

How Do Environmental Subsidies Affect The Environmental Performance of Heavy Polluting Enterprises? Evidence From China

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Abstract

Taking 257 heavily polluted A-share listed companies in Shanghai and Shenzhen from 2010 to 2017 as research samples, this paper investigates the impact effect and mechanism of environmental subsidies on enterprise environmental performance. The study found that environmental subsidies have a positive incentive effect on the environmental performance of heavy polluting enterprises, and its positive incentive effect mainly plays a role through three channels: promoting green technology innovation, increasing government environmental supervision and enhancing executives' environmental awareness. Further research shows that environmental subsidies have a more significant promoting effect on environmental performance in non-state-owned enterprises and enterprises with high degree of financing constraints and high level of risk taking. Based on the perspective of environmental benefits of micro enterprises, this paper not only provides direct evidence at the micro level for the implementation effect of government environmental subsidies, but also provides a reference basis for the government to improve the specific implementation path of environmental subsidies. At the same time, it also provides reference for the government to implement directional regulation and accurate implementation of policies according to the particularity of enterprises with different characteristics.

1 Introduction

In just over 40 years since the start of reform and opening up, China has made remarkable achievements in economic growth. The rapid growth of China's economy since the reform and opening up is largely attributed to various industrial policies launched by the government (Han and Hong, 2014). In recent years, with the economic development of our country into a "new normal", the traditional extensive economic growth pattern of the accumulated contradictions increasingly prominent, the problem such as excessive consumption of resources, ecological environment destruction, and gradually become the bottleneck of economic development in our country, which make us pay a heavy price in terms of resources and environment. At the same time, by the "jinshan silver" "Green mountains and clear waters" are gradually disappearing from our vision. According to Yale University's global Environmental Performance rankings, China ranked 94th out of 133 countries in the 2006 Environmental Performance Index, and 128th in air quality (sixth from the bottom in the world). China's environmental performance Index ranked 120th out of 180 countries in 2018, and China's air quality index ranked 177th (4th from the bottom in the world). These data show that China's environmental quality is still far behind the world, in stark contrast to its current position as the world's second largest economy. How to coordinate the conflict between environmental protection and economic growth has become the most important challenge faced by the government in environmental governance. As an important source of environmental pollution, industrial enterprises, especially heavy polluting enterprises, pose a major threat to the living environment of human beings (Walls et al., 2012). Therefore, if we can effectively control the environmental pollution of heavy polluting enterprises, improve their environmental quality and improve their environmental performance, it will make an important contribution to the sustained and healthy development of China's national economy.

As one of the important means of government macro-control, environmental protection subsidy policy can well reflect the industrial policy of a country or region in a certain period. In order to correct the impact of market failure on the national economy, governments of various countries generally use industrial policy to drive the transformation and upgrading of related industries, especially the transformation and upgrading of environmental protection industry. As a means to optimize the industrial structure, environmental protection subsidy policy is widely adopted by governments of various countries, mainly because the ecological environment has the characteristic of public goods, which is easy to lead to excessive consumption and environmental protection market failure. Therefore, government plays an indispensable role in the allocation of resources. As the new structural economics emphasizes, economic development requires both efficient markets and an effective government (Lin, 2012). The promulgation and implementation of environmental protection subsidy policy is the main form of government intervention in enterprises. Whether the environmental protection subsidy policy can achieve the win-win goal of "reducing pollution" and "increasing efficiency" has become the criterion to measure the success of environmental protection industrial policy in the world. It should be noted that the key to the effectiveness of environmental protection industrial policies lies in whether the design intention of the government's macro policies can be effectively implemented at the level of micro enterprises. As China's economic development enters the "new normal", ecological and environmental problems become more and more prominent and gradually become the bottleneck of restricting China's economic development. In the framework of the "new normal" of economic development, China's economic development is more and more regulated by environmental protection policies. In order to alleviate the dual pressure of "pollution reduction" and "efficiency increase", the government has invested a large amount of environmental subsidies to promote environmental governance in heavy polluting industries, and the effect of subsidies has attracted much attention. Then, can environmental protection subsidies improve the environmental performance of heavy polluting enterprises? If so, what are the possible channels of action?

At the same time, considering the different kinds of enterprises with different characteristics, they have different resources and different risk levels due to different property rights, therefore, the environmental protection subsidies have different incentive effects on the environmental performance of different enterprises. In addition, government environmental protection subsidies are usually controlled by industrial policies and independent of the aided units, while the heterogeneity of enterprises is inherent in enterprises, embedded in organizational structure and corporate culture. On environmental governance, if the government in making the related environmental subsidy policy, the enterprise heterogeneity and policy resources of coordination, according to different characteristics of the enterprise to differentiate environmental subsidies, which can accurately, effectively controlling of directional control, this will greatly improve the environmental performance and production efficiency of environmental subsidies.

Most of the existing studies have discussed the impact of environmental subsidies on environmental technology innovation, but few literatures have investigated the impact of environmental subsidies on enterprises' environmental performance, let alone explored the mechanism of environmental subsidies on enterprises' environmental performance from the three aspects of environmental technology innovation,

government environmental regulation and executive environmental awareness. The development of existing research in this paper is mainly reflected in the following aspects : (1) firstly, based on the perspective of environmental performance of micro enterprises, this paper provides direct evidence for the implementation effect of government environmental protection subsidies at the micro level, and expands relevant researches on the effectiveness of environmental protection subsidies; (2) It attempts to explore the mechanism of government environmental protection subsidies on enterprises' environmental performance. Based on the study of the relationship between environmental protection subsidies and environmental performance of enterprises, this paper deeply discusses the role path of environmental protection subsidies on environmental performance of enterprises. Moreover, the intermediary mechanism shows that environmental subsidies affect the environmental performance of enterprises through green technology innovation, government environmental supervision and environmental awareness of senior executives. This paper analyzes the mechanism of environmental protection subsidies affecting enterprises' environmental performance from three aspects of supervision, behavior and consciousness, so as to further investigate the deep-rooted causes of the consequences of environmental protection subsidies policy, which provides reference value for the government's targeted regulation and targeted policy.

2 Theoretical Analysis And Research Hypothesis

The "promoting effect" of government environmental protection subsidies on enterprises' environmental performance is mainly reflected in resource compensation and signal transmission. In order to gain long-term competitive advantage, enterprises are willing to make environmental investment and actively undertake environmental responsibility. According to the relevant national environmental policies, such as "several provisions on strengthening the management of environmental protection subsidy funds", "the environmental protection tax law of the People's Republic of China" and other relevant provisions, enterprises encouraged by environmental protection subsidy policies are more likely to obtain government resource support on the one hand, and release good signals to the outside world on the other hand, which is conducive to boost investor confidence, reduce the cost of financing, so as to encourage enterprises to participate in environmental governance.

As one of the important means of government macro-control, environmental protection subsidy can well reflect the industrial policy of a country or region in a certain period. In order to correct the impact of market failure on national economy, governments of various countries generally use fiscal subsidies and other policy tools to drive the transformation and upgrading of related industries, especially the transformation and upgrading of environmental protection industries. Some scholars believe that since China's energy conservation and environmental protection industry plays an important role in alleviating environmental externalities, as a capital-intensive environmental protection industry, it needs policy support or government subsidies in the emerging stage of innovation(Xu et al.,2021). Some studies believe that environmental subsidies promote environmental management innovation, but have no impact on environmental technology innovation[Ren et al.,2021]. Therefore, whether the government environmental protection subsidies can achieve effective results lies in whether the government's macro

policy design intention is effectively implemented at the micro enterprise level. Although the ecological environment governance requires a large amount of long-term investment of resources, the ecological environment has the characteristics of a public product, private enterprises have no strong motivation to participate in environmental governance, and lack of resource incentives and constraints are the problems that beset the environmental governance of enterprises (Grossman and Helpman, 2018). According to the theory of public goods, the ecological environment is not privately owned, but belongs to public resource. The governance of the ecological environment will occupy other productive investments originally used by enterprises, which is undoubtedly extra cost for enterprises. In this case, enterprises will lose the original motivation for green governance of their pollution behaviors. A large number of enterprises in environmental governance "free ride" phenomenon will lead to environmental market failure. The environmental protection subsidy policy implemented by the government alleviates the lack of funds needed by enterprises for environmental governance, helps enterprises expand reproduction and form economies of scale, so as to reduce the cost of environmental governance and make up for the profit loss caused by the positive externalities of environmental governance activities. At the same time, the government environmental protection subsidies incentive constraints, heavier pollution enterprises to seek their own profit maximization, in daily production operations have strong willingness to adopt green technology and new energy technology, pollution to eliminate backward production capacity, which can improve the efficiency of resource allocation in enterprise, finally realizes the "reducing pollution emissions " and " Increasing economic efficiency " double benefit (Yu et al., 2019).

On the one hand, the government environmental protection subsidy has the resource compensation effect; on the other hand, once an enterprise enjoys government environmental protection subsidies, it will be subject to more stringent environmental supervision by government departments, and the government will mainly supervise and evaluate the direction and efficiency of the use of special environmental protection funds (Stoever and Weche, 2018). Therefore, the government's environmental supervision of enterprises' environmental protection subsidy funds will undoubtedly restrict enterprises' non-green production and environmental illegal behaviors, so as to improve enterprises' environmental performance.

Existing studies have shown that executives' awareness of environmental protection is a specific manifestation of executives' cognition (Zhang et al., 2015), and executives' cognition of environment determines whether enterprises actively adopt green production behaviors (Yang et al., 2012). Government environmental protection subsidy policy support makes enterprise executives realize that government subsidy funds can reduce the risk of environmental protection investment and reduce the cost of environmental governance (Henriques and Sadorsky, 1996; Li and xiao, 2020). The stronger the support for environmental protection subsidies, the more likely it is for enterprise executives to pay attention to environmental policies and regulations, information on government support policies, and the latest trends of government punishments or rewards based on the environmental performance of peer enterprises (Suk et al., 2013). Therefore, senior executives are more aware of the importance of environmental issues to the development of enterprises (Gholami et al., 2013), and are more likely to implement positive environmental strategies to respond to the government's intention of environmental

policy (Zhang et al., 2015), which can undoubtedly improve the environmental performance of enterprises.

Based on the theory of signal transmission, companies that receive environmental subsidies from the government, there is no doubt that it sends an important signal to the world, this kind of company is behind the government as a recessive guarantee, which will enhance the company's financing gravity (Zhang, etc., 2017), be helpful for enterprises to raise funds through the capital market, boost the confidence of the stakeholders to the enterprise green development, reduce financing costs of enterprises and encourage enterprises to participate in environmental governance, which reduce negative expectations of stakeholders on non-green environmental protection behaviors of enterprises (Buysse and Verbeke, 2003). And it has a positive impact on effectively reducing the financing difficulties of enterprises, increasing investment in green technology innovation and improving the efficiency of environmental governance. For enterprises with heavy environmental pollution, their environmental governance is characterized by large investment in special equipment, long investment cycle span, high risk and slow effect (Rabelo and Melo, 2019), which is undoubtedly inseparable from the support of sufficient cash flow. And the enterprises that receive the government environmental protection subsidies obviously send a favorable signal to the external stakeholders: the implicit government guarantee behind the enterprises facilitates the enterprises to raise funds from the bond market and the stock market. More importantly, an enterprise's active participation in green environmental governance is no different from sending a signal of its legitimate operation to the outside world, promoting its good image of fulfilling its social responsibilities, providing psychological guarantee for investors to make decisions, raising investors' good expectations for the enterprise, helping to reduce financing costs and providing financial guarantee for enterprises to improve environmental performance (Martin and Moser, 2016). The government provides support to heavily polluting enterprises participating in environmental governance through measures such as environmental protection subsidies, which can help them expand reproduction, reduce the uncertainty and irreversibility of their environmental governance investment, and then promote enterprises to adopt green environmental protection equipment and new green technologies (Hamamoto, 2006). Thus it is conducive to the improvement of environmental performance. Therefore, government environmental protection subsidies have a positive incentive effect on environmental protection investment and environmental governance of enterprises. Based on the above analysis, the following assumptions are proposed:

H1: Government environmental protection subsidies have a positive impact on the improvement of environmental performance of heavily polluting enterprises.

As we all know, environmental protection subsidies have become an important economic means for the government to intervene in enterprises' practice of green environmental protection. In order to alleviate the pollution problem, the government invests a large amount of environmental protection subsidies every year. How these subsidies help enterprises reduce emissions and reduce pollution and clean production, as well as the effect of environmental protection subsidies, are important practical issues that need to be studied in depth. The above theoretical analysis shows that government environmental protection

subsidies will affect the environmental performance of enterprises. Therefore, through which channels the government environmental subsidies affect the environmental performance of enterprises, and to clarify the mechanism of action between the two will help reveal the "black box" in which the government's macro policies affect the micro behaviors of enterprises. Based on the existing research results, this paper argues that green technology innovation of enterprises, environmental regulation of government and environmental awareness of executives are important ways for environmental subsidies to affect green production behavior and environmental performance of enterprises. The reasons are as follows.

(1) Environmental protection subsidies affect enterprises' environmental performance: green technology innovation mechanism

First of all, according to the theory of technological innovation, green technological innovation can improve the efficiency of resource utilization, significantly reduce the energy consumption per unit product, and eliminate backward polluting capacity, so as to promote enterprises to realize green production. However, technological innovation of enterprises is of high risk, great uncertainty, and needs a large amount of sustained capital investment as support. Difficulties in financing and lack of motivation have always troubled enterprises' green technology innovation (Hsu et al., 2014). However, the government's environmental protection subsidies have provided financial support for enterprises' green technology innovation. It reduces the financing constraints faced by enterprises due to green innovation, reduces the high risk and uncertainty of innovation activities (Stiglitz, 2015), and reduces the cost of green innovation, which is conducive to encouraging enterprises to carry out green innovation. Empirical evidence of Shapiro and Walker (2018) also shows that government green environmental protection subsidies are conducive to promoting enterprises' green technology innovation.

Secondly, based on the externality theory, innovation once appear, the owner usually is unable or difficult to exclude others for the use of green technology innovation, or can't fully control the spread of the green innovation technology, so as to make the innovation the private income is less than the social benefits of the enterprise, show the Spillover effects of green technology innovation (Spillover Effect). Government environmental protection subsidies can effectively overcome the cost-benefit asymmetry caused by the spillover effect of enterprises' green technology innovation, which is conducive to improving enterprises' enthusiasm for green technology innovation, and thus can alleviate the problem of insufficient investment in private enterprises' green technology innovation. More importantly, enterprises use green innovative technologies and green intelligent equipment in the production process. On the one hand, it is conducive to accelerating the green production process of enterprises, reducing the dependence on the original production methods that damage the environment, so as to reduce the cost of environmental supervision and improve the environmental performance of enterprises (Shapiro & Walker, 2018). On the other hand, through the green technology innovation chain, enterprises produce green differentiated products to create new market demand and enhance green competitiveness, which is conducive to maintaining existing markets and even expanding new markets (Barney, 1991). It can be concluded that the government environmental protection subsidies can stimulate enterprises to increase their investment

in green technology innovation under the premise that the government environmental protection subsidies can relieve the resource constraints of enterprises' innovation.

And the government's environmental protection subsidies may help to encourage heavily polluting enterprises to invest in green technology innovation, mainly because: Whether an enterprise can carry out green technology innovation depends on whether it can meet the threshold conditions of innovation, especially with the support of continuous cash flow. The government's environmental protection subsidies can help an enterprise to cross the threshold conditions of green technology innovation and reduce the uncertainty and irreversibility of its green technology innovation. Thus, it is helpful for enterprises to make green technology innovation decisions (Hamamoto, 2006), and green technology innovation of enterprises helps them to eliminate polluting and backward production capacity, improve production efficiency and environmental performance (Porter & Linde, 1995; Hu et al., 2020). Based on the above analysis, the following assumptions are proposed:

H2: Environmental protection subsidies can encourage enterprises to innovate in green technology, thus helping to improve their environmental performance.

(2) Environmental subsidies affect the environmental performance of enterprises: government environmental supervision mechanism

As a special subsidy supported by the government, the use of environmental protection subsidy funds should comply with the "Provisions on Strengthening the Management of Environmental Protection Subsidy Funds", according to this regulation, environmental protection subsidies should be used for "comprehensive environmental treatment, key pollution source treatment", special funds, not diverted for other purposes. Enterprises that have obtained special environmental protection subsidy funds will become the target of the government's key supervision, and the government will mainly supervise the use direction and use efficiency of the special environmental protection funds. Therefore, the government's supervision of enterprise environmental protection subsidy funds will restrict enterprises' non-green production and environmental illegal behaviors, so as to improve the environmental performance of enterprises.

With the increasingly severe resource and environmental constraints, it is urgent to promote green production and improve environmental performance of enterprises. As the core content of environmental protection system, the effectiveness of environmental law enforcement supervision is directly related to the implementation effect of national environmental protection policies, and is an important factor that determines the production and emission behavior of individual enterprises and even the environmental quality of the whole region. Environmental protection law enforcement and supervision is the main driving force leading the change of green technology choice of enterprises (Wang et al., 2018). Zhang and Jiang (2013) showed that strengthening the environmental protection law enforcement will improve access of polluting, energy intensive industries and survival threshold, this will encourage enterprises to carry out the green technology innovation and application, thus is advantageous to the enterprise energy conservation and emission reduction and green production, and realize the innovation drive "win-win" and

environmental performance. Recent studies also show that stringent administrative regulation is the primary driver for companies to reduce pollution emissions (Shapiro & Walker, 2018). The reason why the government should regulate the enterprises that obtain financial subsidies is more based on the stakeholders proposed by experts and scholars represented by Freeman. In modern economic society, as the stakeholder of enterprises, the importance of the government is irreplaceable, mainly because: on the one hand, the government provides financial support, tax reduction and other preferential policies for the development of enterprises; on the other hand, it is also responsible for the supervision of enterprises' micro behaviors, especially their performance of environmental responsibility. Environmental protection subsidies are financial support provided to enterprises by the government to encourage enterprises to carry out energy conservation and emission reduction and actively participate in environmental governance for the purpose of environmental governance. They are free transferring payments unilaterally provided by the government and undoubtedly have specific objectives and related environmental performance requirements. In order to optimize the allocation of resources, increase the benefit of environmental subsidies, ensure that using limited special allowance incentive can implement specific economic, environmental and social objectives, implement enterprise's main body responsibility, the government will undoubtedly strengthen the regulation of enterprise production and operation activities, it will restrict the production of the enterprise sewage behavior, which is helpful for the improvement of the corporate environmental performance.

Based on the above analysis, the following assumptions are proposed:

H3: After the implementation of environmental protection subsidies, the government's environmental supervision will be strengthened, which is conducive to the improvement of enterprises' environmental performance.

(3) Environmental subsidies affect corporate environmental performance: the mechanism of environmental awareness of senior executives

Although domestic and foreign scholars have conducted cross-industry dynamic studies on the impact of environmental protection subsidies, there is still insufficient research on the following basic practical issues: why do enterprises in the same industry receive the same amount of environmental protection subsidies under the same institutional environment adopt different environmental protection behaviors? In other words, why do environmental protection subsidies have heterogeneous effects on environmental protection behaviors of enterprises in the same industry?

According to Upper Echelons Theory, senior executives are the core predictive variables that affect the strategic choice and performance level of an enterprise (Hambrick & Mason, 1984). Executives make bounded rational decisions based on their background characteristics, personal psychological traits and cognitive paradigm (Hambrick, 1994). The research of Yang et al. (2012) shows that executives' cognition of environment determines whether enterprises actively adopt green production behaviors. The environmental awareness of senior executives is a specific manifestation of their cognition (Zhang et al., 2015).

The guiding effect of government environmental protection support is mainly reflected in the following aspects: On the one hand, it makes enterprise executives realize that government subsidy funds can reduce the risks of environmental protection investment and reduce the cost of environmental governance (Henriques and Sadorsky, 1996; Li and xiao, 2020); On the other hand, the greater the government's support for environmental protection for enterprises, the more it can encourage enterprise executives to pay attention to environmental policies and regulations, information on government support policies and the latest trends of government's punishment or reward based on the environmental performance of peer enterprises (Suk et al., 2013). As a result, senior executives have obtained more information about green environmental protection, so that they are more aware of the importance of environmental issues to the development of enterprises, and more positively and optimistically interpret the guiding function of the policy guidance of environmental protection subsidies on the green production behavior of enterprises (Gholami et al., 2013). Therefore, it is more likely to implement positive environmental strategies to respond to the government's environmental protection subsidy policies to achieve the purpose of environmental protection (Zhang et al., 2015), which is conducive to the improvement of enterprises' environmental performance.

H4: Government environmental protection subsidies can enhance the environmental awareness of senior executives, thus help to improve the environmental performance of enterprises.

3 Research Design

(1) Data source and sample selection

According to the classification of heavy pollution enterprises, the heavy pollution industries are selected as the objects of investigation. In this paper, environmental performance is measured by the ecological benefit method. According to the Environmental Protection Law of the People's Republic of China promulgated in 2017, the environmental protection tax was officially levied on January 1, 2018, and the standard of the discharge fee changed to some extent. Therefore, the data of the discharge fee in the ecological benefit law is up to 2017. Therefore, this paper selects 16 listed companies of heavy pollution industries in China's A-share market from 2010 to 2017 as research samples.

The environmental performance data of the explained variables in this paper are from CSMAR database and Great Tide Information network. Among them, the sewage fee data used in the ecological benefit method is obtained from the manual sorting of annual reports and corporate social responsibility reports.

Explanatory variable Environmental protection subsidy data comes from the amount of government subsidy in the notes to the financial statements of the company's annual report. By searching keywords such as "energy saving", "emission reduction", "pollution control", "environmental protection", "clean" and "green", the specific environmental protection subsidy projects and the amount are determined by manual screening and sorting.

The intermediary variable enterprise green technology innovation data comes from the amount of enterprise R&D investment projects in the CSMAR database, and by searching keywords such as "environmental protection", "green", "energy saving and emission reduction", "clean", "pollution control", "garbage", "waste water", "waste gas", "three wastes" and "recycling", etc., Manual screening, sorting to determine the specific green nature of related R&D investment as the enterprise green technology innovation variables; The data of environmental supervision intensity came from the data center of the Government website of the Ministry of Environmental Protection, and the data included in the list of national key monitoring enterprises were sorted out by manual search. The data of senior executives' awareness of environmental responsibility comes from detailed data in hexun's corporate social responsibility score profile.

Control variables environmental management system certification data from the national Certification and Accreditation Administration official website, through the website certification results link under the "national certification and accreditation information public service platform" manual sorting sample enterprise environmental management system certification data. Other control variable data comes from the CSMAR database. According to the above 16 categories of heavy pollution industry screening A stock listed companies, eliminate ST*ST, companies; Remove abnormal samples of financial data; At the same time, in order to eliminate the influence of outliers, the main continuous variables were treated 1% Winsorize on both sides. After the above treatment, the samples of 257 listed companies with heavy pollution were obtained, with a total of 1382 observed values.

(2) Selection and definition of variables

☒ Explained variables

In the model, the dependent variable is environmental performance of enterprise. Existing literature has not yet reached a unified conclusion on the measurement of environmental performance indicators. Moreover, since most enterprises in China do not disclose specific pollutant emission details, it is quite difficult to obtain the emission data at the micro level of enterprises. In addition, the measures of environmental performance indicators in domestic literature mainly include ecological benefit method, environmental responsibility scoring method, environmental reward and honor scoring method, etc. In view of ecological, because the focus of this chapter to study the effect of environmental subsidies to the enterprise environmental performance, mainly focused on environmental policy resources for enterprises to reduce pollution emissions. Therefore, the method of ecological emulation is used to measure environmental performance in this paper.

This paper adopts the index framework of the World Council for Sustainable Development of Enterprises, and emulates the practices of Zhang et al. (2015), Li and Wang (2015), Zhang et al. (2019) and Yu et al. (2020), measuring environmental performance of enterprises with ecological benefit method. Its estimation formula is: ecological benefit = value of products or services/environmental impact, the higher the index value, the better the environmental performance. Among them, the environmental impact is expressed by the pollutant discharge fee paid by the enterprise, and the value of the product or service of

the enterprise is expressed by the business income. Therefore, based on the practices of Zhang et al. (2019), Zhang et al. (2015) and Li and Wang (2015), and Yu et al. (2020), the ratio of logarithmic operating revenue to logarithmic sewage charge was used as the ecological benefit method which is measured the environmental performance.

☒ Explanatory variables

The explanatory variable represents environmental protection subsidies. Environmental protection subsidy is the financial support provided to enterprises by the government for the purpose of environmental protection to encourage enterprises to carry out energy conservation and emission reduction and actively participate in green environmental governance. The amount of environmental protection subsidy is the data related to environmental protection that is sorted out manually according to the key words "energy saving", "emission reduction", "pollution control", "environmental protection", "green" and "clean" in the government subsidy data. As for the measurement of the environmental protection subsidy of the explanatory variable, following the measurement method of government subsidy of Shao and Bao (2012), Mao and Xu (2016), the environmental protection subsidy is measured by the ratio of the sum of the environmental protection subsidy received by the enterprise in the current year to the operating income.

☒ Mediating variables

Green technology innovation is measured by the ratio of a firm's green R&D expenditure to its revenue. Green R&D expenditure mainly refers to the technical transformation expenditure, the facility investment and maintenance expenditure related to environmental protection or green, etc. In the R&D expenditure, it can be obtained the green related R & D expenditure by selecting keywords such as "environmental protection", "energy saving", "green", "emission reduction", "pollution" and "clean".

Government environmental supervision, based on the practice of Pan and Guo (2018), environmental supervision intensity is measured by whether heavy polluting enterprises are included in the list of national Key monitoring enterprises. If listed, it is 1; otherwise, it is 0. The categories of government environmental supervision include wastewater, waste gas, hazardous waste, heavy metals, etc.

Corporate executive environmental awareness, measured by the corporate environmental awareness score.

☒ Control variables

In addition to the impact of environmental protection subsidies, the environmental performance of enterprises is also affected by the control variables of enterprise characteristics. According to the research of Shen et al. (2017) and Zhang et al. (2020), Control variables include company size, financial leverage, capital intensity, operating cash flow, age of listing, ownership concentration, and environmental management system certification. In addition, the model also controls time and industry dummy variables. Specific variables are defined in Table 1.

Table 1
Variable name and definition

variable type	variable name	variable symbol	variable definition
Explained variable	Environmental performance	<i>Envir</i>	Logarithmic main business income divided by logarithmic enterprise sewage charge
Explanatory variable	Environmental subsidy	<i>Subsid</i>	Environmental subsidies as a percentage of revenue
Intermediary variables	Green technology innovation	<i>Innov</i>	The ratio of a firm's green R&D expenditure to its revenue
	Government's environmental supervision	<i>Super</i>	The value is 1 if heavy polluting enterprises is listed national Key monitoring enterprises, otherwise, it is 0.
	Senior executives' environmental awareness	<i>Aware</i>	Represented by corporate environmental awareness score
Control variable	Company size	<i>Size</i>	Take the natural log of total assets at the end of the year
	Growth	<i>Grow</i>	Growth rate of operating revenue for periods T-1 and T
	Financial leverage	<i>Lev</i>	Expressed as the ratio of total liabilities to total assets at the end of the period
	Capital intensity	<i>Capital</i>	Net fixed assets/total assets
	profitability	<i>ROA</i>	Net profit divided by total assets
	Operating cash flow	<i>Cf</i>	The ratio of net operating cash flow to total assets
	Listed age	<i>Age</i>	The number of listing years is logarithmic
	Ownership concentration	<i>Share</i>	Proportion of shares held by top five shareholders
	Environmental certification	<i>ISO</i>	The enterprise is assigned a value of 1 through ISO14001, otherwise it is assigned a value of 0
	Year	<i>u</i>	Annual dummy variable
Industry	<i>v</i>	Industry dummy variable	

(3) Model design

Firstly, in order to reveal the impact of environmental subsidies on environmental performance of enterprises; At the same time, to consider environmental protection subsidies and enterprise environmental performance may reverse causation problems, to ease its reverse cause and effect of endogenous problems, this chapter constructs the regression model (1), the explanation variable lag

issue data regression, was established to verify the hypothesis H1, and control the industry and the effect of the year, and the use of robust standard overcome heteroscedasticity and serial correlation problem. The model is constructed as follows:

$$Envir_{it} = a_0 + a_1 Subsid_{it-1} + \beta X_{it} + u_k + v_j + e_i \quad (1)$$

In the model, Envir is the explained variable, representing environmental performance; Subside is the explanatory variable, representing environmental subsidy; X_{it} is a series of control variables, and U_k and V_j are annual and industry dummy variables respectively. The specific variables are defined in Table 1. In model (1), i represents the enterprise individual and t represents the year. If coefficient a is significantly positive, it indicates that environmental protection subsidies have significant positive impact on the environmental performance of enterprises. If coefficient a is significantly negative, it indicates that environmental protection subsidies have a significant negative impact on the environmental performance of enterprises.

This chapter uses the mediation effect test principle to test the mediation mechanism to verify whether the hypotheses H2, H3 and H4 are valid. The mediation mechanism test model is as follows:

$$Envir_{it} = a_0 + a_1 Subsid_{it-1} + \beta X_{it} + u_k + v_j + e_{it} \quad (1)$$

$$Medium_var_{it} = a_0 + a_1 Subsid_{it-1} + \beta X_{it} + u_k + v_j + e_{it} \quad (2)$$

$$Envir_{it} = a_0 + a_1 Subsid_{it-1} + a_2 Media_var_{it} + \beta X_{it} + u_k + v_j + e_{it} \quad (3)$$

Mediation effect test principle: test whether the regression coefficient a_1 of the independent variable versus the dependent variable in model (1) is significant; If significant, inspection model (2) the independent variable on the intermediary variable regression coefficient a_1 is significant, if the model (2) the coefficient of a_1 significant, directly to the third step, test model (3) the intermediary variable on the dependent variable regression coefficient a_2 is significant, and the independent variable on the dependent variable coefficient a_1 is significant, if step 3 a_2 is significant, a_1 is not significant, then the full mediating effect is established. If the independent variable coefficient a_1 in the second step is significant, and the independent variable coefficient a_1 in model (3) is significant, but a_1 is significantly smaller than the a_1 coefficient in model (1), then partial mediation effect is valid. However, if the independent variable coefficient a_1 in the second step is not significant, the Sobel test should be carried out. If the Sobel test is statistically significant, the above mediation effect still holds.

In the above model, Medium_var represents the intermediary variables, which are enterprise's green technology innovation, government's environmental supervision, and senior executives' environmental awareness. Mediation variables are defined in Table 1.

4 Empirical Results And Analysis

(1) Descriptive statistics

Table 2 describes the statistical results of major variables, and describes the statistical characteristics of environmental performance, environmental protection subsidies and other variables of heavily polluting enterprises. The mean value of environmental performance is 1.501, the median value is 1.453, the minimum value is 1.062, and the maximum value is 2.895, indicating that nearly half of the enterprises in the sample reach the mean level of environmental performance, and there are differences in environmental performance among enterprises. The mean value of environmental protection subsidies in the sample is 0.016, indicating that the government has given more support to heavily polluting enterprises in environmental governance in recent years. The minimum value of environmental protection subsidy is 0.000, and the maximum value is 0.184, indicating that there is a great difference in environmental protection subsidy among enterprises. The mean value of green technology innovation is 0.018, the median value is 0.013, the minimum value is 0, and the maximum value is 0.546, indicating that the green technology innovation of heavy polluting enterprises is also quite different, and the green technology innovation level of most heavy polluting enterprises cannot reach the industry average level ($0.013 < 0.018$). Therefore, China's heavy polluting enterprises' overall expenditure on green technology innovation is low. The mean value of government environmental supervision intensity is 0.378, the minimum value is 0.000, and the maximum value is 1.000, indicating that nearly 40% of the enterprises in the sample are listed in the list of national key monitoring enterprises. The mean value of executives' environmental awareness is 1.83, the median value is 2.000, the minimum value is 0.000, and the maximum value is 4.000, indicating that most executives of heavy polluting enterprises have a good sense of environmental responsibility.

Table 2
Main variables descriptive statistics

Variable	Sample	Mean	Med	SD	Min	Max
<i>Envir</i>	1382	1.501	1.453	0.226	1.062	2.895
<i>Subsid</i>	1382	0.016	0.009	0.023	0.000	0.184
<i>Innov</i>	1382	0.018	0.013	0.037	0.000	0.546
<i>Super</i>	1382	0.378	0.000	0.493	0.000	1.000
<i>Aware</i>	1382	1.830	2.000	1.910	0.000	4.000
<i>Size</i>	1382	21.684	21.541	1.091	19.276	25.520
<i>Grow</i>	1382	0.151	0.107	0.294	-0.373	1.267
<i>Lev</i>	1382	0.411	0.383	0.178	0.013	0.958
<i>Cf</i>	1382	0.062	0.093	0.079	-0.152	0.338
<i>ROA</i>	1382	0.044	0.060	0.037	-0.197	0.249
<i>Capital</i>	1382	0.373	0.333	0.051	0.300	0.571
<i>Age</i>	1382	2.921	2.944	0.242	1.791	3.146
<i>Share</i>	1382	0.541	0.543	0.156	0.189	0.918
<i>ISO</i>	1382	0.441	1.000	0.496	0.000	1.000

For the variables of enterprise characteristics, enterprise size, growth, asset-liability ratio and other indicators are within a reasonable range, and other variables have little difference.

(2) Basic regression analysis

Column (1) in Table 3 shows that the impact coefficient of environmental protection subsidies on environmental performance of enterprises is 0.038, which is significantly positive at the 1% level. It is verified that there is a significant positive correlation between environmental protection subsidies and environmental performance, that is, environmental protection subsidies can promote the improvement of environmental performance. Hypothesis H1 is verified.

Table 3

The relationship between environmental protection subsidies and enterprises' environmental performance and the test of the mechanism of action

Variable	<i>Envir</i>	<i>Innov</i>	<i>Envir</i>	<i>Super</i>	<i>Envir</i>	<i>Aware</i>	<i>Envir</i>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>Subsid</i>	0.048*** (3.19)	0.026*** (2.97)	0.031*** (3.07)	0.103** (2.03)	0.027*** (2.74)	0.125** (2.06)	0.033*** (3.04)
<i>Innov</i>			0.037*** (3.24)				
<i>Super</i>					0.023** (2.21)		
<i>Aware</i>							0.041** (2.13)
<i>Size</i>	-0.081** (-2.12)	0.035** (2.02)	-0.080** (-2.09)	0.262*** (2.88)	-0.084** (-2.19)	0.462** (2.48)	-0.078** (-2.07)
<i>Grow</i>	0.001 (0.16)	0.004** (2.46)	0.001 (0.14)	-0.002 (-0.97)	0.001 (0.37)	0.012 (0.37)	0.000 (0.12)
<i>Lev</i>	-0.078 (-1.09)	-0.014** (-2.06)	-0.076 (-1.08)	0.173* (1.78)	-0.079 (-1.08)	-0.576* (-1.79)	-0.078 (-1.06)
<i>Cf</i>	-0.255** (-2.22)	-0.033* (-1.86)	-0.252** (-2.18)	-0.594** (-2.09)	-0.258** (-2.23)	-0.094** (-2.09)	-0.249** (-2.16)
<i>ROA</i>	-0.006 (-0.17)	0.052*** (3.19)	-0.008 (-0.24)	-0.203** (-1.99)	-0.007 (-0.28)	0.123 (1.26)	-0.007 (-0.21)
<i>Age</i>	0.012*** (2.73)	0.008 (1.15)	0.012*** (2.75)	0.024 (1.56)	0.011*** (2.62)	-0.144*** (-6.16)	0.012*** (2.76)
<i>Capital</i>	-0.357*** (-3.78)	0.001 (0.25)	-0.346*** (-3.62)	-0.452*** (-3.33)	-0.348*** (-3.69)	-0.134 (-0.25)	-0.354*** (-3.76)
<i>Share</i>	-0.001 (-1.46)	-0.067* (-1.66)	-0.000 (-0.99)	0.003 (0.58)	-0.001 (-1.33)	0.003** (2.38)	-0.002 (-1.58)
<i>ISO</i>	0.354*** (4.03)	0.277*** (3.23)	0.362*** (4.09)	0.112* (1.89)	0.358*** (4.05)	0.189*** (4.28)	0.369*** (4.10)

Variable	<i>Envir</i>	<i>Innov</i>	<i>Envir</i>	<i>Super</i>	<i>Envir</i>	<i>Aware</i>	<i>Envir</i>
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>constant term</i>	1.549*** (8.23)	0.008** (2.47)	1.541*** (8.17)	1.131** (2.38)	1.522*** (7.94)	-7.632* (-1.88)	1.520*** (8.14)
<i>Industry/Year</i>	control	control	control	control	control	control	control
<i>Sample size</i>	1382	1382	1382	1382	1382	1382	1382
<i>Adjusted R²</i>	0.164	0.116	0.166	0.152	0.168	0.199	0.161
***, ** and * represents the significance level of 1%, 5% and 10%, () is the value of t, the same as below.							

Column (1) - column (3) in Table 3 tests the mediating role of green technology innovation in the relationship between environmental protection subsidies and environmental performance of enterprises. Firstly, the impact of environmental subsidies on green technology innovation is investigated. Column (2) shows that the coefficient of environmental subsidies is significantly positive at the 1% level, indicating that environmental subsidies promote green technology innovation. Secondly, the impact of green technology innovation on environmental performance of enterprises is tested. Column (3) Green technology innovation coefficients are all significantly positive at the 1% level, indicating that green technology innovation improves the environmental performance of enterprises; Thirdly, by testing the change of the influence coefficient of environmental protection subsidies on the environmental performance of enterprises, the environmental protection subsidy coefficients in Column (1) are also significantly positive at the 1% level, indicating that the environmental protection subsidy has a significant promoting effect on the environmental performance of enterprises, and the environmental protection subsidy coefficient in Column (3) is 0.031, which is smaller than that in column (1) 0.048. Based on the above results, it can be seen that green technology innovation has a significant partial mediating effect on the relationship between environmental protection subsidies and environmental performance of enterprises, namely, hypothesis H2 is established.

In Table 3, columns (1), (4) and (5) examine the results of the intermediary mechanism of government environmental regulation. Column (4) environmental subsidies coefficient under the 5% level significantly positive, indicating that the environmental protection subsidy strengthens the intensity of government environmental supervision. In Column (5), the intensity coefficient of government environmental regulation is significantly positive at the 5% level, indicating that the intensity of government environmental regulation is conducive to the improvement of enterprises' environmental performance. The environmental protection subsidy coefficient in Column (5) is 0.027, which is significantly positive at the 1% level, and smaller than the environmental protection subsidy coefficient in Column (1), which is 0.048, indicating that the government environmental regulation plays a significant and partial intermediary role in the relationship between environmental protection subsidy and environmental performance of enterprises. Hypothesis H3 is established.

In Table 3, columns (1), (6) and (7) examine the results of the mediation mechanism of executives' environmental awareness. The coefficient of environmental protection subsidy in Column (6) is significantly positive at the 1% level, indicating that the government environmental protection subsidy is conducive to enhancing the environmental protection awareness of senior executives; the coefficient of environmental protection awareness in Column (7) is significantly positive at the 5% level, indicating that the environmental protection awareness of senior executives promotes the improvement of the environmental performance of enterprises. In addition, the coefficient of environmental protection subsidy in Column (7) is 0.033 which is smaller than that in column (1), which is 0.048. The above results indicate that the environmental awareness of senior executives plays a significant partially mediating role in the process of environmental protection subsidies promoting the environmental performance of enterprises.

In addition, the related control variables in the model show that both the firm size and environmental performance are significantly negative, indicating that the bigger the firm size is, the environmental performance does not get better. It may be that the bigger the firm size is, the lower the environmental governance efficiency and the lower the environmental performance. There is a significant negative correlation between operating cash flow and environmental performance, indicating that operating cash flow will negatively affect the environmental performance of enterprises. It may be that the more busy enterprises are with production and operation activities, the more likely they are to neglect environmental governance. Companies that have been listed for a long time also have good environmental performance. Capital intensity is negatively correlated with environmental performance of enterprises. Generally speaking, enterprises with heavy pollution have a higher proportion of fixed assets, and the results also show that enterprises with large proportion of fixed assets have a poorer environmental performance, which is in line with the fact that enterprises with heavy pollution have a poorer environmental performance.

(3) Robustness test

The above results verify the significant positive correlation between environmental protection subsidies and environmental performance, reveal the positive impact of government environmental protection subsidies on the improvement of environmental performance of enterprises, and verify the three intermediary mechanisms of environmental protection subsidies on environmental performance of enterprises. However, in view of the environmental subsidies and enterprise environmental performance between endogenous problems may be heavier, also need through various robustness test to verify further, especially endogenous problems should pay attention to the following two aspects: on the one hand is the core explanation and be explained variables may exist between the endogenous problem caused by the reverse causality; on the other hand is the endogeneity problem caused by the omission of important variables. Therefore, the main test in this chapter uses the explanatory variable with one lag, and the propensity score matching method is used for robustness test.

This paper aims to evaluate the impact of environmental subsidies on firms' environmental performance, namely to reveal whether there is a causal relationship between environmental subsidies and firms'

environmental performance. If the ordinary least squares method or the firm's fixed effects model is used for identification, the problem of selectivity bias and mixed bias may occur, mainly because whether an enterprise gets environmental protection subsidies from the government in reality may be non-random: On the one hand, subsidies may be affected by enterprises' own environmental governance capabilities, that is, the government may consider enterprises' environmental governance capabilities when giving environmental protection subsidies; On the other hand, government environmental protection subsidies and enterprises' environmental performance may also be influenced by other factors (such as the size of enterprises). The optimal identification method in this paper is to compare the differences between the environmental performance of a heavily polluting enterprise that receives subsidies under the condition of "subsidy" and "non-subsidy", so as to exclude the influence of other enterprise characteristics, and then reveal the actual effect of government environmental protection subsidies on the environmental performance of enterprises. In practice, however, we cannot observe the environmental performance of the subsidized enterprises in the "non-subsidized" situation, because this situation is a counterfactual. The propensity score matching method proposed by Heckman et al. (1997) is an effective tool to deal with the above problems. The tendency score matching method is used to estimate the relationship between environmental protection subsidies and environmental performance of enterprises. Firstly, data matching is carried out, and the balance test is carried out. Then, the model is re-regressed with the matching samples.

First, data matching is performed to make the characteristics of the matching variables as similar as possible between the control group and the processing group. Before calculating propensity score, matching variables should be selected. The matching covariate in this paper are all the control variables in the previous model, including: company size, profitability, growth, financial leverage, operating cash flow, equity structure, capital intensity, company age and ISO certification variables.

The Logit method is used to estimate the binary variables and calculate the propensity score of each enterprise. The calculation process is as follows:

$$P(X_{it}) = P(Dsub_{it} = 1 | X_{it}) = \frac{\exp(\alpha X_{it})}{1 + \exp(\alpha X_{it})}$$

Where, the binary dummy variable Dsub={0,1}, when Dsub is 1, it means that the government environmental protection subsidy is enjoyed, when Dsub is 0, it means that the government environmental protection subsidy is not enjoyed, and X is the matching variable. The above scores reflect the probability of an enterprise enjoying government environmental protection subsidies. The probability value obtained by estimating the above equation is the probability predicted value of the treatment group and the control group. "A pair of four is put back to neighbor matching", and the balance test is carried out. Its expression is as follows:

$$\Pi(i) = \min_j \|\hat{P}_i - \hat{P}_j\|, j \in (Dsub = 0)$$

$\pi(i)$ represents the matching set from the control group enterprise corresponding to the processing group enterprise.

Secondly, a balance test is performed. Before matching sample regression, the test results are shown in Table 4. From the balance test, it is easy to know that the standard deviation of relevant control variables after matching is less than 10%, and the t-test results of control variables accept the null hypothesis that there is no significant difference between the treatment group and the control group, which indicates that the characteristic differences between enterprises receiving environmental protection subsidies and enterprises without environmental protection subsidies have been eliminated to a large extent.

Table 4
Balance test of matching variables

Variable	Matching	Mean		standard deviation	t-test
		Treatment group	Control group	Range(%)	
<i>Size</i>	Unmatched	21.955	22.318	-25.2	-8.36***
	Matched	21.967	21.954	0.8	0.76
<i>Lev</i>	Unmatched	0.366	0.412	-24.2	-8.28***
	Matched	0.370	0.368	1.2	0.89
<i>Grow</i>	Unmatched	0.222	0.295	-10.9	-3.12***
	Matched	0.223	0.228	-2.4	-1.36
<i>Cf</i>	Unmatched	0.061	0.064	-4.2	-2.08**
	Matched	0.062	0.061	0.7	0.74
<i>ROA</i>	Unmatched	0.038	0.042	-9.3	-3.01***
	Matched	0.038	0.038	0.1	0.05
<i>Age</i>	Unmatched	2.332	2.345	-5.7	-2.43**
	Matched	2.332	2.334	-1.1	-0.85
<i>Capital</i>	Unmatched	0.369	0.357	7.2	2.68***
	Matched	0.371	0.368	2.5	1.39
<i>Share</i>	Unmatched	0.564	0.584	-13.4	-5.78***
	Matched	0.563	0.563	0.1	0.05
<i>ISO</i>	Unmatched	0.394	0.439	-21.2	-8.19***
	Matched	0.395	0.398	-1.6	-1.03

Finally, based on the samples obtained from PSM, this paper re-regressed models (1) - (3) to test the effect and mechanism of environmental protection subsidies on enterprises' environmental performance. The results are shown in Table 5.

Table 5 reports the regression results and mechanism of the relationship between environmental protection subsidies and environmental performance of enterprises after matching samples. In order to alleviate the endogeneity problem caused by the reverse causality between environmental protection subsidies and enterprises' environmental performance, the explanatory variable is used to test the data with a lag of one period in model regression. Columns (1) environmental subsidies coefficient is 0.081, significant under 1% level is positive, that tend to score after the match the regression results also verify the environmental subsidies there were significantly positive correlation with the enterprise environmental

performance, namely environmental subsidies is helpful for the improvement of the corporate environmental performance, therefore, assuming that H1 is proved, and this result indicates that the previous conclusion is still robust. In addition, the column (1) - (3) the mediation mechanism of test results verified the green technology innovation in environmental subsidies and enterprise environmental performance relationship plays a significant intermediary role. Column (1), (4) and columns (5) the mediation mechanism shows that the government environmental regulation in the environmental protection subsidies to promote enterprise environmental performance relationship plays a significant intermediary role. Column (1), column (6) and column (7) show that the environmental awareness of senior executives plays a significant mediating role in the positive correlation between environmental subsidies and environmental performance. In conclusion, the results in Table 6 further verify H1, H2, H3 and H4.

Table 5 PSM test: The relationship and mechanism between environmental protection subsidies and environmental performance of enterprises

Variable	<i>Envir</i>	<i>Innov</i>	<i>Envir</i>	<i>Super</i>	<i>Envir</i>	<i>Aware</i>	<i>Envir</i>
	1	2	3	4	5	6	7
<i>Subsid</i>	0.081*** [4.31]	0.029*** [3.45]	0.067*** [3.67]	0.091** [2.12]	0.052*** [2.91]	0.128** [2.13]	0.060*** [3.58]
<i>Innov</i>			0.034*** [3.15]				
<i>Super</i>					0.029** [2.24]		
<i>Aware</i>							0.045** [2.18]
<i>Size</i>	-0.094*** [-3.02]	0.037** [2.08]	-0.091*** [-3.01]	0.264*** [2.89]	-0.087*** [-2.94]	0.467** [2.48]	-0.088*** [-2.86]
<i>Grow</i>	0.002* [1.73]	-0.004 [-0.45]	0.002* [1.74]	-0.001 [-0.66]	0.001 [1.61]	-0.014 [-0.37]	0.002* [1.72]
<i>Lev</i>	-0.092* [-1.84]	-0.014** [-2.07]	-0.091* [-1.81]	0.166* [1.70]	-0.087* [-1.78]	-0.573* [-1.72]	-0.089* [-1.81]
<i>Cf</i>	-0.268** [-2.09]	-0.032* [-1.76]	-0.263** [-1.98]	-0.605** [-2.07]	-0.265** [-2.04]	0.583 [0.80]	-0.261** [-2.02]
<i>ROA</i>	-0.008 [-0.64]	0.049*** [2.94]	-0.008 [-0.66]	-0.193* [-1.89]	-0.007 [-0.56]	0.127 [1.32]	-0.009 [-0.81]
<i>Age</i>	0.011*** [2.68]	0.008 [1.19]	0.011*** [2.69]	0.021 [1.54]	0.010*** [2.64]	-0.155*** [-6.32]	0.012*** [2.66]
<i>Capital</i>	-0.296*** [-2.77]	0.001 [0.20]	-0.294*** [-2.73]	-0.449*** [-3.27]	-0.288*** [-2.71]	-0.136 [-0.29]	-0.292*** [-2.72]
<i>Share</i>	-0.001 [-1.29]	-0.036 [-1.42]	-0.001 [-1.22]	0.003 [1.59]	-0.000 [-0.87]	0.002** [2.31]	-0.001 [-1.04]
<i>ISO</i>	0.452*** [4.87]	0.342*** [3.17]	0.455*** [4.89]	0.111* [1.86]	0.448*** [4.81]	-0.164 [-1.19]	0.446*** [4.76]
<i>constant term</i>	1.822*** [4.69]	0.008** [2.48]	1.828*** [4.71]	1.129** [2.36]	1.814*** [4.44]	-6.687* [-1.93]	1.825*** [4.72]

<i>Industry/Year</i>	control						
<i>Sample size</i>	992	992	992	992	992	992	992
<i>Adjusted R²</i>	0.155	0.123	0.159	0.154	0.158	0.193	0.173

5 Further Analysis: Enterprise Heterogeneity Test

As mentioned above, this paper analyzes the impact of environmental protection subsidies on enterprises' environmental performance, and discusses the mechanism of environmental protection subsidies on enterprises' environmental performance from three aspects: government environmental supervision, enterprises' green technology innovation behavior and executives' environmental awareness. It is found that environmental protection subsidies have a positive impact on the improvement of environmental performance of enterprises. The main reason is that environmental protection subsidies increase the environmental supervision of the government, stimulate the green technology innovation behavior of enterprises, and strengthen the environmental awareness of executives, so as to significantly improve the environmental performance of enterprises. However, there is a big gap between the environmental protection subsidies obtained by enterprises under different property rights, and the use efficiency of environmental protection subsidies is also very different. At the same time, enterprises with different financing constraints have different use values of environmental protection subsidies, and their impacts on environmental performance are also different. In addition, enterprises with different risk levels have different willingness to invest in green technology innovation or environmental governance, and their impact on environmental performance is also different. Therefore, it is necessary to continue to explore the effects of different property rights, different financing constraints and different levels of risk taking on the relationship between environmental subsidies and environmental performance.

First, test the impact of property heterogeneity on the relationship between environmental protection subsidies and environmental performance of enterprises. Column (1) in Table 6 is the group of state-owned enterprises, and column (2) is the group of non-state-owned enterprises. The environmental protection subsidy coefficient of column (1) is 0.041, which is significantly positive at the 10% level. The environmental protection subsidy coefficient of column (2) is 0.107, which is significantly positive at 1% level. In addition, through the group coefficient comparison results show that there is a significant difference between the two, environmental protection subsidies to enterprises.

Second, test the impact of heterogeneity of financing constraints on the relationship between environmental subsidies and environmental performance. According to the research on financing constraint measurement, (2017), Based on the practices of Hadlock and Pierce(2010), Wu Qiusheng and Huang Xianhuan (2017), the index is used to measure the financing constraint index, and its formula is:

$$SA_{it} = |-0.737 Size_{it} + 0.043 Size_{it}^2 - 0.040 * Age_{it}|$$

The greater the absolute value of SA, the lower the degree of financing constraint. When testing the heterogeneity of financing constraints, according to the SA index, the group with low financing constraints was defined as those with greater than or equal to the median, and those with less than the median were defined as high financing constraints. The test results are shown in columns (3) and (4) of Table 6. In the high financing constraint group in column (3), the regression coefficient of environmental subsidies on the environmental performance of enterprises is 0.084, which is significantly positive at the 1% level. In the low financing constraint group in column (4), the regression coefficient of environmental protection subsidies on the environmental performance of enterprises is 0.023, which does not pass the significance test. The above results indicate that the environmental protection subsidies do not have a high promoting effect on the environmental performance of enterprises with low financing constraints. In addition, the coefficient between the two groups showed significant differences. Based on the above results, it can be seen that environmental protection subsidies have a stronger promoting effect on the environmental performance of enterprises with high financing constraints, which indicates that government environmental protection subsidies have a better environmental governance effect on enterprises with high financing constraints.

Third, test the impact of heterogeneity of risk bearing level on the relationship between environmental protection subsidies and environmental performance of enterprises. As for the measurement of risk bearing level, refer to the practice of John et al.(2008) and use the earnings volatility index to measure it and estimate it by the three-year standard deviation of industry-adjusted return on assets of listed companies in the observation period. The specific calculation formula is as follows:

$$SDROA_{it} = \sqrt{\frac{1}{N-1} \sum_{n=1}^N (Adj_ROA_{in} - \frac{1}{N} \sum_{n=1}^N Adj_ROA_{in})^2} | 3$$

$$Adj_ROA_{in} = \frac{EBIT_{in}}{ASSETS_{in}} - \frac{1}{X_n} \sum_{k=1}^X \frac{EBIT_{kn}}{ASSETS_{kn}}$$

In the above formula, i is the enterprise, n is 1-3, which represents the year of the observation period, x represents the total number of enterprises in the industry, k is the KTH enterprise in an industry, EBIT is the profit before interest and tax of the corresponding year, ASSETS is the total ASSETS at the end of the year, and the higher the SDROA value, the higher the risk bearing level. In the heterogeneity test of risk bearing level, groups were also grouped according to the median. Those greater than or equal to the median were classified as high-risk level group, and those less than the median were classified as low-risk level group. The test results are shown in columns (5) ~ (6) of Table 6. Column (5) is the group with high risk bearing level, and its environmental subsidy coefficient is 0.093, which is significantly positive at the 1% level. Column (6) is the group with low risk bearing level, its environmental protection subsidy coefficient is 0.052, which is significantly positive at the 10% level, and the coefficient comparison between the two groups shows that there is a significant difference. Therefore, the above results indicate that, compared with the enterprises with low risk level, the environmental protection subsidies of enterprises with high risk level have a more significant promotion effect on environmental performance.

Table 6 A test of the relationship between environmental subsidies and environmental performance under firm heterogeneity

variable	Heterogeneity of property rights		Heterogeneity of financing constraints		Heterogeneity of risk taking	
	11	12	13	14	15	16
	SOEs	NSOE	High financing constraints	Low financing constraints	High risk taking	Low risk taking
<i>Subsid</i>	0.041* [1.71]	0.107*** [4.16]	0.084*** [3.79]	0.023 [1.44]	0.093*** [4.05]	0.052* [1.92]
<i>Size</i>	-0.026* [-1.84]	-0.094** [-2.28]	-0.017 [-1.57]	-0.082** [-2.14]	-0.088** [-2.17]	-0.051* [-1.91]
<i>Grow</i>	-0.000 [-0.16]	0.001 [0.54]	0.002 [1.29]	0.001 [0.39]	0.000 [0.22]	-0.001 [-0.78]
<i>Lev</i>	-0.057 [-1.36]	-0.114 [-0.97]	-0.095 [-0.76]	-0.071 [-1.56]	-0.068 [-0.55]	0.006 [0.04]
<i>Cf</i>	-0.251** [-2.13]	-0.164 [-1.53]	-0.167 [-1.61]	-0.234* [-1.81]	-0.228* [-1.76]	-0.206* [-1.69]
<i>ROA</i>	0.005 [0.59]	-0.002 [-0.14]	0.006 [0.33]	0.004 [0.21]	-0.013 [-1.07]	0.008 [0.72]
<i>Age</i>	0.013*** [2.86]	0.009** [2.44]	0.008** [2.15]	0.012*** [2.79]	0.010** [2.47]	0.005 [1.15]
<i>Capital</i>	-0.338*** [-3.22]	-0.261** [-2.43]	-0.315*** [-2.73]	-0.296*** [-2.81]	-0.163** [-2.24]	-0.324*** [-2.90]
<i>Share</i>	0.048*** [4.60]	-0.003 [-0.31]	-0.001 [-0.58]	0.027*** [2.74]	-0.001 [-1.05]	-0.001 [-0.94]
<i>ISO</i>	0.264*** [2.92]	0.311*** [3.24]	0.278*** [3.09]	0.245*** [2.89]	0.392*** [3.31]	0.363*** [3.15]
<i>constant term</i>	1.670*** [5.95]	2.331*** [8.72]	3.169*** [9.33]	2.454*** [6.71]	5.048*** [6.33]	3.732*** [4.97]
<i>Industry/Year</i>	control	control	control	control	control	control
<i>Comparison of coefficients between groups</i>	8.26***		10.42***		7.57***	

<i>Sample size</i>	734	648	685	697	597	785
<i>Adjusted R²</i>	0.194	0.278	0.213	0.202	0.189	0.163

6 Research Conclusions And Policy Implications

This chapter takes 257 enterprises in China from 2010 to 2017 as the research object, and empirically tests the impact and mechanism of government environmental protection subsidies on enterprises' environmental performance by using various methods such as ordinary least square method and propensity score matching. Furthermore, the effects of different property rights, different financing constraints and different levels of risk taking on the relationship between environmental protection subsidies and environmental performance of enterprises are further discussed. The main conclusions are as follows: First, the government environmental protection subsidies have a positive effect on the environmental performance of enterprises. Secondly, the analysis and test results of the intermediary mechanism show that the environmental protection subsidy will encourage enterprises to innovate green technology, strengthen the environmental supervision of the government and enhance the channels of enterprise environmental awareness to improve the environmental performance of enterprises. Thirdly, there is a significant difference in the impact of firm heterogeneity on the relationship between environmental protection subsidies and environmental performance of enterprises. Compared with state-owned enterprises, environmental protection subsidies of non-state-owned enterprises have a more significant promoting effect on environmental performance. Compared with enterprises with low financing constraints, environmental subsidies have a more significant promoting effect on environmental performance in enterprises with high financing constraints. Compared with enterprises with low risk level taking, the promotion effect of environmental subsidies on environmental performance is more obvious in enterprises with high risk level taking.

The above results indicate that government environmental subsidies can improve the environmental performance of heavily polluting enterprises through enterprise green technology innovation, government environmental supervision and environmental awareness of executives, which is helpful to understand the objective performance and deep-rooted reasons of the impact of government environmental protection subsidies on enterprises' environmental performance, thus providing supporting evidence for the micro effects of government environmental protection subsidies. In addition, further analysis shows that there are significant differences in the incentive effects of environmental protection subsidies on environmental performance of enterprises with different characteristics. Therefore, to improve the effect of macroeconomic policies, it is necessary to implement targeted regulation and targeted policies, which provides direct evidence for the government to improve the dynamic adjustment mechanism of environmental protection subsidy policies.

Based on the above research, the following policy implications are obtained:

First, give full play to the signaling function of government environmental protection subsidies, and actively guide and cultivate corporate executives' awareness of environmental responsibility. The

government should strengthen the environmental protection subsidy policies for heavy polluting enterprises, form institutional arrangements, give full play to the signal transmission function of environmental protection subsidy, and actively guide and cultivate the sense of environmental responsibility of corporate executives, so as to improve the environmental governance efficiency of enterprises.

Secondly, we should increase policy support for enterprises' green technology innovation activities. In order to achieve the dual benefits of "emission reduction" and "efficiency increase", the government should increase the policy support for enterprises' green technology innovation activities, and effectively promote the green innovation transformation of heavy polluting enterprises, rather than be limited to direct environmental protection investment. Environmental protection subsidies have an incentive effect on enterprises' green technology innovation, and enterprises can enhance their unique green competitive advantage through green technology innovation, so that the long-term effect of environmental governance can be reflected.

Thirdly, build environmental information supervision platform to improve environmental information disclosure mechanism. At present, the environmental awareness of senior executives in Chinese enterprises is generally not strong, so the government's incentive and guidance function should be strengthened, the environmental information supervision platform should be constructed, the environmental information disclosure mechanism should be further improved, the supervision and reward and punishment system should be improved, and the supervision should be accepted by the media and the masses under the "sunshine supervision" of the public. Therefore, the government should build a scientific and transparent information management platform for environmental protection subsidies, which includes two sub-information systems: one is to integrate environmental protection information, environmental performance and other information into the basic information system. The second is to include green technology innovation input information, "blacklist", enterprises' performance of production responsibilities and other information into the credit information system, so as to serve as the reference basis for heavy pollution enterprises to obtain environmental protection subsidies.

Finally, different environmental protection policies should be introduced according to different characteristics of enterprises. The use efficiency of environmental protection subsidies in non-state-owned enterprises is higher than that in state-owned enterprises; the use efficiency of environmental protection subsidies in enterprises with strong financing constraints is higher than that in enterprises with low financing constraints; the use efficiency of environmental protection subsidies in enterprises with high risk bearing is higher than that in enterprises with low risk bearing. Therefore, the government should fully consider the heterogeneity of enterprises with different characteristics and implement different subsidy policies for enterprises with different characteristics when issuing environmental protection subsidy policies. If the government's macro environmental protection subsidy policy adopts the "one size fits all" incentive mode, the implementation effect of the subsidy policy is not ideal, and there may even be resistance against the design intention of the policy, which may not only lead to huge policy waste, but also may delay the government's timely regulation. In order to improve the effect of macro environmental

protection subsidy policy, it is necessary to implement macro regulation and control. When stimulating enterprises with heterogeneous characteristics, different policies should be implemented according to the particularity of enterprises with different characteristics, so as to improve the precision of policies.

Declarations

Ethics approval and consent to participate

The study does not involve any ethical approval issues and all authors agree to participate.

Consent for publication

All authors agree to publish without dispute.

Authors' contributions

Among the authors in the list, as the first author of this article, Feimei Liao provided the main inspiration for the formation of this article, built the article framework, conceived the main research methods and models of this article, undertook the main writing work of the article; Songqin Ye is the corresponding author, who was responsible for data collection, provided the main ideas for the research of this article.

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Availability of data and materials

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