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Environmental Protection Tax Reform and the Risk of Enterprises' Low-Carbon Transformation: A Quasi-Natural Experiment Based on Environmental Protection "Fee to Tax"

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Abstract: In the context of the "dual carbon" goal, it is of great significance to identify institutional arrangements that can effectively mitigate the risks of low-carbon transformation of enterprises. This paper takes A-share listed companies from 2010 to 2024 as a sample and constructs a double difference model (DID) based on the implementation of the quasi-natural experiment of environmental protection "fee to tax" in 2018 to empirically test the impact of environmental protection tax reform on the low-carbon transformation risk of enterprises. The study found that the "fee-to-tax" environmental protection significantly reduces the risk of low-carbon transformation of enterprises, and this conclusion is still valid after a number of robustness tests. The mechanism analysis shows that environmental protection tax plays a risk mitigation role by promoting green innovation, easing financing constraints, and enhancing executives' green awareness. Further analysis shows that corporate ESG performance has a certain distorting effect on effects, and some enterprises may replace substantive low-carbon investment with "signal-based" improvements such as information disclosure.

Keywords: Environmental Protection Tax; Low-Carbon Transition Risks; ESG Distortion Effect; Green Innovation

1. Introduction

Under the guidance of the "dual carbon" goal China's ecological civilization construction has entered a stage of synergy between pollution reduction and carbon reduction. Unlike traditional environmental performance indicators, low-carbon transition risks refers to the financial and operational challenges brought about by changes in policies, technologies, market dynamics, or social preferences in the process of moving towards a low-carbon economy. These risks are not only relevant to the resilience of companies themselves but are also increasingly becoming an important basis for policymakers and investors to identify climate-related financial risks [1]. For enterprises in high-carbon industries, if they cannot adjust their energy structure and production processes in a timely manner, they may not only face rising compliance costs and cash flow fluctuations but also cause high-carbon assets to "run aground" [2], financing restrictions and rising risk premiums [3], and other consequences. Therefore, identifying institutional arrangements that can effectively mitigate the risks of low-carbon transformation of enterprises is of great significance to promote green transformation, enhance corporate resilience, and prevent financial systemic risks [4].As an important part of China's ecological civilization system, the Environmental Protection Tax Law of the People's Republic of China was officially implemented in 2018, marking the implementation of environmental protection "fee to tax." Compared with pollutant discharge fees, environmental protection tax is stronger in terms of legal level, rigidity, and standardization, which helps to make the external cost of pollution explicit and strengthen corporate compliance constraints. Existing research on the economic consequences of environmental regulation has yielded rich results, mainly focusing on corporate pollution reduction [5], green innovation [6], investment efficiency [7], business performance [8], new quality productivity [9], etc., but the attention to the "low-carbon transformation risk" of enterprises is relatively insufficient. Theoretically, on the one hand, an environmental protection tax may force enterprises to carry out green technology transformation and optimize the energy structure and governance system by increasing pollutant

costs and compliance pressure [10], thereby reducing the uncertainty of future environmental penalties, policy shocks, and the depreciation of high-carbon assets; on the other hand, rising tax burdens may also squeeze corporate cash flow and increase financing demand in the short term [11]and amplify operational fluctuations, thereby exacerbating transformation risks.

In view of this, this paper implements this quasi-natural experiment based on the "fee to tax" of environmental protection, constructs a double difference (DID) model, and uses the data of A-share listed companies from 2010 to 2024 to empirically test the impact of environmental protection tax system changes on the low-carbon transformation risk of enterprises. The possible marginal contributions of this paper are the following: First, this paper provides a new research perspective for understanding and mitigating the risks of low-carbon transformation of enterprises. Although the existing studies have extensively examined the impact of environmental protection tax on carbon emissions, pollution control, and corporate green behavior, there is still a lack of empirical research on the relationship between environmental protection tax and enterprise low-carbon transformation risk based on company-level data systems. This paper takes the risk of low-carbon transformation of enterprises as the core explanatory variable, focuses on the risk effect of environmental protection "fee to tax," a market-oriented environmental regulation tool, and examines its impact mechanism on enterprise transformation risk. To a certain extent, it expands the analytical boundaries of environmental regulation and enterprise transformation research.

Second, this paper reveals the role path of environmental protection "fee to tax" affecting the low-carbon transformation risk of enterprises from the perspective of a multi-dimensional mechanism. The study finds that the environmental protection "fee to tax" not only reduces the risk of high-carbon assets "stranding" by promoting green innovation and clean technology transformation of enterprises but also improves the availability of corporate financing and alleviates financing constraints through the "risk repricing-resource reconfiguration" mechanism and strengthens the management's attention to green strategies and carbon constraints so as to promote enterprises to adopt more active low-carbon governance and green investment behaviors.

Third, this paper further finds that ESG performance has a certain distortion effect on the effect of environmental tax policies; that is, some enterprises may replace substantive low-carbon inputs through "signal-based" improvements such as information disclosure and green certification, thereby weakening the risk mitigation effect of policies to a certain extent. The above findings provide a new mechanism for understanding how environmental regulation affects the risk of low-carbon transition of enterprises.

2. Theoretical Analysis and Hypothesis Proposal

The Pigou tax theory reveals the essence of the environmental protection tax system: when there are externalities in the market, that is, the social costs or benefits of economic activities are not fully internalized, the government should correct market failures through taxation and other means to guide the more effective allocation of resources. And compared with the pollutant fee, the implementation of the environmental protection tax is more standardized. Air pollutants and greenhouse gases have strong homology in emission sources and production processes, and environmental protection tax helps to strengthen the emission reduction incentives of enterprises and promote enterprises to optimize energy utilization methods and production structures in advance by reasonably setting tax rates. In this process, enterprises can adapt to green regulatory requirements earlier and mitigate risks such as rising compliance costs, lagging technological adjustments, and policy shocks that may be faced in the future low-carbon transformation process.

Based on this, the following hypotheses are proposed:

Hypothesis 1: The implementation of environmental protection fee tax reform promotes enterprises to reduce the risk of low-carbon transformation.

After environmental regulation increases the cost of pollution emissions, in order to reduce tax burden pressure and meet environmental regulatory requirements, enterprises often improve production processes, improve energy utilization efficiency, or develop cleaner production technologies through technological innovation so as to achieve pollution emission reduction and resource utilization efficiency

improvement. In addition, the tax incentives included in the environmental protection tax provide support for enterprises' investment in green innovation and promote their green production transformation [12]. It can also reduce the innovation cost of enterprises to a certain extent, encourage enterprises to increase investment in green R&D, and promote the transformation of green technology achievements. Green innovation can not only reduce corporate pollution emissions but also significantly improve the ability of enterprises to cope with the risks of low-carbon transformation. Green technology innovation can reduce the carbon emission level of enterprises by optimizing production processes, improving energy efficiency, and developing low-carbon products. On the other hand, green innovation can also improve the environmental performance of enterprises in the capital market, enhance investor confidence, and create conditions for enterprises to obtain green investment and financing support. Green innovation is an essential tool which alleviates the operational uncertainty and financial risks faced by enterprises in the process of low-carbon transformation by improving their technical capabilities and environmental performance [13]. Based on the above analysis, the following research hypotheses are proposed:

Hypothesis 2: Environmental protection tax reduces the risk of low-carbon transformation by promoting green technology innovation of enterprises.

In the process of low-carbon economic transformation, enterprises not only need to upgrade technology and adjust production methods but also need to invest in energy conservation green technology research and development, and production process optimization. Enterprises often face prominent financing constraints in the process of transformation. The existence of financing constraints may limit the investment ability of enterprises in low-carbon technology research and development and green production, thereby increasing the operational risks and financial pressure faced by enterprises in the process of low-carbon transformation.

In this context, the implementation of the environmental protection "fee-to-tax" policy may affect the financing environment of enterprises, which in turn affects their low-carbon transformation risks. On the one hand, the environmental protection "fee to tax" has strengthened the supervision of enterprises, increased the cost of emissions, and prompted enterprises to adopt green response strategies, such as increasing environmental protection investment. With the strengthening of regulations, financial institutions are gradually taking into account the environmental risks of enterprises in credit decision-making. Research shows that banks will consider the environmental transition risks faced by enterprises in the loan pricing process and increase financing costs or strengthen credit constraints for enterprises with higher environmental risks [4]. At the same time, financial institutions are more inclined to provide credit support to companies with better environmental performance [14], thereby improving their financing conditions. Enterprises that actively promote green transformation can send positive signals to the capital market by improving environmental performance, reducing information asymmetry, and improving the availability of bank loans. On the other hand, in the context of the continuous strengthening of green development policies, the government usually supports enterprises to carry out emission reduction activities through supporting policies such as financial subsidies, and tax incentives so as to provide more financing channels and financial support for enterprises.

The easing of financing constraints will help enterprises better cope with the risks of low-carbon transition. On the one hand, enterprises with lower financing constraints can obtain more funds for green innovation, equipment renewal, and energy structure adjustment, thereby improving their adaptability .Moreover, sufficient financial support can help enterprises hedge against the uncertainty caused by policy changes, market fluctuations, and technological upgrades and reduce the operational and financial risks of enterprises in the process of low-carbon transformation. Therefore, by easing corporate financing constraints, environmental protection taxes may further reduce the risk of low-carbon transformation of enterprises.

The analysis presented above leads to the following research hypothesis being put forth:

Hypothesis 3: Environmental protection tax reduces the risk of low-carbon transformation by easing corporate financing constraints.

From the perspective of the internal decision-making mechanism of enterprises, executives'

cognitive abilities and core values play a crucial role in shaping corporate strategic choices. According to the Upper Echelons Theory, the strategic decision and business behavior of an enterprise largely depend on the personal characteristics, values, and cognitive structure of executives. The understanding and judgment of executives on changes in the external environment will affect the company's cognition and response to policy shocks, thereby determining the direction of the company's strategic adjustment to a certain extent.

In the context of the continuous strengthening of environmental regulations, environmental protection tax not only directly constrains enterprises but also affects the awareness and concern of corporate executives about environmental issues through policy signal mechanisms. When enterprises face environmental regulatory pressures such as environmental protection taxes, executives are more likely to be aware of the potential risks brought about by stricter environmental policies, so they place greater emphasis on corporate environmental outcomes and sustainable development issues and strengthen the emphasis on green development goals at the corporate strategic level. The environmental protection [15] tax policy can significantly enhance the environmental awareness of corporate executives and further promote the implementation of green innovation strategies.

With the increasing environmental awareness of executives, it is easier for enterprises to identify green technology development trends and potential opportunities brought by low-carbon transformation and promote green technology innovation by optimizing resource allocation. Executives with strong environmental awareness usually pay more attention to the long-term development and sustainable competitive advantages of enterprises and tend to reduce environmental risks and improve corporate environmental performance through green innovation and green investment so as to improve firms' ability to adapt to uncertainties such as policy adjustments, market changes, and technological upgrades in the process of low-carbon transformation.

Based on the above analysis, the following research hypotheses are proposed:

Hypothesis 4: Environmental protection tax reduces the risk of low-carbon transformation of enterprises by enhancing executives' green awareness.

3. Study Design

3.1 Sample Selection and Data Source

This paper takes listed companies from 2010 to 2024 as a sample to explore the impact of the implementation of the Environmental Protection Tax Law on the low-carbon transition risk (CTR) of enterprises. In terms of sample processing, this paper screens and cleans up the original samples: (1) Companies with abnormal trading status (ST, *ST, PT) are excluded during the sample period; (2) Exclude companies in the financial industry; (3) Eliminate the missing observations of key variables. Finally, 35,268 samples were obtained for regression analysis.

3.2 Variable Description

Dependent variables: The explained variable in this paper is the enterprise low-carbon transition risk (CTR), which is used to measure the risk level of rising costs, technological transformation, compliance constraints, and operational uncertainty encountered by businesses undergoing low-carbon and green transformation.

Specifically, this paper first constructs the risk factor for low-carbon transition (stranded) and introduces this factor into the extended market model to conduct regression analysis of corporate stock returns. The regression model is set as follows:

$$Return_{i,m} = \alpha_i + \beta_i^M Market_m + \beta_i^S Stranded_m + \varepsilon_{i,m} \quad (1)$$

Where $Return_{i,m}$ denotes the stock return of firm i in month m; $Market_m$ represents the market return, measured by the monthly return of the CSI 300 Index; and $Stranded_m$ refers to the low-carbon transition risk factor, which captures the stranded asset risks faced by fossil energy-related assets amid low-carbon transition. Specifically, this factor is constructed as the weighted average return of the energy industry index (30%) and the coal industry index (70%), minus the concurrent return of the CSI 300 Index. It effectively reflects systemic transition risks arising from low-carbon policy shocks and energy structure adjustments.

n the above model, β_i^M indicates the sensitivity of enterprises to overall market risk. β_i^S describes the exposure of corporate stock returns to the impacts of low-carbon

transformation, namely enterprises' low-carbon transition risks. According to Reference[1], the climate transition risk coefficient (Climate Beta) can directly reflect capital market pricing outcomes regarding uncertainties surrounding enterprises' future low-carbon transformation, and serves as an effective indicator for measuring corporate low-carbon transformation risks.

Independent variable: In the environmental protection "fee-to-tax" policy, not all regions have changed the environmental protection tax standard. In order to prevent the environmental protection "fee-to-tax" policy from having an excessive impact on local enterprises, some regions have followed the previous collection standards of pollutant discharge fees when formulating environmental protection tax standards, so that the pollution emission costs faced by enterprises before and after the implementation of the policy remain basically unchanged (i.e., areas where the tax burden is shifted). while some regions increase the amount of environmental protection tax on the basis of the original sewage fee standard to strengthen environmental governance and increase support for local environmental protection investment (i.e., areas with increased tax burden). On this basis, this paper groups enterprises according to whether the environmental tax burden standard in the same region is higher than the emission fee standard and constructs the grouping virtual variable (Treat) and time virtual variable (Post) in the double difference (DID) model, which are defined as follows:

Grouping virtual variable (Treat): If the province has increased its environmental protection tax burden standard compared with the previous pollutant fee standard after the implementation of the environmental protection "fee to tax," the enterprise is divided into an experimental group, and the Treat value is 1; if the environmental protection tax burden standard is basically the same as the pollutant discharge fee standard, the enterprise is divided into a control group, and the Treat value is 0.

Time dummy variable (Post): With the official implementation of the Environmental Protection Tax Law on January 1, 2018, as the policy impact point, the value is 1 in 2018 and subsequent years, and the value before 2018 is 0. Accordingly, this paper constructs the core explanatory variable treatpost = treat × post to describe the difference in low-carbon transition risk (CTR) between enterprises in areas with increased tax burden compared to enterprises in areas with tax burden translation after the implementation of environmental protection tax policies.

Control variables: To increase the reliability of the study, refer to existing studies[16] and introduce a series of control variables, including the size of the enterprise (Size), asset-liability ratio (Lev), profitability (LENGTH), operating cash flow (Cash flow), proportion of fixed assets (FIXED), ratio of independent directors (Indep), integration of two positions (Dual), shareholding ratio of the largest shareholder (Top1), and years of establishment (Firm Age).

3.3 Research Methods and Model Construction

In order to systematically investigate the impact of environmental protection tax policy implementation on the low-carbon transformation risk of enterprises, this paper regards the implementation of the Environmental Protection Tax Law as a quasi-natural experiment and uses the double difference method (DID) to conduct an empirical analysis. This method compares the differences in the risk changes of low-carbon transition between enterprises in areas with tax burden enhancement (treatment group) and enterprises in areas with tax burden translation (control group) before and after the implementation of the policy, so as to identify the causal effect of environmental protection tax policies.

$$CTR_{i,t} = \alpha + \beta treatpost_{i,t} + \gamma' Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

$CTR_{i,t}$ indicates the risk level of low-carbon transformation of the enterprise in the year; TreatPost is the core explanatory variable, which is equivalent to the interaction term between the virtual variable of the treatment group (Treat) and the virtual variable (Post) of the time after the implementation of the policy, which is used to describe the change of the low-carbon transformation risk of enterprises in the area where the tax burden is increased compared with the tax burden translation after the implementation of the environmental protection tax policy.

Controls is a series of control variables. μ_i represents the fixed effect of the enterprise, which is used to control the individual characteristics of the enterprise that do not change with time. λ_t represents the fixed effect

of the year, which is used to control the macroeconomic environment, policy cycles, and other annual shocks. $\varepsilon_{i,t}$ is a random perturbation term. In this paper, standard error is clustered at the enterprise level in regression to control for possible heteroskedasticity and series-related problems.

In the above model, the coefficient is the core parameter of this paper, and its symbol and significance reflect the direction and intensity of the impact of environmental protection tax policies on the low-carbon transformation risk of enterprises. If β>0, it means that the environmental protection tax policy has increased the risk of low-carbon transformation of enterprises, if it is β<0, it means that the environmental protection tax policy motivates firms to reduce their low-carbon transformation risks through technological upgrading, resource allocation optimization, or governance improvement.

3.4 Descriptive Statistics

Table 1 reports descriptive statistical results for the main variables. From the perspective of dependent variables, the mean value of low-carbon transition risk (CTR) of enterprises is 0.118, the standard deviation is 0.611, the minimum value is −2.075, and the maximum value is 2.283, indicating that there are obvious differences in the level of low-carbon transition risk between different enterprises, and the sample distribution has a certain degree of discreteness, indicating that the exposure of enterprises in coping with the impact of low-carbon transition is different, and it is necessary and feasible to carry out empirical research. The mean value of the core explanatory variable "treatpost" was 0.227, the standard deviation was 0.419, the minimum value was 0, and the maximum value was 1, indicating that about 22.7% of the samples belonged to the observation value of "tax burden increase area " and the treatment group and the control group had sufficient distribution in the samples, which was conducive to the effective identification of the double difference model. In general, the value range of each variable is reasonable, and there are no obvious outliers.

Table 1. Descriptive Statistical Tables

ExistName	obs	Mean	SD	Min	Max
CTR	35268	0.118	0.611	-2.075	2.283
treatpost	35268	0.227	0.419	0.000	1.000
Size	35268	22.443	1.322	19.663	27.622
Lev	35268	0.453	0.204	0.067	0.966
LENGTH	35268	0.030	0.068	-0.276	0.216
Cashflow	35268	0.046	0.068	-0.177	0.242
FIXED	35268	0.215	0.161	0.001	0.695
Indep	35268	37.764	5.443	33.330	57.140
Dual	35268	0.256	0.437	0.000	1.000
Top1	35268	0.328	0.148	0.078	0.736
FirmAge	35268	3.010	0.298	2.079	3.584

4. Empirical Results and Analysis

4.1 Benchmark Regression

Table 2 reports the benchmark regression results of environmental tax policies on the impact of corporate low-carbon transition risks (CTR). Column (1) only controls the fixed effect of enterprises and the fixed effect of the year and examines the overall effect of the impact of environmental tax policy without adding other control variables; Column (2) On this basis, control variables such as corporate financial characteristics and corporate governance are further added.

From the results of column (1), it can be seen that the regression coefficient of the core explanatory variable treatpost is −0.0560, which is significant at the 1% level, indicating that the low-carbon transformation risk of enterprises in areas with increased tax burden is remains markedly smaller than enterprises in areas where the tax burden is translated when other corporate characteristics are not controlled. This result preliminarily shows that the environmental protection tax policy does not exacerbate the risk of low-carbon transformation of enterprises but may promote enterprises to adjust their production and business decisions in advance by strengthening constraints and incentive mechanisms, thereby reducing the uncertainty of the transformation they face. Column (2) reports the baseline regression results after adding all control variables to test the net effect of environmental penalties on the low-carbon transformation risk of enterprises. The results show that the coefficient of the core explanatory variable "treatpost" is -0.5213, which is significant at the 1% statistical level, indicating that the risk of low-carbon transformation of enterprises is significantly reduced after the implementation of environmental protection penalties, which verifies the risk inhibition effect of environmental protection penalties.

4.2 Robustness Test

(1)Parallel trend test

In order to ensure the reliability of the benchmark regression results, a parallel trend test is implemented This paper draws on the common practice of event research methods to construct the relative time dummy variables before and after the implementation of the policy. Specifically, the year before the policy implementation is used as the baseline period, and this period is excluded in the regression to avoid the problem of complete collinearity [17]; the coefficients of the remaining periods represent dynamic changes relative to the base period [18]. The results are shown in Figure 1. Accordingly, before the implementation of the environmental protection "fee to tax," the estimated coefficients of each period fluctuated around 0, and there was no significant difference trend. Namely, enterprise Low-carbon transition risks There is no significant difference between the tax burden upgrading group and the tax burden translation group, which satisfies the assumption. In the current period and after the implementation of the policy, the coefficients of each period are significantly negative, indicating that the implementation of the environmental protection tax policy has significantly reduced the risk of low-carbon transformation of enterprises, and the risk reduction effect has a certain degree of sustainability.

Table 2. Benchmark Regression Table

	(1)	(2)
	CTR	CTR
treatpost	-0.0560***	-0.0523***
	(-2.77)	(-2.61)
Size		-0.0253**
		(-2.11)
Lev		-0.0702
		(-1.52)
LENGTH		-0.0904
		(-1.21)
Cashflow		-0.0707
		(-1.26)
FIXED		0.0821
		(1.39)
Indep		0.0007
		(0.65)
Dual		-0.0076
		(-0.54)
Top1		0.1659*
		(1.96)
FirmAge		-0.3262***
		(-2.65)
_cons	0.1309***	1.6220***
	(28.63)	(3.63)
ID FE	Yes	Yes
year FE	Yes	Yes
N	35268	35268
R2	0.485	0.487

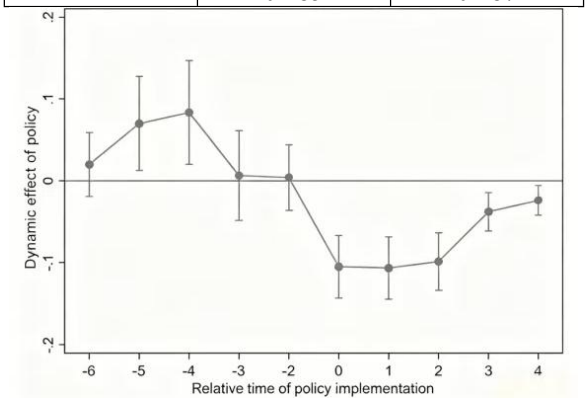

Figure 1. Parallel Trend Hypothesis Testing

(2)Placebo test

In order to better alleviate the interference of unobservable factors on the estimated results, a placebo test was performed again. The specific method is to perform 500 random samplings of treatment group variables. As can be seen from the nuclear density curve in Figure 2, the results of the placebo test are clustered around 0 and are normally distributed. It shows that in the absence of policy intervention, most of the estimation coefficients are close to zero, and there is no significant difference trend. In the real sample of policy implementation, the estimation coefficients of each period are substantial negative, indicating that the implementation of the environmental protection tax has effectively reduced the risk of low-carbon transformation of enterprises. Through this analysis, we can further verify that the treatment effects observed in the benchmark regression model are not caused by external factors or interferences but by the real impact of policy. Therefore, the conclusion of benchmark regression on environmental protection tax to promote the low-carbon transformation of enterprises is relatively roable.

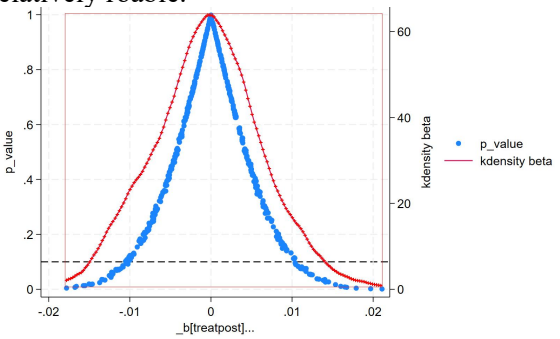

Figure 2. Placebo Test Results

(3)Other robustness tests

Excluding epidemic years: Considering that the

new crown epidemic in 2020-2021 may have a systemic impact on the operating conditions of enterprises, capital market performance, and the low-carbon transformation process, thereby interfering with the identification of environmental protection tax policy effects, this paper excludes the sample observations from 2020 and 2021 and re-estimates the benchmark model. The results of Table 3 show that the coefficient direction and significance level of the core explanatory variable "treatpost" have not changed substantially, indicating that the conclusion of this paper is not driven by the special economic environment during the epidemic.

Excluding samples from municipalities: In view of the significant differences in economic development level, industrial structure, environmental supervision and policy implementation intensity of municipalities, and their environmental protection tax collection standards and local financial capacity, which may be more special, this paper further excludes the samples of municipalities directly under the Central Government, and conducts a regression analysis. Table 3 shows that the estimation coefficient of the core variable treatpost remains significant, indicating that the impact of environmental tax policies on the low-carbon transition risk of enterprises is not dominated by a few economically developed regions.

Adjusting for fixed effects: In the benchmark model, this paper controls for firm fixed effects and year fixed effects. In order to test the sensitivity of the model setting, this paper replaces the fixed effect of enterprises with the fixed effect of industry and retains the fixed effect of the year for regression. The results show that the coefficient sign and significance level of treatpost remain stable, indicating that the research conclusion does not depend on the setting of a specific fixed effect and has strong robustness.

Table 3. Other Robust Tests

	(1)	(2)	(3)
	CTR	CTR	CTR
treatpost	-0.0561***	-0.0894***	-0.0568***
	(-2.81)	(-3.97)	(-5.26)
Size	-0.0280**	-0.0248*	-0.0089*
	(-2.27)	(-1.83)	(-1.95)
Lev	-0.0474	-0.0585	0.0119
	(-0.97)	(-1.12)	(0.40)
LENGTH	-0.0242	-0.0629	-0.5763***
	(-0.29)	(-0.75)	(-8.17)
Cashflow	-0.0456	-0.0423	-0.2454***
	(-0.73)	(-0.67)	(-3.96)
FIXED	0.0785	0.1111*	0.1701***
	(1.27)	(1.72)	(4.48)
Indep	0.0002	0.0002	-0.0003
	(0.15)	(0.21)	(-0.30)
Dual	-0.0112	0.0011	-0.0513***
	(-0.71)	(0.07)	(-4.52)
Top1	0.1485*	0.1799*	0.0744**
	(1.68)	(1.88)	(1.97)
FirmAge	-0.3210***	-0.3905***	0.1017***
	(-2.60)	(-2.80)	(4.20)
_cons	1.6868***	1.8202***	0.0090
	(3.72)	(3.64)	(0.07)
ID FE	Yes	Yes	Yes
year FE	Yes	Yes	Yes
N	29264	28307	35268
R2	0.503	0.493	0.168

5. Heterogeneity Analysis

5.1 Industry Heterogeneity Analysis

Amid the implementation of environmental protection fee-to-tax transition, enterprises with severe pollution serve as major policy-affected subjects. This paper draws on the division of heavy polluting enterprises and non-heavy polluting enterprises to examine the impact of environmental protection tax on the low-carbon transformation risk of enterprises with different pollution levels. The results show that the impact of environmental protection tax on the low-carbon transformation of heavy polluting enterprises is significantly negative, but the impact on the low-carbon transformation risk of non-heavy polluting enterprises is not significant. Compared with non-heavy polluting enterprises, heavy polluting enterprises usually have the characteristics of strong asset specificity, high capital intensity, and high homology of emission intensity. Once the environmental tax policy is strengthened, the relevant assets face higher compliance costs and stricter emission constraints, the discounted value of future cash flow decreases, and the probability of early scrapping or technology elimination of assets increases significantly, making it easier to form "stranded assets."

Stranded asset envoy companies are facing stronger short-term liquidity pressure [19]. High-emission fixed assets face impairment risks in the context of policy strengthening, balance sheet robustness declines, and financial leverage constraints tighten. The capital market will incorporate policy shocks into the pricing system,

adjust risk premiums for high-carbon enterprises, increase financing costs, and tighten external financing constraints.

However, unlike non-heavy polluting enterprises, heavy polluting enterprises are more directly and persistently affected by policy impacts and face stronger institutional pressure and social supervision. Under the expectation of continuous strengthening of policy constraints, if enterprises do not carry out technological upgrading and structural adjustment, the scale of stranded assets will continue to expand, and asset impairment and financing constraints will further deteriorate. Therefore, environmental protection tax policy not only produces a risk exposure effect in heavy polluting enterprises but also forms a significant backward pressure effect. By accelerating green technology upgrades and capacity restructuring, enterprises can reduce the risk of asset depreciation caused by future policy uncertainty, thereby effectively mitigating the risk of low-carbon transformation.

5.2 Regional Heterogeneity Analysis

Table 4. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)
	CTR (Heavy Pollution)	CTR (Non-Heavy Pollution)	CTR (East)	CTR (Medium)	CTR (West)
treatpost	-0.1302***	-0.0337	-0.0612**	-0.0239	-0.0188
	(-3.31)	(-1.42)	(-2.40)	(-0.52)	(-0.41)
Size	-0.0127	-0.0313**	-0.0166	-0.0665**	-0.0265
	(-0.54)	(-2.14)	(-1.12)	(-2.16)	(-0.91)
Lev	-0.1312	-0.0362	-0.0661	-0.0853	0.0177
	(-1.46)	(-0.65)	(-1.14)	(-0.78)	(0.16)
LENGTH	-0.0991	-0.1517*	-0.1272	-0.1825	0.0383
	(-0.63)	(-1.79)	(-1.44)	(-0.89)	(0.21)
Cashflow	0.1658	-0.1331**	-0.0998	-0.1268	0.0779
	(1.41)	(-2.08)	(-1.47)	(-0.90)	(0.57)
FIXED	0.0591	0.0709	0.0883	-0.0542	0.0870
	(0.61)	(0.89)	(1.11)	(-0.37)	(0.78)
Indep	-0.0002	0.0008	0.0015	-0.0012	0.0006
	(-0.09)	(0.65)	(1.08)	(-0.49)	(0.31)
Dual	-0.0399	-0.0005	-0.0031	0.0055	-0.0257
	(-1.33)	(-0.03)	(-0.19)	(0.15)	(-0.73)
Top1	-0.0494	0.2291**	0.1994*	0.2938	-0.0185
	(-0.31)	(2.23)	(1.90)	(1.38)	(-0.09)
FirmAge	-0.7258***	-0.2661*	-0.2487*	-1.0964***	0.1981
	(-2.77)	(-1.87)	(-1.70)	(-3.47)	(0.61)
_cons	2.8453***	1.4908***	1.1196**	4.9932***	0.1574
	(3.13)	(2.79)	(2.11)	(4.36)	(0.15)
ID FE	Yes	Yes	Yes	Yes	Yes
year FE	Yes	Yes	Yes	Yes	Yes
N	7919	27349	24576	5774	4746
R2	0.540	0.471	0.471	0.539	0.547

Table 4 shows that the impact of environmental protection tax on low-carbon transition risk in the eastern region is significantly negative, but the impact on enterprises in the central and western regions is not significant. The possible reasons are the following: first, the eastern region has a high degree of marketization and a developed financial system, and enterprises are more sensitive to policy signals; second, the overall technical level of eastern enterprises is higher, with stronger green innovation ability and capital acquisition ability, and they can more effectively respond to the impact of environmental protection tax through technological upgrading and structural adjustment; Third, the environmental protection law enforcement and information transparency in the eastern region are relatively high, and the policy implementation is stricter, thus strengthening the policy effect. In contrast, central and western regions feature an outdated and conservative industrial structure. the green technology reserves are insufficient, and the policy transmission mechanism is relatively weak, so the impact of the environmental protection tax on the risk of low-carbon transformation of enterprises has not been significantly reflected.

6. Mechanism Test

6.1 Green Innovation

In light of low-carbon transformation, the impact of environmental regulation policies on corporate behavior is often realized through technological innovation. An environmental protection tax affects the resource allocation decision of enterprises by raising enterprises' pollution discharge expenses and changing the price structure of production factors.

In order to maintain profitability and market competitiveness, enterprises often tend to reduce pollution emissions through the improvement of pollution mitigation and energy efficiency technologies and the optimization of cleaner production methods. Therefore, green innovation may become an important transmission channel for environmental protection taxes to affect the risk of low-carbon transformation of enterprises.

Table 5. Mechanism Test Results Table

	(1)	(2)	(3)	(4)
	CTR	GP	FC	GreenCognition
treatpost	-0.0523***	0.0074**	-0.0059*	0.2368***
	(-2.61)	(2.43)	(-1.90)	(4.01)
Size	-0.0253**	0.0033**	-0.1379***	0.4717***
	(-2.11)	(2.00)	(-132.60)	(23.50)
Lev	-0.0702	0.0003	-0.4040***	0.2359*
	(-1.52)	(0.04)	(-66.10)	(1.90)
LENGTH	-0.0904	-0.0180	0.4602***	1.2018***
	(-1.21)	(-1.50)	(27.31)	(3.46)
Cashflow	-0.0707	-0.0154	-0.2340***	-0.6029*
	(-1.26)	(-1.60)	(-16.45)	(-1.92)
FIXED	0.0821	0.0063	-0.0233***	2.5312***

	(1.39)	(0.67)	(-4.39)	(14.72)
Indep	0.0007	0.0000	0.0006***	-0.0128***
	(0.65)	(0.13)	(4.03)	(-3.43)
Dual	-0.0076	-0.0015	0.0070***	-0.3179***
	(-0.54)	(-0.73)	(3.93)	(-6.84)
Top1	0.1659*	-0.0073	0.0148***	0.3078**
	(1.96)	(-0.62)	(2.70)	(2.09)
FirmAge	-0.3262***	-0.0207	-0.0290***	-0.0196
	(-2.65)	(-1.18)	(-9.24)	(-0.24)
_cons	1.6220***	0.0291	3.7549***	-7.4607***
	(3.63)	(0.44)	(167.62)	(-14.26)
ID FE	Yes	Yes	Yes	Yes
year FE	Yes	Yes	Yes	Yes
N	35268	35222	35264	35168
R2	0.487	0.517	0.765	0.265

Combined with the benchmark regression results reported in Table 5, it can be found that technological innovation exerts a vital effect on shaping the risk exposure of enterprises' low-carbon transformation [13]. Green innovation enhances the adaptability of enterprises to stricter environmental policies in the future by upgrading energy-saving capacity and emission reduction technology and resource utilization efficiency and fundamentally mitigates the potential risk of "stranded assets." Green innovation also affects the pricing of enterprises' low-carbon transformation risks by improving their future cash flow expectations and investors' assessment of corporate climate adaptability.

It is evident that the environmental protection tax effectively reduces its risk exposure to low-carbon transformation by prompting firms to conduct green technological innovation and improving their technological adaptability and climate risk management capabilities. Eco-friendly innovation serves as an essential transmission channel amid the correlation between environmental tax levies and firms' low-carbon transformation uncertainties.

6.2 Financing Constraints

From the perspective of financial market risk pricing, environmental regulation may affect the external financing conditions of enterprises by changing their risk exposure and information verifiability. Based on the theoretical framework of "risk repricing-resource reallocation," this paper uses the financing constraint index as an intermediary variable to test whether the environmental protection "fee to tax" affects the low-carbon transformation risk through changes in financing conditions.

The empirical results show that after the implementation of the environmental protection "fee to tax," the overall financing constraints have been significantly alleviated. The possible reasons for this are that, on the one hand, environmental protection tax, as a more rigid market-oriented environmental regulation tool, makes the external cost of pollution explicit and strengthens compliance constraints, allowing financial institutions to more fully incorporate corporate environmental risks and cash flow uncertainty into credit assessment and project management, thereby promoting the repricing of credit risks [20]. Under the guidance of green finance policies and the possible effect of local supporting tools (such as green credit guidance, loan discounts, or risk compensation mechanisms, etc.), banks will tend to allocate more financial resources to green and low-carbon projects in order to reduce the spillover of environmental risks to credit asset portfolios and, at the same time, relatively tighten financing for projects with high emissions and high environmental risks

Under the above mechanism, if enterprises can form verifiable improvements in low-carbon governance, green investment, and environmental performance, they are more likely to obtain marginal returns in terms of financing availability, financing costs, and credit continuity, thereby reducing the capital threshold and financial pressure of low-carbon transformation investment and improving the feasibility and solvency of long-term low-carbon investment. As a result, the environmental protection "fee to tax" further reduces the risk of low-carbon transformation of enterprises by easing the financing constraints of enterprises.

6.3 Executive Green Cognition

This article refers to existing research. [15]The following model is constructed on the basis of the benchmark regression model for mechanism testing. The green cognition of executives uses the text analysis method to lock in 75 keywords related to the environmental protection behavior of executives and uses Python software to crawl green-related keywords in the annual reports and counts the frequency of keywords in the annual reports to measure the green cognition of executives. Environmental protection fee tax reform policy the impact on executives' green perception is significantly positive, indicating that policy shock smarkedly strengthens executives' green environmental cognition thereby strengthening the strategic emphasis on environmental issues. Environmental protection tax internalizes external environmental costs to

form a visible cost signal and enhances management's attention to environmental issues. When their green awareness improves, they will be more willing to identify green opportunities, allocate resources, and promote internal innovation. This allocation change improves the predictability and technical adaptability of long-term cash flows, reducing the risk of future "stranded assets," which affects the risk assessment of creditors and investors.

6.4 Further Analysis

This paper uses two types of indicators, ESG comprehensive score and ESG comprehensive assignment, to measure the ESG performance of enterprises and further examines the impact of environmental protection tax implementation on the low-carbon transition risk (CTR) of enterprises. Table 6 results show that higher ESG levels are significantly associated with lower transition risks. However, when the interaction term of environmental tax policy is introduced, the ESG score attenuates the policy's reduction in corporate transformation risk under certain conditions—a phenomenon that may stem from behavioral shifts (i.e., distortions) caused by indicator-based incentives.

Table 6. Mechanism Analysis Table

	(1)	(2)
	CTR	CTR
treatpost	-0.2415***	-0.0900***
	(-2.72)	(-3.25)
Score	-0.0024***	
	(-3.15)	
c.treatpost#c. Score	0.0026**	
	(2.20)	
Rating		-0.0091**
		(-2.43)
c.treatpost#c. Rating		0.0098*
		(1.68)
Size	-0.0271***	-0.0278***
	(-3.49)	(-3.59)
Lev	-0.0736**	-0.0711**
	(-2.24)	(-2.17)
ROA	-0.0703	-0.0708
	(-1.18)	(-1.18)
Cashflow	-0.0859*	-0.0861*
	(-1.68)	(-1.68)
FIXED	0.0833**	0.0835**
	(2.02)	(2.03)
Indep	0.0007	0.0007
	(0.92)	(0.89)
Dual	-0.0096	-0.0095
	(-0.93)	(-0.92)
Top1	0.1858***	0.1862***
	(3.36)	(3.36)
FirmAge	-0.3067***	-0.3067***
	(-3.95)	(-3.95)
_cons	1.7736***	1.6501***
	(6.09)	(5.69)
ID FE	Yes	Yes
year FE	Yes	Yes
N	35002	35002
R^2	0.487	0.487

Due to the lack of policy supervision and information barriers between the government and enterprises [21] Companies with high ESG scores are better at using disclosures, green certifications, or governance structures to signal "low risk" to respond to environmental protection policies, thus obtaining short-term tolerance in regulation or financial markets. But these behaviors sometimes favor visible improvements at the governance level rather than real technological transformations or long-term emission reduction investments. Especially in the context of ESG incentives, some enterprises, in order to improve ESG scores, obtain green financing, etc. A "green rinse" may occur, implementing a series of strategic innovation behaviors. [22] Companies are more inclined to invest limited green investment or management efforts in projects that can quickly improve ESG scores, rather than exposing long-term high-cost emission reductions or technological breakthroughs. For example, enterprises may choose easier green utility model patents to respond to the green development required by policies, rather than green invention patents that can substantially facilitate firms' low-carbon transition. The result is that the policy is supposed to promote substantial emission reductions, but high ESG firms partially replace real inputs with "signal capital," diluting the marginal effect of the policy. That is, distorted incentives occurred.

7. Conclusions and Recommendations

Against the backdrop of dual-carbon targets, facilitating corporate green upgrading and mitigating low-carbon transformation risks via environmental governance regulation has emerged as a vital topic widely discussed in academic research and policy formulation. This paper takes A-share listed companies from 2010 to 2024 as a research sample, constructs a double difference (DID) model based on the institutional change of environmental protection from "fee to tax," and systematically examines the impact of environmental tax reform on the risk of low-carbon transformation of enterprises

and its mechanism. The study yielded the following main conclusions. First, the "fee to tax" of environmental protection significantly reduces the risk of low-carbon transformation of enterprises. This conclusion was valid after incorporating control variables and performing parallel trend tests, placebo tests, and multiple robustness tests.

The mechanism analysis shows that environmental protection tax plays a risk mitigation role by promoting green innovation, easing corporate financing constraints, and enhancing executives' green awareness, thereby promoting enterprises to adopt more active low-carbon transformation strategies and effectively reducing the uncertainty and potential risks of enterprises in the process of low-carbon transformation. At the same time, this paper finds that the ESG performance of enterprises has a certain distortion effect on the effect of environmental protection tax policies, and some enterprises may replace substantive low-carbon investment through "signal-based" behaviors such as information disclosure or green certification, which weakens the risk mitigation effect of the policy. Third, the heterogeneity analysis shows that the impact of environmental protection tax on the low-carbon transformation risk of enterprises is significantly distinct among different enterprises and regions. Specifically, the environmental protection tax reform has a more significant risk mitigation effect in enterprises in heavy polluting industries and enterprises in developed areas in the east. This shows that in areas with greater environmental regulatory pressure is more likely to play a policy effect on promoting the green transformation of enterprises.

First, continue to improve the environmental protection tax system and strengthen the market-oriented incentive role of environmental regulation. The government should further improve the environmental protection tax collection mechanism; reasonably increase the cost of pollution emissions: and guide enterprises to take the initiative to carry out green technology innovation and low-carbon transformation. At the same time, the stability and predictability of environmental protection tax policies should be strengthened, and the impact of policy uncertainty on enterprises' investment decisions should be reduced.

Second, strengthen the internal green governance mechanism of enterprises and enhance the environmental awareness of senior executives. Enterprises should strengthen the integration of green development concepts into corporate governance, improve management's awareness of environmental risks and low-carbon transformation issues, and incorporate environmental performance into the corporate performance appraisal system. By enhancing the environmental awareness of executives, enterprises are attach greater priority to green technological innovation and low-carbon production methods at the strategic level, so as to enhance their adaptability and long-term competitiveness.

Third, improve the ESG information disclosure system to prevent "green greenwashing." Regulatory authorities should further standardize corporate ESG information disclosure standards, improve information transparency, and reduce the space for enterprises to engage in "greenwashing" through formal information disclosure or certification. The supervision and evaluation of the environmental performance of enterprises should be strengthened to ensure that enterprises make real and effective low-carbon investments in the process of green transformation so as to improve the implementation effect of environmental protection tax policies.

In summary, environmental protection tax plays an active role in promoting the green transformation of enterprises and reducing the risk of low-carbon transformation. In the future, by continuously improving the environmental regulation system and strengthening the construction of green finance and corporate governance mechanisms, the institutional effect of environmental protection tax policies in promoting the green and low-carbon transformation of the economy can be further enhanced.

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