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One Fee, Two Reductions: The Double Abatement Effect of Pollutant Discharge Fees on Industrial Pollution and Carbon Emissions

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Formulating policies under the dual policy objectives of environmental protection and carbon neutrality in China is essential. This paper utilizes enterprise-level data to construct a panel model. Our empirical test indicates that increasing China's pollutant discharge fee can effectively reduce industrial pollutants, including wastewater and exhaust gas. The empirical results indicate that in terms of enterprises, pollutant discharge fees can not only directly reduce carbon emissions but also indirectly by reducing coal assumption. This paper also constructs a threshold model of the carbon emission reduction effect of population size. It has been proved that when the population size does not exceed the threshold, the utility of the pollutant discharge fee is apparent. According to this study's heterogeneity test, the carbon emission reduction effect of the pollutant discharge fee is more evident in large- and medium-sized enterprises and heavy pollution enterprises.

Keywords: pollutant discharge fee, industrial pollution, carbon emission, panel regression, mediation effect, threshold effect

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1 INTRODUCTION

The economic growth and human activities continue to expand carbon emissions, increasing the risk of environmental deterioration. Many researchers have begun to emphasize the importance of the carbon neutrality (Ji et al., 2021). Since the 2015 Paris Agreement, various member countries of the United Nations Climate Change Conference (21st Conference of the Parties, or COP21) are working on policies and strategies to control the problem of carbon dioxide (CO_2) emissions (Zhang and Wang, 2017). Sustainable environmental development is becoming a global consensus. Many countries strive to develop policies to control environmental degradation and reduce environmental pollution.

Among many environmental regulations in China, the pollutant discharge fee has an extensive history. At the corporate level, the most common way to protect the environment is to charge pollutant discharge fees. This paper establishes a model of pollutant discharge fees and other variables to explore the impact of charges on industrial pollutants and carbon emissions. The Chinese government promulgated the regulation for pollutant discharge fees in 1979. But there are two

Abbreviations: COP21, 21st Conference of the Parties; CO_2, Carbon Dioxide; APEC, Asia-Pacific Economic Cooperation; DID, Difference-in-Difference; PM2.5, Fine Particulate Matter; GHG, Greenhouse Gas; GDP, Gross Domestic Product; AESPF, Annual Environmental Survey of Polluting Firms; ASIF, Annual Survey of Industrial Firms; NBSC, National Bureau of Statistics of China problems, lack of motivation for corporate pollution control and significant differences in charging standards in different areas. In 2003, the Chinese government issued the second edition of the regulation and implemented it at the end of 2017. However, as the environment is a non-exclusive public good, many enterprises did not pay the fee as stipulated, leading to low resource allocation efficiency and environmental problems (Hu et al., 2020; Li et al., 2021).

The purpose of charging the pollutant discharge fee is to reduce pollutant emissions. There is evidence demonstrates that it does achieve this purpose. However, it is unclear whether the policy's implementation has played an important role in reducing carbon emissions. To fill this gap, this paper establishes a panel regression model and analyzes the role of pollutant discharge fees. We find that pollutant discharge fees also can reduce carbon emissions. With different population sizes, the carbon emission reduction effect of pollutant discharge fees is different. Further, the type and scale of enterprises also affect the emission reduction effect of the fees.

In addition to the direct effect, we also find that pollutant discharge fees can indirectly influence carbon emissions by reducing the use of coal. The consumption of fossil fuels such as coal is an important source of CO_2. China's current industrial sector requires coal to operate power plants, steel plants, and chemical plants and create electricity, steel, ammonia, methanol, urea, and agricultural fertilizer (Jia and Lin, 2021). Coal is China's major energy source and the most prominent contributor to the country's GHG emissions. The Chinese government attaches great importance to reducing GHG emissions. Energy conservation and emission reduction is the most critical step for China to address global climate change and other environmental issues in the present and future (Zhou et al., 2020). Reducing carbon emissions also have a positive impact on the Chinese government's proposal at the 75th UN General Assembly to achieve carbon neutrality by 2060.

Amid a critical time of global warming, it is effective for China to adopt new policies to reduce carbon emissions, but this will have significant costs. Utilizing existing systems to achieve the goal of reducing carbon emissions is a more efficient approach. In theory, there is a large overlap between the sources of environmental pollutants and CO_2 emissions. This paper uses data at the enterprise level to provide empirical evidence that there is also a negative correlation between the number of emission fees and carbon emissions.

This article provides the following contributions to the existing literature. First, in terms of this paper's research perspective, the pollutant discharge fee is a considerable part of Chinese environmental protection law. Charging for polluters is also a common practice throughout the world. Such regulation is of great significance for reducing environmental pollution and improving environmental quality (Wang et al., 2014a). Studying the actual emission reduction effect of the pollutant discharge fee has great reference value for decision makers to establish more suitable regulatory policies. However, the existing research only focuses on the promoting effect of pollutant discharge fees on environmental pollution, air pollution, and exhaust emission. Few literatures mentioned the effect of this policy on carbon emissions. This paper fills this research gap and studies the dual function of the pollutant discharge fee in China. While having a great inhibitory effect on air pollutants, the pollutant discharge fee also has a significant abatement effect on carbon emissions. Second, from the perspective of research objects, rather than the studying the impact of policies at the provincial or macro level, this paper quantitatively studies the reverse relationship between pollutant discharge fees and carbon emissions at the enterprise level to study the impact of Chinese government procurement of coal substitutions.

The remainder of this study is arranged as follows: **Section 2** presents the related literature review and hypotheses. **Section 3** describes the data and methodology. **Section 4** discusses the empirical results. **Section 5** carries out the heterogeneity analysis. The last section concludes.

2 LITERATURE

Since Arthur C. Pigou first proposed environmental tax in his externality theory, academia has not reached a unified conclusion on the governance effect of environmental tax. China adheres to the policy of the pollutant discharge fee, while other countries implement the environmental tax. Previous studies mainly focus on the role of environmental tax. Many literatures can prove that the implementation of environmental tax has the effects of reducing industrial pollution, strengthening green economies, and inhibiting environmental degradation (Lin and Li, 2011). used the Differences-in-Differences (DID) model to comprehensively evaluate the impact of carbon tax on environmental governance in five Nordic countries (Denmark, Finland, Sweden, the Netherlands, and Norway) and found that environmental taxes had a negative effect on CO_2 emissions in Finland. However, this effect was weak in the other four countries. For the first time (Han and Li, 2020), quantified the impact of environmental taxes on the PM2.5 emissions in China's provinces and noted that clean air policies and environmental taxes could significantly reduce its pollution (Chien et al., 2021). Also proved that environmental taxes and ecological innovation have a positive impact on reducing carbon emissions and haze formation in Asian countries.

There is substantial evidence in various countries that charging taxes is an effective means of reducing environmental damage (Meng et al., 2013). Collated data and noted that carbon taxes can effectively reduce CO_2 emissions. For example, Australia has imposed environmental taxes since 2012 to meet Copenhagen targets for its CO_2 emission reductions. In Europe and China, environmental taxes also have a negative impact on GHG emissions (Yang et al., 2014; Onofrei et al., 2017), indicating that environmental taxes have an important role in reducing environmental pollution (Vallés-Giménez and Zárate-Marco, 2020). Reported that the GHG emissions in Spain are spatially dependent, spatially persistent and temporally. In this case, taxes that aim at reducing emissions have a slight inhibiting effect. However, sometimes environmental taxes have a negative impact on economic development (Floros and Vlachou, 2005). Assessed the impact of environmental tax and found that carbon tax in the

Greek manufacturing industry has been an effective environmental policy to alleviate global warming. But it has proved to be expensive and detrimental to the economic development (Gao and Chen, 2002; Lu et al., 2010). Also illustrated that the implementation of environmental taxes in China will reduce carbon emissions while it may have a negative impact on the country's economy.

Implementing environmental tax has the function of strengthening a green economy. As mentioned for China (Li et al., 2021), explained that the use of environmental taxes and regulatory supervision by relevant institutions can promote the use of green technologies and reduce industrial pollution. More stringent environmental taxes can encourage enterprises to reduce emissions, and there is an inverted U-shaped relationship between industrial pollution reduction and environmental tax rate (Cheng and Li, 2022). Proved that the industrial green total factor productivity (GTFP) increases significantly by increasing the standard pollutant discharge fee. Their conclusion remains valid after alleviating endogenous problems and conducting robustness tests. Increasing environmental costs can promote industrial green growth and improve the level of green technology innovation, which can better transform the mode of a country's economic growth and achieve green industry development. The relationship between environmental taxes and green technology innovation is achieved through incentives for environmental regulatory instruments (Anthony et al., 2011; Jaffe et al., 2002). Some countries are improving green information systems, strengthening internal environmental management (Khan and Yu, 2020), and developing green practices (Khan et al., 2020) and green financial intermediary channels to achieve a zero-carbon economy (Umar et al., 2021).

In addition, environmental taxes affect the choice of pollutant products in the decision-making process, creating incentives to reduce high-pollution products and improve environmental quality (Elkins and Baker, 2002; Niu et al., 2018; He et al., 2019). In other words, environmental taxes correct environmental problems (such as pollution), in whole or in part, by increasing incentives for alternative behaviors. Environmental taxes can increase environmental investment and reduce air pollution emissions. Moreover, according to the idea of asylum tax, in complete competition, the optimal environmental tax can offset the gap between private costs and social costs. These findings suggest that well-designed environmental taxes may be an effective policy tool for the internalization of environmental costs. Threshold regression results have highlighted that there is an optimal tax rate for green technology innovation (Wang and Yu, 2021), However, it is important that China's current environmental tax rate is lower than this tax rate.

World economic and finance development has an important impact on the emission of CO_2 (Xiang et al., 2021; Ren et al., 2022a; Yin et al., 2022). Economic development is inseparable from the demand for resources. Increased demand for resources puts increasing pressure on the natural environment. One of the increasing pressures on the natural environment is that there are more carbon emissions, haze pollution, and unhealthy byproducts produced by different activities (Malghani, 2021), and the increase in economic development leads to more carbon emissions, especially in countries such as China and India (Ran et al., 2021). Except for the economic situation, coal prices can largely affect the use of coal, which are affected by many factors (Ren et al., 2021b). Proposes two new methods to evaluate the predictability of a large group of factors on carbon futures returns.

China's economic growth has been accompanied by substantial energy consumption, surpassing the energy consumption of the United States for the first time in 2010. Furthermore, the annual report of China's energy development illustrated that the renewable energy in China satisfies for only a small proportion of total energy consumption (accounting for 13% in 2016). Conversely, coal (characterized as a high-carbon, high-pollution, and high-emission energy source) represented a large proportion of the total energy consumption (61.8%), while oil and gas accounted for 18.3% and 6.4%, respectively. In addition, there are distinct differences in the energy consumption patterns between China and the world's major developed countries and its energy consumption intensity is significantly higher than that of developed countries. Reliance on coal as a fuel for production is likely to cause higher carbon emissions. This paper verifies whether the increase in pollutant discharge fees can reduce the use of coal, the main contributor to greenhouse gases, and further reduce carbon emissions.

How to mitigate carbon emissions is a hot topic in recent years. There are many direct and indirect factors that affect corporate carbon emissions. For example, relying on fossil fuels for production produces a large amount of carbon dioxide, which puts a certain pressure on the global environment. In addition, increased national climate risk will also promote the carbon emissions of enterprises (Ren et al., 2021).

Meanwhile, researchers work to find ways to reduce carbon emissions. For example, increasing the use of renewable energy can effectively alleviate environmental pressure (Dong et al., 2020). Environmental innovation is also considered one of the critical tools for reducing CO_2 emissions (Cws et al., 2020; Umar et al., 2020). Fostering a migration from traditional energy to renewable energy is not only environmental-friendly but also crucial for steady development of society and economy (Ayres et al., 2013; Wang et al., 2014b). For government policy, mandatory environmental regulation and soft policies directly or indirectly reduce carbon emissions. In addition, some researchers point out that China's energy development will have a significant impact on its economic growth (Li et al., 2017; Xie et al., 2018).

Few studies have investigated the quantitative impact of environmental tax on carbon emissions. Some scholars believe that environmental tax will lead to environmental deterioration (Asmi et al., 2019). However, another school believes that environmental taxes help reduce carbon emissions (Thi et al., 2020). Studied the relationship between environmental taxes, natural resource consumption taxes, and carbon emissions from 2001 to 2018, and the multivariate analysis indicated that the increased environmental taxes can lead to Vietnam's CO_2

emissions reducing. Other studies have indicated that environmental taxes can reduce CO_2 emissions at a higher level worldwide (Wolde-Rufael and Mulat-Weldemeskel, 2021). Collected data on aggregate environmental taxes, energy taxes, and environmental policies in seven emerging countries from 1994 to 2005 and tested the green dividend hypothesis, proving that aggregate environmental taxes and energy taxes improved the environmental quality of these countries.

Environmental taxes may reduce carbon emissions through a variety of ways. Environmental taxes may lead to technological upgrades, potentially combatting the problems associated with high emissions (Borozan, 2019). Ulucak et al. (2020) believed that environmental taxes can achieve the non-linear impact on carbon emissions by improving innovation and energy efficiency. The marginal impact of environmental taxes on natural resource rents and renewable energy consumption rises in a statistically significant manner with increasing tax levels, further affecting carbon emissions. Raising environmental taxes can also have a negative impact on the consumption of traditional energy sources such as coal, indirectly reducing carbon emissions (Martins et al., 2021).

Many environmental tax studies have involved industrial pollution to measure environmental quality, yet rarely involve resource utilization, such as ecological footprint (Ac and Acar, 2018; Sun et al., 2020). Studies have reported that environmental tax can reduce water pollution (Higano et al., 2020), solid waste (Prats et al., 2020), and resource consumption (Söderholm, 2011).

3 METHODOLOGY AND DATA

3.1 Panel Regression Model

In the research method, we use panel regression with time and individual fixed effects. The original intention for the establishment of the pollutant discharge fee was to reduce industrial pollution, so we first explored the direct emission reduction effect of the pollutant discharge fee on waste gas and wastewater. In addition, we regressed CO_2 data to estimate whether this policy has an impact on CO_2 emissions. The baseline measurement model is as follows:

$$w\_gas_{it} = \alpha_1 + \beta_1 fee_{it} + \gamma_1 X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (1)$$

$$w\_water_{it} = \alpha_2 + \beta_2 fee_{it} + \gamma_2 X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (2)$$

$$CO_{2_{it}} = \alpha_3 + \beta_3 fee_{it} + \gamma_3 X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (3)$$

Where i and t denote enterprise and year, respectively, w_gas_{it}, w_water_{it}, and $CO_{2_{it}}$ severally represent industrial waste gas emissions and water emissions and CO_2 emissions, which are calculated by the natural logarithm of CO_2 emissions plus one from industrial enterprises. fee_{it} is the natural logarithm of emission fee for a specific enterprise in a given year. X_{it} is a vector of control variables (Xing et al., 2020), including corporate financial leverage, return on assets, proportion of management expenses, regional per capita GDP, and export value (if the export value is greater than one, the value is one; otherwise, it is zero). ε_{it} is the error term.

3.2 Mediation Effect Model

This study assessed the direct and indirect effects of pollutant discharge fees on carbon emissions by utilizing a mediating effect model. Higher environmental taxes can reduce the use of fossil fuels, such as coal (Murray and Brian, 2015), by promoting green technology and improving the quality of green investment (Lambertini et al., 2020) as well as competitiveness of renewable energy technologies (Wesseh and Lin, 2019). Simultaneously, changes in coal consumption will affect CO_2 emissions in the short and long term (Martins et al., 2021). We speculated that the pollutant discharge fee system can reduce carbon emissions by reducing the use of coal, so our mechanism analysis addressed coal consumption as an intermediary variable. We adopted the following regression model:

$$coal_{it} = \xi + \zeta fee_{it} + \varsigma X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (4)$$

$$CO_{2_{it}} = \alpha + \beta fee_{it} + \theta coal_{it} + \gamma X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (5)$$

Here, i and t denote enterprise and year. $coal_{it}$ and $CO_{2_{it}}$ represent the coal consumption intensity and CO_2 emissions, respectively. fee_{it} refers to the emission fee for a specific enterprise in a given year. X_{it} is a vector of control variables. ε_{it} is the error term.

3.3 Threshold Effect Model

The panel regression model only verifies the existence of a carbon emission reduction effect caused by the pollutant discharge fee, but whether there are other factors, such as population, that affect the carbon emission reduction effect (Wang et al., 2022). Believed that the multi-center structure of urban agglomeration would produce large amounts of carbon emissions (Fan et al., 2021; Wang and Wang, 2021). Indicated that there is a non-linear relationship between aging populations and carbon emissions. However, we believed that different population sizes also have an impact on the CO_2 emission reduction effect. Due to the differences in geographical location, economic foundation, and construction conditions, the population size of cities in China vary. If the urban population size is larger than the population capacity, it indicates that the urban population has caused great pressure, or even damage, to the environment, which is not conducive to the green development of these urban environments. In this case, we speculated that the carbon emission reduction effect of the pollutant discharge fee may be heterogeneous with different population sizes, that is, the impact of urban population size on carbon emissions may have a threshold effect. According to the threshold model constructed by (Hansen, 1999), we constructed the threshold regression model explaining the non-linear influence of population size on CO_2 emissions from pollution charges. In this study, the single-threshold econometric model was as follows:

$$CO_{2_{it}} = \alpha_0 + \beta_1 fee_{it} I(pop \le \gamma) + \beta_2 fee_{it} I(pop > \gamma) + \theta' X_{it} + \mu_t + \eta_i + \varepsilon_{\text{it}} \quad (6)$$

TABLE 1 | Definitions of variables.

	Variable name	Variable symbol	Definitions of variables
Dependent Variables	co2	CO_2 emission	Log (1 + CO_2), where CO_2 is converted from standard coal, the conversion formula is:CO_2 = standard coal*0.714*2.492
	w_gas	industrial waste gas emissions	Total industrial waste gas emissions million standard cubic meters/10000
	w_water	industrial wastewater emissions	Industrial wastewater emissions tonnes/10000
Independent Variable	fee	Pollutant discharge fee	Natural logarithm of emission fee
Control Variables	roa	rate of return on assets	Operating profit/Total assets
	lev	financial leverage	Total liabilities/Total assets
	admin	Proportion of management costs	Ratio of management expenses to sales income of main products
	export	Whether the enterprise has export behavior	0–1 dummy variable, if export value >0, export value is 1, otherwise 0
	lpgdp	Regional per capita GDP	Natural logarithm of per capita GDP in the province where the enterprise is located
Mediator	coal	Coal consumption intensity	Coal consumption amount (million tons)
Threshold Variable	pop	population size	Natural logarithm of end-of-year population in cities where the enterprises is located

In addition to the previously mentioned variables, pop is the population size, the natural logarithm of an urban population at the end of the year. $I(\cdot)$ represents the indication function, which is determined by the threshold variable, pop, and threshold value, γ. The number of thresholds is determined by the significance of F-statistics. μ_t and η_i represent the provincial fixed effect and year fixed effect, respectively, and ε_{it} is the error term.

3.4 Data Sources

The data on firms' pollution emissions comes from Annual Environmental Survey of Polluting Firms (AESPF), which was established by the Ministry of Ecology and Environment (formerly known as the Ministry of Environmental Protection) in the 1980s to record environmental pollution and emission reduction in China. AESPF provides information on corporate environmental performance, including emissions of major pollutants, pollution treatment equipment, and energy consumption. The CO_2 emission data was converted from standard coal data.

Corporate financial control variables (such as asset-liability ratio, corporate scale, corporate age, and enterprise import and export data) are derived from the Annual Survey of Industrial Firms (ASIF), which is one of the most comprehensive and widely used Chinese firm-level dataset maintained by the National Bureau of Statistics of China (NBSC). The ASIF dataset covers all state-owned industrial firms and non-state-owned industrial firms with annual sales above 5 million RMB in China. It contains detailed financial and characteristic information about each firm. The gross domestic product per capita and urban population at the end of the year in the province where the enterprise is located are based on data from the NBSC. We matched the above data according to the enterprise name and the enterprise code and received 178,473 pieces of data. The following table indicates how the study variables are defined (**Table 1**).

TABLE 2 | Descriptive statistics.

Variable	Obs	Mean	Sd	Min	p50	Max
co_2	210454	6.356	3.623	0.000	7.320	16.534
fee	469632	11.212	0.647	8.799	11.393	12.227
roa	418667	0.112	0.213	−0.220	0.042	0.989
Lev	418790	0.575	0.287	0.029	0.583	1.539
admin	418375	0.060	0.069	0.001	0.039	0.534
export	469632	0.557	0.497	0.000	1.000	1.000
lpgdp	469632	10.278	0.567	8.346	10.37	11.230
coal	223207	0.028	0.212	0.000	0.001	13.879
pop	442289	6.057	0.576	1.596	6.135	7.088

TABLE 3 | Full sample regression results.

Variables	(1)	(2)
	w_gas	w_water
Fee	−0.2092**	−1.2978**
	(−2.39)	(−1.97)
roa	−2.1065***	−12.6835***
	(−18.59)	(−19.69)
Lev	−0.1966**	2.0711***
	(−2.12)	(3.69)
admin	−3.6420***	−8.1654***
	(−10.51)	(−3.71)
export	1.1967***	7.5602***
	(11.77)	(15.98)
lpgdp	0.4531	−2.7303
	(0.79)	(−1.46)
Constant	−3.0304	60.7645**
	(−0.50)	(2.47)
Time Effect	YES	YES
Industry Effect	YES	YES
Local Effect	YES	YES
Cluster at Firm	YES	YES
Observations	204,321	351,386
R-squared	0.125	0.105

, **, and * indicate significance at 10%, 5% and 1% level, respectively.*

TABLE 4 | Full sample regression results.

Variables	(1)	(2)	(3)	(4)
	CO_2	CO_2	CO_2	CO_2
fee	−0.0797***	−0.0244*	−0.2232***	−0.2232***
	(−6.74)	(−1.88)	(−5.20)	(−6.13)
roa		0.0332	−0.1616***	-0.1616***
		(0.82)	(−3.99)	(−3.12)
Lev		0.6576***	0.4346***	0.4346***
		(23.05)	(15.82)	(11.18)
admin		−0.8590***	−1.2152***	−1.2152***
		(−7.32)	(−11.06)	(−7.94)
export		−0.0630***	0.1014***	0.1014***
		(−2.87)	(4.87)	(3.37)
lpgdp			−1.5757***	−1.5757***
			(−8.27)	(−8.18)
Constant	5.8197***	4.8855***	24.1222***	24.1222***
	(42.87)	(32.49)	(11.77)	(11.58)
Time Fixed-effect	YES	YES	YES	YES
Industry Fixed-effect	YES	YES	YES	YES
Location Fixed-effect	NO	NO	YES	YES
Cluster at Firm	NO	NO	NO	YES
Observations	210,454	178,473	178,473	178,473
R-squared	0.191	0.204	0.268	0.268

, **, and * indicate significance at 10%, 5% and 1% level, respectively.*

TABLE 5 | mediating effect analysis.

Variables	(1)	(2)	(3)
	CO_2	Coal	CO_2
fee	−0.2232***	−0.0056***	−0.2079***
	(−6.13)	(−3.06)	(−5.74)
coal			2.2418***
			(8.28)
roa	−0.1616***	−0.0114***	−0.1405***
	(−3.12)	(−5.91)	(−2.73)
Lev	0.4346***	−0.0003	0.4374***
	(11.18)	(−0.22)	(11.37)
admin	−1.2152***	−0.0734***	−1.0639***
	(−7.94)	(−11.95)	(−6.97)
export	0.1014***	0.0270***	0.0426
	(3.37)	(6.32)	(1.45)
lpgdp	−1.5757***	−0.0335*	−1.4805***
	(−8.18)	(−1.94)	(−7.75)
Constant	24.1222***	0.4045**	22.9801***
	(11.58)	(2.16)	(11.10)
Time Fixed-effect	YES	YES	YES
Industry Fixed-effect	YES	YES	YES
Location Fixed-effect	YES	YES	YES
Cluster at Firm	YES	YES	YES
Observations	178,473	188,948	178,429
R-squared	0.268	0.095	0.283

, **, and * indicate significance at 10%, 5% and 1% level, respectively.*

4 EMPIRICAL ANALYSIS AND DISCUSSION

4.1 Panel Regression Results

The summary statistics of variables such as CO_2 emissions, pollutant discharge fees and coal consumption intensity are exhibited in **Table 2**.

Before investigating the carbon reduction effect of the pollutant discharge fee, we examined its impact on industrial pollutant discharges. The quantities of industrial waste gas and wastewater were regressed on the number of pollutant discharge fees paid and other control variables. The results are reported in **Table 3**. The results prove that this policy has a significant inhibiting effect on industrial waste gas and wastewater emissions at the level of 5%. It proves that the increase of the pollutant discharge fee can promote enterprises to optimize their energy structure independently and replace traditional fossil fuels with clean energy to reduce the emissions of polluting exhaust and wastewater. The original intention of pollutant discharge fee system is to reduce emissions of pollutant, and the results illustrate that this system is effect. This paper attempts to explore whether the pollutant discharge fee has other effects in addition to inhibiting industrial pollution. Furthermore, we hope to explore whether the pollutant discharge fee is conducive to reducing enterprise carbon emissions.

All columns in **Table 4** present basic estimated results of the models with the original data, including firm fixed effects and year fixed effects. In column (1), the coefficient value is −0.0797 which is significant and negative. This result indicates that higher pollution charges will reduce CO_2 emissions, while the effect decreases slightly as more corporate-level covariates are included in the regression. As for other control variables, we can see that rate of return, proportion of management costs, and regional per capita GDP are all important negative factors affecting CO_2 emissions at the corporate level, while financial leverage has positive effects.

TABLE 6 | Test for multiple thresholds.

Threshold	RSS	MSE	F-stat	Prob
Single	4.73e + 04	1.5107	288.58	0.0000
Double	4.71e + 04	1.5040	137.80	0.1167

4.2 Mediation Effect Result

We used the stepwise regression coefficient method to verify the negative mediating effect of coal consumption intensity for CO_2 emissions. **Table 5** indicates that when there is no mediating effect, the coefficient is apparent, which explains the direct negative effect of pollutant discharge fees on CO_2 emissions. When there is a mediator, the indirect impact of pollutant discharge fees on carbon emissions through coal consumption should also be considered. The pollutant discharge fee reduces the use of coal to the level of 1%, and coal consumption can significantly increase CO_2 emissions. The coefficient was 2.2418, which concludes that coal consumption has a partial mediating effect on CO_2 emissions.

4.3 Threshold Effect Result

According to the threshold model constructed by urban population size, the single-threshold test results are clear, while the model rejects the double-threshold hypothesis as shown in **Table 6**. So the effectiveness of pollutant discharge fees in carbon emission reduction is only applicable to the single-threshold hypothesis

TABLE 7 | Threshold effect test results.

Variables	(1)
	CO_2
Roa	0.1615**
	(2.14)
Lev	−0.0297
	(−0.53)
Admin	−0.3495
	(−1.47)
Export	−0.0525**
	(−1.99)
Lpgdp	0.6543***
	(15.65)
0b._cat#c.fee	−0.1260***
	(−3.13)
1._cat#c.fee	0.0522
	(1.41)
Constant	0.9180**
	(2.32)
Observations	31,332
R-squared	0.032
Number of firm	5,222

*, **, and *** indicate significance at 10%, 5% and 1% level, respectively.

of population size. According to **Table 7**, we found that when the population size is below the threshold value of 4.9577, the pollutant discharge fee has a significantly negative effect on CO_2 emissions. When the threshold value is 4.9577–5.8875, the coefficient changes from negative to positive, but the effect is not noticeable. It is shown that when the population does not reach the first threshold, the increase in pollutant discharge fees is significantly conducive to the reduction of carbon emissions. However, after exceeding the threshold, the increase in pollutant discharge fees will increase carbon emissions and cause certain damage to the environment. The population size of a city should be controlled within a certain range. Currently, the inhibitory effect of this policy on carbon emissions is effective. Unrestrained population expansion will not only impose a substantial burden on the environment itself but also weaken the energy saving and emission reduction effect of environmental protection policies, such as emission fee policies.

5 HETEROGENEOUS ANALYSIS

5.1 Enterprise Scale

We divided the enterprise scale into three categories (large, medium, and small) and then completed regression respective to each category to observe whether the CO_2 emission level of enterprises of different scales is affected by variables such as the pollutant discharge fee. For large-scale enterprises, the pollutant discharge fee has a significant inhibitory effect on carbon emissions at the level of 10%, and the return on assets and financial leverage of enterprises have significant positive and negative effects on carbon emissions, respectively. For medium-sized enterprises, the suppressive effect of the increase of the pollutant discharge fee on carbon emissions is significant at the 1% level, while it is not significant for small enterprises. It is necessary to strengthen the supervision of large- and medium-sized enterprises' emission payments and continue the innovation to create useful policies for small-sized enterprises. The results in **Table 8** illustrate that pollutant discharge fees are beneficial to environmental protection and effectively reduce the carbon emissions of large- and medium-sized enterprises.

TABLE 8 | Heterogeneity—enterprise scale.

Variables	(1)	(2)	(3)
	Large scale	Middle scale	Small scale
	CO_2	CO_2	CO_2
fee	−0.8704*	−1.4262***	0.0404
	(−1.85)	(−9.48)	(0.99)
roa	−2.2226***	−0.0141	0.0622
	(−2.82)	(−0.10)	(1.19)
Lev	1.0432***	0.5609***	0.4057***
	(2.94)	(5.89)	(10.30)
admin	−0.5013	−1.1205***	−1.2194***
	(−0.36)	(−3.15)	(−7.91)
export	0.1245	−0.2732***	−0.2915***
	(0.74)	(−4.98)	(−8.70)
lpgdp	−7.6053***	−3.2042***	−1.7953***
	(−4.18)	(−6.04)	(−8.82)
Constant	94.6390***	53.6197***	23.6125***
	(5.03)	(9.61)	(11.31)
Time Effect	YES	YES	YES
Industry Effect	YES	YES	YES
Local Effect	YES	YES	YES
Cluster at Firm	YES	YES	YES
Observations	4,712	36,347	137,414
R-squared	0.414	0.334	0.261

*, **, and *** indicate significance at 10%, 5% and 1% level, respectively.

TABLE 9 | Heterogeneity—Light/heavy industries.

Variables	(1)	(2)
	Light industry	Heavy industry
	CO_2	CO_2
Fee	−0.0450	−0.2606*
	(−1.03)	(−1.91)
Roa	−0.2067***	−0.1409
	(−3.76)	(−1.40)
Lev	0.4747***	0.3198***
	(11.45)	(4.83)
Admin	−1.7168***	−0.0096
	(−10.57)	(−0.04)
Export	−0.0298	0.3556***
	(−0.89)	(6.74)
Lpgdp	−2.0821***	1.0328
	(−10.35)	(1.10)
Constant	27.6884***	−1.7550
	(12.83)	(−0.18)
Time Effect	YES	YES
Industry Effect	YES	YES
Local Effect	YES	YES
Cluster at Firm	YES	YES
Observations	128,829	49,644
R-squared	0.259	0.299

*, **, and *** indicate significance at 10%, 5% and 1% level, respectively.

5.2 Light and Heavy Industries

Statistics indicate that between 2005 and 2019, the average ratio of the Chinese heavy industry's CO_2 emissions to the total CO_2 emissions was about 55%. The heavy industry is the pillar of the Chinese national economy (Xu and Lin, 2020). In the early development stages, broad economic growth spurred rapid growth in the industry, accompanied by high levels of CO_2 emissions (Zhang and Ma, 2020). Statistics demonstrate that between 2005 and 2019, China's heavy industry CO_2 emissions accounted for an average of about 55% of the country's total CO_2 emissions.

To observe the role of the pollutant discharge fee more specifically, we categorized enterprises as part of the light industry or heavy industry. Empirical test proves that the pollutant discharge fee has a significant inhibitory effect on the carbon emissions of heavy industry. For light industry, the coefficient of pollutant discharge fees is negative, but insignificant. The heavy industry does more harm to the environment than the light industry, so it is acceptable that the effect of the pollutant discharge fee on the heavy industry is greater than that of the light industry. **Table 9** demonstrates that the pollutant discharge fee can significantly reduce carbon emissions from heavy industry enterprises.

6 CONCLUSION

Based on the enterprise pollution emission data and financial data, this paper analyzes whether the increase in pollutant discharge fees can reduce industrial pollution. Furtherly, whether it can achieve the purpose of reducing carbon emissions. We established a panel model with time fixed effects and individual fixed effects. The empirical analysis shows that the increase of pollutant discharge fees is useful for companies to increase the use of clean energy, and ultimately achieve the purpose of reducing waste water and waste gas. Meanwhile, by promoting the optimization of the energy structure of enterprises, the increase in pollutant discharge fees can also reduce carbon emissions. With the addition of more corporate variables, pollutant discharge fees continue to maintain a restraining effect on carbon emissions. In addition to the direct impact, pollutant discharge fees can also indirectly reduce carbon emissions. The increase in pollutant discharge fees is conducive to promoting the improvement of green technology and improving the competitiveness of renewable energy, thereby reducing the use of fossil fuels such as coal. The reduction of coal use can reduce CO_2 emissions. Therefore, we believe that the increase in pollutant discharge fees can further reduce carbon emissions by inhibiting the use of coal (i.e., the main contributor of China's greenhouse gases). We also established a threshold model and found that when the urban population is within a certain scale, the inhibitory effect of sewage charges is more significant.

From a national perspective, China should be attentive to its environmental protection efforts while promoting economic development and weigh its speed of economic development with its status quo of environmental governance. The pollutant discharge fee system is not only a mandatory environmental law but also a driver for economic development in the Chinese market, supporting enterprises to reduce the intensity of coal use, encouraging the use of clean energy, and promoting technological innovation and environmental awareness. The Chinese government should introduce mature regulatory policies as well as improve the regulatory system to implement these policies. Simultaneously, researchers should recognize that population size has a certain impact on the effectiveness of environmental protection measures and population size should be controlled as reasonably possible to prevent it from exceeding the threshold to weaken the effect of the country's emission policy.

As mentioned for the enterprises, improving the use of clean gas can reduce CO_2 emissions and reduce harmful gas emissions to improve the environment, thereby reducing the amount of emission fees, achieving the goal of energy structure optimization in the short term, and establishing a more comprehensive carbon neutralization in the long term. While achieving economic goals, the government should continually have a global view and strengthen technological innovations to optimize enterprise energy structures. Enterprises should be environmentally conscious and bear its corresponding social responsibility, comply with the market and government forces, and enhance the competitiveness of their respective markets. Enterprises should also improve their production technology, reduce industrial pollution, reduce energy supplies using coal as fuel for product production, and increase the use of clean energies, such as natural gas, to effectively reduce carbon emissions.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

ZW: methodology, writing—review and editing, validation, resources, and data curation. LY: methodology, software, resources and visualization. MZ: data curation, supervision and investigation. YX: formal analysis, writing—review and editing, and project administration. XL: data curation, formal analysis and data curation. YW: resources, software, and visualization. ZX: conceptualization, supervision, funding acquisition and writing original draft. All authors: contributed to the article and approved the submitted version.

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