includes all control variables, with the DID coefficient being 0.0984, significant at 1%. The DID and PSM-DID regression results indicate that the core explanatory variable DID's regression coefficient is significantly positive, suggesting that the implementation of the environmental protection tax significantly increases the valuation of heavily polluting enterprises, thus confirming Hypothesis 1.

Table 3. Baseline regression analysis

Variable	(1) TobinQ	(2) TobinQ	(3) TobinQ	(4) TobinQ
DID	0.1810***	0.1792****	0.1144**	0.0984***
	(2.6051)	(2.5798)	(2.3701)	(2.6008)
Lev		0.4003		−0.2638*
		(0.5492)		(−1.9487)
Growth		-0.0148		0.0257
		(−0.7019)		(1.1274)
Size		-0.1910		-0.0500
		(−0.9861)		(−1.1286)
Age		−0.0486***		−0.0978**
		(−4.1747)		(−2.0945)
Roa		1.0253*		0.5324***
		(1.7115)		(2.6801)
share		-0.0025		0.0020
		(−0.6759)		(1.0730)
Indep		0.0097**		0.0016
		(2.0982)		(0.8104)
Bm		−3.8363***		−3.9415***
		(−19.0165)		(−38.2064)
Constant Term	3.1594***	9.1870**	2.9761***	6.8686***
	(63.4307)	(2.2532)	(102.6639)	(6.4202)
Individual Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Number of Samples	13,935	13,935	13,935	13,935
R-squared	0.132	0.249	0.254	0.528
Number of companies	1,935	1,935	1,935	1,935

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

4.3 Robustness Test

4.3.1 Parallel trends test

To apply the DID method, it is necessary to pass the parallel trends test, which requires that the treatment and control groups have the same trends before the implementation of the policy. This paper uses the event study method for the parallel trends test. To avoid perfect collinearity, the year 2017 is excluded, using it as the base period for regression estimation. Figure 2 is the parallel trend graph, reporting the estimated coefficients of the core explanatory variable DID and its 95% confidence interval. Figure 2 shows that before the policy implementation, the confidence intervals cover 0, and the estimated coefficients of the core explanatory variable DID are not significant. Thus, there was no significant difference between the treatment and control groups before the implementation of the environmental protection tax. After the implementation of the environmental protection tax, the estimated coefficients of the core explanatory variable DID are significantly non-zero and consistently positive, showing that the implementation of the environmental protection tax can increase the valuation of heavily polluting enterprises, passing the parallel trends test.

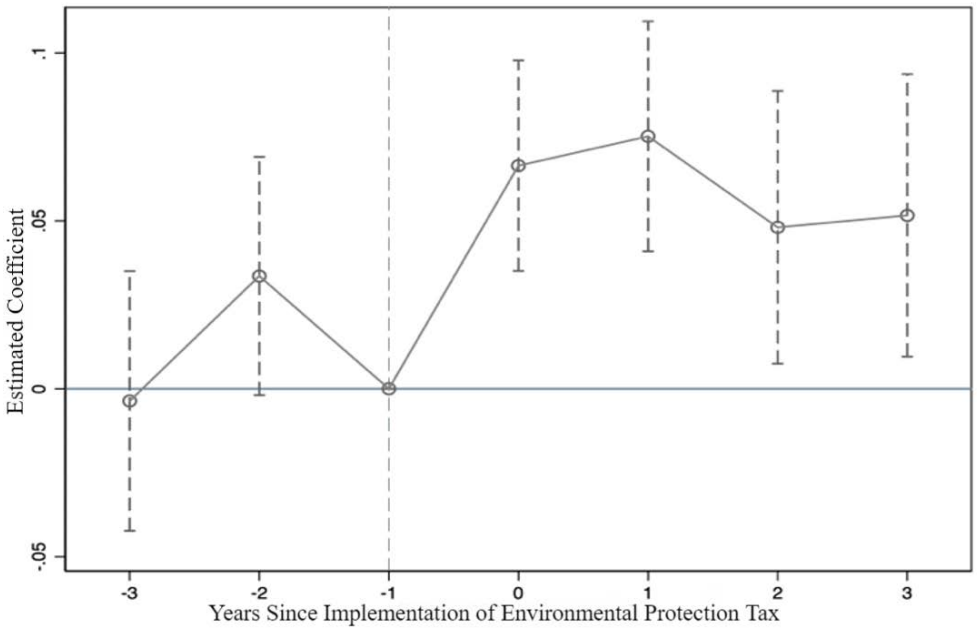

Figure 2. Parallel trends test

4.3.2 Placebo test

To prevent unobservable omitted variables from interfering with the baseline regression results, this paper redistributes the treatment and control groups to conduct a placebo test. Specifically, a certain proportion of enterprises are randomly selected from all samples as the dummy treatment group, and the remaining enterprises as the dummy control group. On this basis, regression is performed on the obtained samples to estimate the coefficient of the core explanatory variable DID. This operation is repeated 500 times, yielding 500 regression coefficient estimates, generating the probability distribution of DID estimates as shown in Figure 3, from which, it can be seen that the majority of the estimated coefficients obtained by regression based on random sampling are near 0, while the baseline regression estimate is 0.0934. This means that the randomly selected dummy treatment group does not affect the valuation of enterprises. Therefore, it can be concluded that the baseline regression results are not caused by unobservable factors, and the positive impact of the environmental protection tax on the valuation of heavily polluting enterprises is robust.

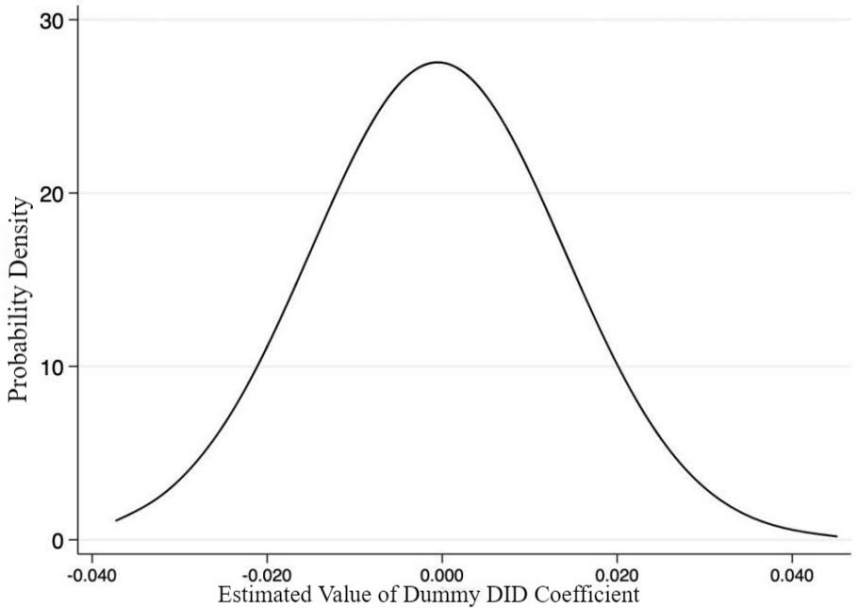

Figure 3. Placebo test

4.3.3 Replacement of the dependent variable

To further verify the reliability of the conclusions, this paper uses the Price-to-Book ratio (PB) to replace the TobinQ value as the dependent variable in the baseline regression, with other variables the same as in Eq. (2). Table 4 shows the results of replacing the dependent variable with the PB. Columns (1) and (2) both include individual and time fixed effects. Column (1), without control variables, shows that the core explanatory variable DID's regression coefficient is 0.2649, significant at 5%. Column (2), including all control variables, shows that the DID coefficient is 0.3883, significant at 1%. The results show that the DID coefficients in both regressions are significantly positive, indicating that the implementation of the environmental protection tax can significantly increase the valuation of heavily polluting enterprises. This is consistent with previous study results, indicating the robustness of the conclusions of this paper.

4.3.4 Change in policy execution year

To prevent the regression results from being affected by other policies or random factors, this paper shifts the implementation year of the environmental protection tax policy two periods later, to 2020. Regression is then performed using the DID model. If the core explanatory variable DID's coefficient is not significant, it implies that the change in valuation of heavily polluting enterprises is due to the implementation of the environmental protection tax, indirectly proving the robustness of the result that the environmental protection tax policy has a positive impact on the valuation of heavily polluting enterprises. The regression results are shown in Table 4. Columns (3) and (4) both include individual and time fixed effects. Column (3) does not include control variables, while column (4) includes all control variables. The results in Table 4 show that when 2020 is considered as the year of implementation of the environmental protection tax policy, the coefficient of the core explanatory variable DID is completely insignificant. This demonstrates that the increase in valuation of heavily polluting enterprises after 2018 is not caused by other policy interference or random factors, but due to the implementation of the environmental protection tax policy, further strengthening the robustness of the conclusions of this paper.

Table 4. Robustness test results after replacing the dependent variable and changing the year of policy execution

Variable	**(1)** **PB**	**(2)** **PB**	**(3)** **TobinQ**	**(4)** **TobinQ**
DID	0.2649^{**}	0.3883^{***}	0.0486	0.0101
	(2.3494)	(4.1882)	(1.1359)	(0.3254)
Lev		5.6882^{***}		-0.2796^{*}
		(13.7526)		(-2.0612)
Growth		0.2417^{***}		0.0280
		(3.6218)		(1.2269)
Size		-0.8240^{***}		-0.0493
		(-6.5493)		(-1.1168)
Age		0.7944^{***}		-0.0940^{**}
		(6.0016)		(-2.0089)
Roa		1.1671^{**}		0.5655^{***}
		(2.1206)		(2.8568)
share		$0.0149**$		0.0021
		(2.9167)		(1.1428)
Indep		0.0053		0.0017
		(0.9264)		(0.8159)
Bm		-7.4499^{***}		-3.9386^{***}
		(-33.2009)		(-38.2506)
Constant Term	5.4736^{***}	15.6310^{***}	2.9761^{***}	6.8125^{***}
	(85.0750)	(5.1909)	(102.4401)	(6.3820)
Individual Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Number of Samples	13,935	13,935	13,935	13,935
R-squared	0.252	0.486	0.253	0.527
Number of companies	1935	1935	1,935	1,935

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

4.3.5 Changing the matching approach

In the baseline regression analysis, the nearest neighbor matching method was used to match samples. To verify the robustness of the results, different matching methods were used, specifically radius matching and kernel density

matching, followed by regression using the DID method. Table 5 shows the regression results after changing the matching method. Columns (1) and (2) use the caliper matching method, and columns (3) and (4) use the kernel density matching method. Both include individual and time fixed effects, and columns (2) and (4) include all control variables. The results show that the regression coefficients of the core explanatory variable DID are positive and significant at the 1% level, further verifying the robustness of the baseline regression results.

Table 5. Robustness test results after changing the matching method

Variable	Caliper Matching		Kernel Matching	
	(1)	(2)	(3)	(4)
	TobinQ	TobinQ	TobinQ	TobinQ
DID	0.1806***	0.1790***	0.1815***	0.1803***
	(2.5959)	(2.5873)	(2.6096)	(2.6020)
Control Variable	NO	YES	NO	YES
Constant Term	3.1586***	9.1208**	3.1600***	9.0818**
	(63.3858)	(2.2355)	(63.4399)	(2.2267)
Individual Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.132	0.250	0.132	0.250
Number of Samples	13,935	13,935	13,935	13,935

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Group regression results based on ownership and regional heterogeneity

Variable	State-Owned Companies TobinQ	Non-State-Owned Companies TobinQ	Eastern Region TobinQ	Central Region TobinQ	Western Region TobinQ
DID	0.0220	0.1794***	0.1324***	0.0298	0.0330
	(0.4426)	(3.3312)	(2.9055)	(0.3230)	(0.3180)
Lev	−0.5677**	-0.0331	-0.2123	-0.4198	-0.3065
	(−2.4393)	(−0.1944)	(−1.4137)	(−0.9842)	(−0.8740)
Growth	-0.0306	0.0222	0.0243	-0.0360	0.0191
	(−1.0948)	(0.6846)	(0.8796)	(−0.8784)	(0.2892)
Size	0.0300	-0.0736	-0.0675	-0.0097	0.0601
	(0.4487)	(−1.2307)	(−1.2085)	(−0.0859)	(0.6160)
Age	−0.0659*	−0.1806**	−0.1287**	-0.0897	0.0733
	(−1.8061)	(−2.0128)	(−2.3539)	(−0.9573)	(0.5250)
Roa	0.0307	0.5555**	0.6161***	0.2333	0.7140
	(0.0894)	(2.2880)	(2.7155)	(0.4376)	(1.1627)
share	-0.0035	0.0008	0.0026	-0.0008	0.0011
	(−1.4620)	(0.2791)	(1.0994)	(−0.2143)	(0.2321)
Indep	0.0045*	-0.0037	0.0017	0.0007	0.0029
	(1.6882)	(−1.2151)	(0.6774)	(0.1114)	(0.7379)
Bm	−3.3297***	−4.3626***	−3.9382***	−3.6162***	−4.2524***
	(−23.4785)	(−30.5589)	(−31.2419)	(−16.3506)	(−14.4768)
Constant Term	4.7168***	8.1579***	7.4860***	6.0136**	2.4192
	(3.1151)	(5.4931)	(5.7854)	(2.0848)	(0.8078)
Individual Fixed Effects	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Number of Samples	6,129	7,806	9,497	2,504	1,934
R-squared	0.475	0.570	0.554	0.466	0.491

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

4.4 Heterogeneity Test

4.4.1 Group regression based on ownership heterogeneity

Due to China's unique economic operation system, there are significant differences between state-owned and non-state-owned enterprises in terms of market status and daily operation. Therefore, it is necessary to assess the policy's effects from the perspective of enterprise nature, classifying enterprises into state-owned and non-state-owned for baseline regression. As shown in Table 6, both state-owned and non-state-owned enterprises incorporate all control variables and have individual and time fixed effects in the regression. The results show that the core explanatory variable DID coefficient for state-owned enterprises is 0.022, indicating a positive but insignificant impact. In contrast, the DID coefficient for non-state-owned enterprises is 0.1794, positive and significant at the 1% level. This could be because state-owned heavily polluting enterprises, owned by the national or local governments, may receive more subsidies and support from the government, lessening the economic pressure from environmental tax policies. Moreover, the governance structure of state-owned enterprises is quite complex, and their environmental behavior is more influenced by government regulation and administrative intervention, leading to less flexibility. This might result in a slower response from state-owned heavily polluting enterprises to the implementation of environmental tax policies, thus not significantly impacting them. In contrast, non-state-owned heavily polluting enterprises have more dispersed ownership, with shareholders more concerned about economic benefits and environmental behavior. Their governance structure is usually simpler, with more flexible decision-making, allowing them to adapt to policy changes more quickly, adjust production methods, improve environmental technologies and management measures, thus reducing production costs and increasing enterprise value.

4.4.2 Group regression based on regional heterogeneity

Considering the significant differences in regional development levels in China, it is necessary to evaluate the policy effects from a regional perspective, dividing China's economic regions into the East, Central, and West. For the baseline regression, enterprises are classified into East, Central, and West regions, as shown in Table 6. All regions include all control variables and have individual and time fixed effects. The results indicate that the core explanatory variable DID coefficients for Central and Western regions are 0.0298 and 0.033, respectively, both positive but not significant. However, the DID coefficient for the Eastern region is 0.1324, positive and significant at the 1% level. This suggests that the impact of the environmental protection tax on the valuation of heavily polluting enterprises differs by region. Specifically, the implementation of the environmental protection tax policy significantly affects the valuation of heavily polluting enterprises in the Eastern region, but not in the Central and Western regions. This could be because the Eastern region, located in economically developed and coastal areas, has more abundant production factors and a more mature overall enterprise structure, with a higher degree of marketization. Heavily polluting enterprises in the Eastern region can quickly adapt to policy changes and adjust their production methods and management measures. Moreover, the environmental policy and legal environment in the Eastern region are relatively well-established, with stricter regulation. The implementation of the environmental protection tax policy will make heavily polluting enterprises bear more environmental responsibilities and legal risks, stimulating them to increase environmental investment, introduce advanced environmental technologies and equipment, improve production efficiency, reduce costs, and thereby increase enterprise valuation. In contrast, the Central and Western regions are relatively remote with scarcer production factors. Enterprises in these regions are more concentrated in resource-based industries and traditional manufacturing, which are less environmentally polluting, thus making the impact of the environmental protection tax policy less significant in these areas.

4.5 Mechanism Analysis

Based on the established mechanism test models, a Difference-in-Differences regression was conducted, with results shown in Table 7. Columns (1), (2), and (3) include all control variables and both time and individual fixed effects. The regression coefficients for EDI, EnvrPat, and Intel are 0.6653, 0.0539, and 0.0795, respectively, significant at the 5% level. This indicates that the environmental protection tax has a significant positive impact on environmental information disclosure, green technology innovation, and intelligent transformation. The theoretical analysis and logical reasoning indicate that improvements in environmental information disclosure quality, green technology innovation level, and the degree of intelligent transformation can enhance the valuation of heavily polluting enterprises. Therefore, it can be concluded that the environmental protection tax promotes green technology innovation and intelligent transformation of equipment, improving process technology and production processes, enhancing environmental aspects of enterprises, increasing willingness to disclose environmental information, and ultimately increasing the valuation of heavily polluting enterprises. Hypotheses 2, 3, and 4 are verified.

Table 7. Regression results of mechanism analysis

Variable	(1) EID	(2) EnvrPat	(3) Intel
DID	0.6653**	0.0539**	0.0795**
	(2.0824)	(2.0149)	(2.0650)
Lev	−1.4091**	0.0080	−0.2302**
	(−2.0020)	(0.1343)	(−2.3316)
Growth	−0.2637*	-0.0083	0.0439**
	(−1.7954)	(−0.6203)	(2.3257)
Size	2.4189***	0.0789***	0.2374***
	(9.7984)	(3.8297)	(7.4420)
Age	0.8686***	-0.0231	-0.0276
	(24.6505)	(−1.1121)	(−0.3926)
Roa	-0.6770	-0.0304	0.3764***
	(−0.5902)	(−0.3256)	(2.6751)
Share	0.0122	-0.0006	0.0043***
	(0.9839)	(−0.5451)	(2.6780)
Indep	0.0056	0.0020	-0.0009
	(0.3611)	(1.4790)	(−0.4604)
Bm	−2.9432***	−0.055**	-0.0205
	(−5.7818)	(−2.2558)	(−0.3310)
Constant Term	−52.2887***	−1.2953**	−3.0392***
	(−10.0241)	(−2.5332)	(−3.0121)
Individual Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Number of Samples	13935	13935	13935
R-squared	0.268	0.012	0.293

Note: ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

5 Conclusions and Policy Recommendations

5.1 Conclusions

This paper treats the environmental protection tax policy as a quasi-natural experiment and uses the PSM-DID model to analyze its impact on the valuation of heavily polluting enterprises, based on panel data of 1935 companies.

Main conclusions attained in this study can be drawn as:

(1) Overall, the implementation of the environmental protection tax has increased the valuation of heavily polluting enterprises by 9.8% compared to those not subject to the tax. This indicates that the environmental protection tax has enhanced the valuation of heavily polluting enterprises.

(2) Ownership heterogeneity analysis reveals differences in the impact of the environmental protection tax policy on the valuation of different types of heavily polluting enterprises. The policy has a significant positive valuation effect on non-state-owned heavily polluting enterprises, increasing their valuation by 17.9%, while the impact on state-owned heavily polluting enterprises is not significant.

(3) Regional heterogeneity analysis shows differences in the impact of the environmental protection tax policy on heavily polluting enterprises in different regions. The policy has a significant positive valuation effect on enterprises in the Eastern region, increasing their valuation by 13.2%, while the impact on heavily polluting enterprises in the Central and Western regions is not significant.

(4) Mechanism analysis reveals that the implementation of the environmental protection tax policy has improved the quality of environmental information disclosure by 66.53%, the level of green technology innovation by 5.39%, and the degree of intelligent transformation by 7.95% for heavily polluting enterprises. Furthermore, improvements in environmental information disclosure quality, green technology innovation level, and the degree of intelligent transformation have enhanced the valuation of heavily polluting enterprises.

5.2 Policy Recommendations

Based on the research results, the following policy recommendations are proposed:

(1) Continue to Promote the Implementation of Environmental Protection Tax Policy

Given that the implementation of the environmental protection tax generally increases the valuation of heavily polluting enterprises, it should be actively promoted. The government can strengthen publicity and training and set up

specialized consulting services to answer questions about the environmental protection tax policy, helping enterprises and the public address issues encountered during implementation. This will enable enterprises and the public to fully understand the policy's purpose, details, and related incentives, enhancing their awareness and importance of the environmental protection tax. Additionally, to better leverage the environmental protection tax policy, it's necessary to improve related supporting policies and systems, such as environmental regulations and standards, enforcement and supervision, and promoting the disclosure of corporate environmental information.

(2) Adopt Differentiated Tax Policies for Enterprises with Different Ownership

The study results indicate that the impact of the environmental protection tax policy varies among heavily polluting enterprises with different ownership types. For non-state-owned heavily polluting enterprises, where the policy has a more significant positive effect on valuation, the government could offer tax relief to further encourage these enterprises to continue implementing environmental measures. Non-state-owned enterprises actively adopting such measures could receive financial subsidies from the government. This not only enhances the enterprises' motivation to implement environmental measures but also reduces their tax burden, stimulating continued investment in environmental protection, thereby aiding the transformation and development of non-state-owned heavily polluting enterprises, and further increasing their valuation. For state-owned heavily polluting enterprises, the government should strengthen the supervision and assessment of their environmental measures. Companies that fail to meet environmental standards should face corresponding penalties to enhance their awareness of environmental protection. State-owned enterprises excelling in environmental efforts could receive rewards, such as environmental awards or policy incentives. This would motivate them to adopt more proactive environmental measures, effectively leveraging the regulatory role of taxation.

(3) Implement Differentiated Tax Policies for Different Regions

The research also indicates that the environmental protection tax policy has varying impacts on the valuation of heavily polluting enterprises in different regions. For enterprises in the Eastern region, where the policy's positive effect on valuation is more pronounced, the region's unique geographical advantage as a coastal area can be leveraged. The Eastern region could strengthen environmental cooperation with the international community, introduce more advanced environmental technologies and management practices, and further enhance the valuation of its heavily polluting enterprises. In contrast, the Central and Western regions, located inland, could intensify internal cooperation with neighboring areas and introduce advanced environmental technologies and management experiences from both domestic and international sources, accelerating the development of environmental initiatives in these regions. Given that the Eastern region generally has more abundant production factors compared to the relatively scarce resources in the Central and Western regions, the government could guide the flow of capital, talent, and technology towards heavily polluting enterprises in the Central and Western regions. This would optimize resource allocation and enhance the environmental standards and competitiveness of enterprises in these areas, ultimately achieving a significant positive impact on the valuation of heavily polluting enterprises in the Central and Western regions as a result of the policy implementation.

(4) Strengthen Environmental Information Disclosure, Green Technology Innovation, and Intelligent Transformation

According to the study results, the environmental protection tax can enhance the valuation of heavily polluting enterprises through three pathways: enhancing environmental information disclosure, promoting green technology innovation, and advancing intelligent transformation. Based on these conclusions, the following policy suggestions are proposed: Firstly, to strengthen environmental information disclosure, the government should establish a comprehensive environmental information disclosure system, standardizing the content, method, and timing of corporate environmental disclosures to ensure their authenticity and completeness. At the same time, supervision and enforcement of corporate environmental information disclosure should be intensified, with severe penalties for those who fail to disclose or falsely disclose information. The government could also introduce incentives to encourage voluntary environmental information disclosure by enterprises, such as tax incentives and recognition for proactive disclosure. This would set an example and create a demonstration effect, guiding other enterprises to enhance their environmental information disclosure. Secondly, to enhance green technology innovation, the government should increase investment in green technology research and development, establish dedicated funds for green technology R&D, and support enterprises in the development and application of green technologies. The government could implement policies to support the industrialization of green technologies, such as providing tax incentives and loan support for green technology industrialization projects, to promote the widespread application and industrialization of green technologies. Lastly, to improve the degree of intelligent transformation, the government can introduce policies to support the intelligent transformation of enterprises, such as providing consultancy and training services for intelligent transformation, guiding enterprises to introduce advanced intelligent technologies and equipment. Special funds could be established to financially support intelligent transformation projects. The government could also encourage collaboration between enterprises, universities, and research institutions to jointly promote intelligent transformation, sharing resources and information for the coordinated development of enterprises with academic and

research institutions.

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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