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The impact of environmental subsidy on the performance of corporate environmental responsibility: Evidence from China

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Corporate environmental responsibility (CER) has become a critical factor for measuring the competitiveness of firms in China, and environmental subsidies may be a catalyst for promoting firms' CER. This study uses data from Chinese A-share listed firms during 2010–2020. Using the instrumental variable two-stage least squares (IV-2SLS) method, we found that environmental subsidies significantly improve corporate environmental performance but have no significant impact on the disclosure and governance of pollution emissions. We find that environmental subsidies are better for chemical and energy firms with high pollution levels, provide incentives for non-state-owned firms to improve CER and that their effect in western and eastern China is better than that in the central region. We also found that corporate social responsibility plays a moderating role in environmental subsidies that affect CER. Finally, this study finds that environmental subsidies may crowd out corporate investments to improve environmental performance. Based on the above results, we provide the corresponding policy suggestions.

KEYWORDS

corporate environmental responsibility, environmental subsidies, panel data, IV-2SLS, China

1 Introduction

China's economic development model has shifted from rapid growth to high-quality growth. According to the World Development Indicators (2022), China's GDP growth rate has gradually slowed since 2010. The growth rates of total and per capita carbon emissions have also decreased (World Development Indicator, 2022). However, serious environmental pollution caused by China's rapid economic growth in the past, especially a series of "high pollution-high energy consumption-high emissions" during industrial development, has not been solved (Hanlon, 2020). Environmental issues have attracted considerable attention in recent years. In 2015, the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China incorporated the construction of

ecological civilization into the 13th Five-Year Plan. The concept of green development was considered essential to China's economic development. The Ministry of Finance of China promulgated interim measures to manage energy conservation and emission reduction subsidy funds in 2015. In 2020, the Ministry of Finance revised the Interim Measures for the Management of Energy Conservation and Emission Reduction Subsidy Funds, added a performance management mechanism for energy conservation and emission reduction subsidy funds, and monitored the performance of firms applying for subsidies. Firms should also provide performance information and openly and actively accept social supervision. The continuous implementation of these regulations shows that government environmental subsidies have established a standardized mechanism in China.

From a micro perspective, corporate environmental responsibility (CER) and positive environmental, social responsibility, and corporate governance (ESG) information disclosure can show firms' self-regulatory ability and business operations. This can help attract investment and achieve long-term development goals (Dyck et al., 2019). Firms that lack humanistic care and environmental governance are less attractive to consumers, whereas firms with better environmental performance are more competitive (Wenqi et al., 2022). However, the negative externalities of environmental pollution cause firms to lack the motivation to improve their green social responsibility. As an economic instrument, government environmental subsidies can internalize the positive externalities of firms to improve their environmental performance. These subsidies are compatible with firm incentives compared with administrative instruments and can improve firms' environmental responsibility (Shi et al., 2015). In China, CER is different from other forms of social responsibility because environmental protection is a public management function of the government and is related to government officials' performance and political promotion. Therefore, the Chinese government's CER participation is higher than in other countries (Wang et al., 2020). Compared to Western countries, Chinese firms improve environmental responsibility to obtain government support, and the government can also benefit from improving environmental responsibility (Lee et al., 2017). Environmental subsidies, taxes, and regulations are government policy tools for improving the environment. Some studies have discussed the relationship between environmental subsidies and China's CER (Lee et al., 2017; Qi et al., 2021; Wenqi et al., 2022).

This study obtains data for 2010–2020 for listed firms in China from the China Stock Market and Accounting Research (CSMAR) database and concludes similar to those in the existing literature. Based on this, we expand our empirical research. First, we introduce the two-stage least squares regression method of instrumental variables (IV-2SLS) to overcome endogeneity. Specifically, we consider a firm's industry average environmental subsidy ratio (IV). Second, we distinguish between industries and state-owned or non-state-owned firms and find that environmental subsidies significantly improve CER in manufacturing and non-state-owned firms. Third, corporate social responsibility (CSR) plays a regulatory role. The higher the level of social responsibility, the more likely it is to use environmental subsidies to improve CER performance. Finally, we discuss the mediating mechanism of research and development (R&D) input. A mediating mechanism cannot exist, but we find that environmental subsidies may crowd out private R&D inputs. After summarizing the above findings, this study provides policy suggestions.

2 Literature review

2.1 Influencing factor of corporate environmental responsibility

CER refers to corporate responsibility for sustainable development (Wang et al., 2020). CER is a corporate social responsibility (CSR) branch, but CERs gradually separate from CSR to become independent concepts (Timpere, 2008). Fulfilling environmental responsibilities requires firms to pay additional costs and reduce their profits (Ganescu and Dindire, 2014). However, firms still have incentives to increase their investment in environmental research and improve their environmental performance. In recent years, consumers' willingness to pay for green products has gradually increased, and firms have to respond promptly (DesJardins, 1998). Many factors affect firms' environmental responsibility levels. First, firms of different sizes face varying environmental responsibility constraints. Larger firms usually have higher public awareness, leading to greater public and regulatory pressure; thus, they are more inclined to disclose CER information. They also have better management organizations and a stronger ability to deal with environmental responsibility issues (Brammer and Millington, 2006).

There is scant literature on the relationship between firm age and CER. Yang, (2009) found that the longer a firm's business life, the more conducive it is to establishing a broad social network and a stable image of social responsibility, reducing information asymmetry between firms and investors. CER is also related to the corporate financial situation. Well-funded firms are willing to disclose CER-related information to attract more external investments and ensure that the firm is not undervalued (Chen and Hamilton, 2020). Specifically, some studies show a positive correlation between firms' financial leverage and CER (Dimitropoulos and Koronios, 2021). However, some studies propose the opposite view that high financial leverage will become a burden on environmental investment (Meng et al., 2016). Another critical financial indicator affecting CER is a firm's growth capacity. CER

TABLE 1 Variable description.

Variables	Variable description
Dependent Variables	
Performance	Firms' environmental performance scores calculated by PCA. See Supplementary Appendix S1 for the first principal component
Disclosure	Firms' pollution disclosure scores calculated by PCA. See Supplementary Appendix S1 for the first principal component
Emissred	Firms' pollution governance performance scores calculated by PCA. See Supplementary Appendix S1 for the first principal component
Independent Variable	
Subsidy	Environmental subsidy ratio expressed as environmental subsidy divided by operating revenue. This variable is collected, summarized, and calculated through keyword screening. To facilitate the display of regression results, we multiply the value of this variable by 100
Instrumental Variable	
IV_Subsidy	Taking the classification and code of listed companies published by the CSRC as the basis for industry division, calculate the average environmental subsidy ratio of the industry in which the firm is located
Control Variables	
ROA	Return on total assets, calculated by dividing net profit by total assets
Size	Logarithm of firms' total assets
Lev	Firms' finance leverage
Age	Firm's years of listing calculated by t minus the year the firm was listed
Gr_sales	Growth rate of operating revenue
Int	Net intangible assets divided by total assets
PE	P/E ratio, calculated by share price divided by earnings per share (EPS)

TABLE 2 Descriptive statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Performance	16370	0.3233	1.9823	−1.3216	10.3310
Disclosure	16388	0.2395	1.8757	−0.8644	9.8179
EmissRed	16388	0.3010	2.0228	−1.1910	8.2708
Subsidy	17395	0.0163	0.0609	0.0000	0.6341
IV_subsidy	17395	0.0063	0.0083	0.0000	0.2632
ROA	17395	0.0289	0.0286	−0.1142	0.2690
Size	17395	22.5745	1.0739	19.9251	27.1866
Lev	17395	1.9648	1.9769	0.2925	19.6211
Age	17395	10.2155	7.2375	0.0000	30.0000
Gr_sales	17395	0.2660	0.9482	−0.3219	15.6107
Int	17395	0.0332	0.0303	0.0000	0.2165
PE	17395	76.8824	118.6603	5.9949	1225.4510

information disclosure can show external investors the sustainable development ability and prove their profitability and development prospects to improve access to financing (Crisóstomo et al., 2019). However, some studies find a negative correlation between financial performance and CER. Corporate executives and managers are more willing to invest in projects with higher short-term returns than in CER (Farag et al., 2015). Other studies show that companies with poor financial performance may disclose more CSR information and hide their poor financial performance, resulting in a negative correlation between financial performance and CER disclosure (Li et al., 2004). Although there are some differences in the current research on the influencing factors of CERs, it can be considered that corporate characteristics have a decisive impact on CER; therefore, we select the control variables for regression analysis based on the above research.

2.2 Environment subsidy and corporate environmental responsibility

Subsidies are an effective way to solve externalities (Fogarty and Sagerer, 2016). Existing literature focuses on government subsidies, whereas there are few documents on the economic benefits of environmental subsidies. Environmental subsidies encourage firms to adopt clean technologies, implement energy conservation and emission reduction strategies, and innovate green technologies (Bai et al., 2018). As a policy tool opposed to environmental taxes, although environmental subsidies are less effective than environmental taxes in the short term, they can internalize the external economy in the long run (Li et al., 2004). The government can provide financial resources to ease financing constraints through environmental subsidies, and sufficient funds are invested in CER (Wu, 2019). Whether environmental subsidies or taxes are compatible with incentives, firms may still have room to allocate resources reasonably under the existing subsidies and tax frameworks. In administrative terms, the interests of governments and firms may be inconsistent, and firms' actions may not

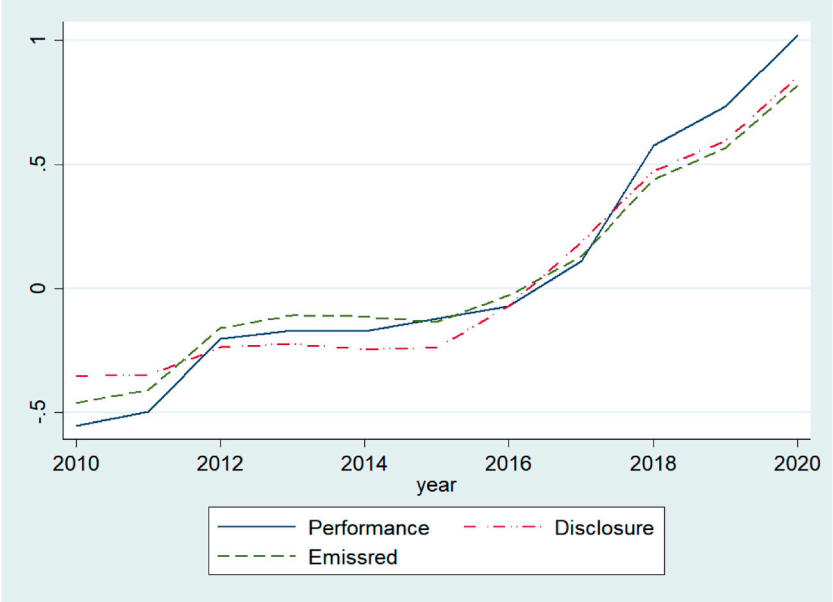

FIGURE 1
Time trend of the dependent variables.

maximize social welfare (Shi et al., 2015). In addition, government environmental subsidies can signal to the market that subsidized firms have been recognized by the government, conducive for firms to compete for resources to improve their CERs (Wei and Zuo, 2018).

Zhang et al. (2014) studied the role of subsidies in China's renewable energy industry and found that government subsidies have increased the overall performance of renewable energy companies. However, the relationship between business executives and the government may weaken the role of subsidies. Therefore, we believe that environmental subsidies positively affect CER. However, some studies have proposed the opposite view, that subsidies are not conducive to improving CER performance. After receiving subsidies, firms may increase their dependence on subsidies and lack the motivation to actively use idle resources to improve CERs (Jia et al., 2021). Rent-seeking may also lead firms to reallocate resources to seek government support, negatively impacting environmental performance (Nilsson, 2017). To ensure future subsidies, firms prioritize R&D research projects that can produce results, leading to improper resource allocation and neglecting clean technologies conducive to improving CER performance (Hall and Harhoff, 2012). The above literature indicates that the relationship between environmental subsidies and CER performance may be more complex. Given China's industrial transformation and upgradation, it is necessary to examine the heterogeneity of environmental subsidies in different industries and property rights. In addition, it is crucial to investigate the theoretical path through which environmental subsidies affect the CER. Therefore, we also check for a mediating effect between environmental subsidies and private R&D investments.

3 Data models and variables

Sample data were obtained from the CSMAR database. Finally, this study determines the sample range of Chinese A-share listed firms during 2010–2020. All nominal variables in this study were reduced to 2010 as the base period. In addition, we winsorized all the variables at the 1% level to reduce the impact of extreme values. Referring to the model settings discussed (Ren et al., 2021; Wang et al., 2021), we used the following measurement model in the regression analysis:

$$Performance_{i,t} = \beta_0 + \beta_1 Subsidy_{i,t} + \delta^T \sum X_{it} + \mu_j + \epsilon_k + \theta_t + \varepsilon_{i,t} \quad (1)$$

$$Disclosure_{i,t} = \beta_0 + \beta_1 Subsidy_{i,t} + \delta^T \sum X_{it} + \mu_j + \epsilon_k + \theta_t + \varepsilon_{i,t} \quad (2)$$

$$EmissRed_{i,t} = \beta_0 + \beta_1 Subsidy_{i,t} + \delta^T \sum X_{it} + \mu_j + \epsilon_k + \theta_t + \varepsilon_{i,t} \quad (3)$$

$Performance_{i,t}$, $Disclosure_{i,t}$, and $EmissRed_{i,t}$ represent the annual environmental performance, emission disclosure, and emission governance scores of firms, respectively, and are

TABLE 3 Results of IV-2SLS regression

	(1)	(2)	(3)	(4)	(5)	(6)
IV-2SLS: Stage I						
Dependent Variable: Subsidy						
IV_subsidy	2.0931*** (12.63)	2.0976*** (12.65)	2.0976*** (12.65)	2.1830*** (12.63)	2.1866*** (12.66)	2.1866*** (12.66)
F Value	159.59	160.12	160.12	159.53	160.20	160.20
IV-2SLS: Stage II	Performance	Disclosure	EmissRed	ΔPerformance	ΔDisclosure	ΔEmissRed
Subsidy	3.7018***	0.2055	1.1354	1.1807	0.9647*	1.0999*
	(3.21)	(0.31)	(1.37)	(1.43)	(1.75)	(1.65)
ROA	1.9739***	3.0281***	3.7787***	1.1521***	1.4140***	0.8609*
	(3.64)	(5.63)	(6.34)	(2.60)	(3.40)	(1.75)
Size	0.6384***	0.4882***	0.5794***	0.0521***	0.0361**	0.0344**
	(38.46)	(27.86)	(33.42)	(3.60)	(2.46)	(2.21)
Lev	0.0448***	0.0591***	0.0638***	0.0089	0.0127*	0.0126*
	(5.42)	(6.69)	(7.01)	(1.37)	(1.87)	(1.71)
Age	0.0090***	0.0011	0.0011	−0.0047**	−0.0042**	−0.0048**
	(3.61)	(0.46)	(0.42)	(-2.40)	(−2.12)	(-2.30)
Gr_sales	−0.0767***	−0.0593***	−0.0784***	0.0081	0.0033	0.0081
	(−5.58)	(−4.75)	(−5.35)	(0.66)	(0.35)	(0.62)
Int	4.1888***	4.0338***	2.9950***	0.5778	0.4252	−0.0680
	(8.60)	(8.64)	(6.28)	(1.42)	(1.12)	(−0.17)
PE	−0.0008***	−0.0003**	−0.0006***	-0.0000	0.0000	−0.0001
	(−7.08)	(-2.51)	(-5.57)	(-0.06)	(0.28)	(−0.78)
Province FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
F Value	89.89	58.25	74.57	6.06	4.10	3.56
N	16370	16388	16388	15401	15428	15428

t-statistics are in parentheses. Significance levels are presented as follows: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

calculated using principal component analysis (PCA). The three CER dimensions provided by CSMAR were used to construct the three dependent variables. Most literature only discusses environmental performance, while few studies discuss the other two dimensions. Therefore, we focus on environmental performance and the other two dimensions as contrasts. Referring to Qiu and Yin (2019) and Chen et al. (2022), we use the corporate environmental performance rules provided by the CSMAR database to construct the first principal component of these three variables. $Subsidy_{i,t}$ represents government environmental subsidies divided by operating revenue. X_{it} represents control variables. The environmental subsidy policy and the performance of CER varies greatly in industry and region; therefore, we control for the fixed effect of the industry and region in the model, represented by $\mu_j$and ϵ_k. The industry is subject to the Classification and Code of Listed Companies published by the China Securities Regulatory Commission (CSRC), and the region is subject to the province to which the firm belongs. We also controlled for the time-fixed effect θ_t, which enables the model to consider the impact of policies such as the Environmental Protection Tax Law on the entire industry. $\varepsilon_{i,t}$ represents random error items. Table 1 lists the variables introduced in the regression analysis and their detailed descriptions.

The environmental protection decisions of listed firms may reflect and affect the trend of environmental protection and impact government policies. Both backward causality and sample selection biases exist. An effective treatment method is the use of IV to overcome the endogeneity problem. Therefore, the IV-2SLS method was used in these regression analyses. IV is the average of $Subsidy_{i,t}$ by industry, represented as $IV\_Subsidy_{i,t}$. As environmental subsidies vary greatly according to the degree of pollution emissions in the industry, the environmental subsidies received by firms are largely related to the industry to which they belong, thus meeting the relevance of IV. To meet the exogenous nature

TABLE 4 Sub-sample regression

Panel A: Distinguishing between state-owned and non-state-owned firms.

	Non-State-owned			State-owned		
	Performance	**Disclosure**	**EmissRed**	**Performance**	**Disclosure**	**EmissRed**
Subsidy	3.5957***	2.6008***	3.1657***	3.5542*	-2.3224**	-0.7722
	(2.89)	(2.68)	(2.65)	(1.77)	(-1.96)	(-0.59)
Province FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
F Value	37.79	24.20	34.34	58.40	38.80	48.25
N	8213	8226	8226	8157	8162	8162

Panel B: Distinguishing industries (dependent variable: Performance).

	Agriculture and Service Industry	Chemical and Energy Industries	Metals and Mining Industries	Electronics and machinery manufacturing	Food and commodity industry	Others
Subsidy	2.9653*	7.9374*	3.9931	−2.56134**	6.7642	4.7737
	(1.88)	(1.95)	(1.38)	(−2.23)	(1.37)	(1.00)
Province FE	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
F Value	39.65	29.84	31.22	31.45	17.78	7.42
N	3059	4214	1639	4937	1927	594

Panel C: Distinguishing regions (dependent variable: Performance).

	Eastern Region	Central Region	Western Region
Subsidy	3.4997***	1.1715	6.8308**
	(2.69)	(0.43)	(2.38)
Province FE	Y	Y	Y
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
F Value	83.68	32.88	30.50
N	11224	3102	2044

t-statistics are in parentheses; significance levels are presented as follows: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

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TABLE 5 Moderating effect (dependent variable: Performance)

	(1)	(2)	(3)
Subsidy	4.1473***	5.2250***	5.7080***
	(2.83)	(4.12)	(3.66)
Subsidy×S	2.1315***		2.2739***
	(3.86)		(3.45)
S	0.2724***		0.2647***
	(23.35)		(20.40)
Subsidy×G		−0.3322	−0.7827
		(−0.48)	(−1.17)
G		0.0560***	0.0039
		(3.71)	(0.28)
Control	Y	Y	Y
Province FE	Y	Y	Y
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
F Value	75.33	134.20	109.83
N	14413	16203	14259

t-statistics are in parentheses; significance levels are presented as follows: ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

TABLE 6 Mechanism analysis.

	(1)	(2)	(3)
	RDInput	**Performance**	**Performance**
Subsidy	−2.6856***	5.4741***	5.6559***
	(−3.02)	(3.62)	(3.76)
RDInput			0.0677***
			(4.51)
Control Variable	Y	Y	Y
Province FE	Y	Y	Y
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
F Value	131.05	77.51	76.59
N	13309	13309	13309

t statistics in parentheses; significance levels are presented as follows: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

of the IV, the environmental subsidies received by firms are not directly related to other firms in the industry. Table 2 presents descriptive statistics of the study variables. The sample firms' CER performance and environmental subsidies are relatively heterogeneous. In Figure 1, we plot the time trend of these three dependent variables, which shows that the CER level of our sample is on the rise and the growth rate has increased significantly since 2015, which may be related to the inclusion of ecological construction in China's 13th Five-Year Plan.

4 Empirical result

4.1 Basic empirical results

Table 3 shows the regression results for the IV-2SLS. Columns 1–3 show the regression results for the dependent variables of environmental performance, emission disclosure, and governance. The dependent variables in Columns 4–6 represent the first-order differences between the above three variables. According to the regression results of the first-stage IV regression in Table 3, the coefficients of *IV_Subsidy* are significantly positive, consistent with expectations, indicating that the environmental subsidy is positively correlated with the average level of the industry. The F value in the first stage was at least 159.53, and the corresponding *p*-value was not more than 1%, indicating that the IV was statistically effective. The results of Stage II show that *Subsidy* only significantly and positively affects corporate environmental performance. However, the regression coefficient of the first-order difference in emission disclosure and governance (i.e., Columns 5 and 6) is significantly positive. In the control variables, the coefficient symbol and significance of the *ROA*, *Size* and *Int* meet the expectations. The coefficient of *Lev* is significantly positive except in Column 4. Under the IV-2SLS method, it can be considered that increasing the environmental subsidy ratio positively affects CER. Our conclusions are close to those in the existing literature (Wenqi et al., 2022), but this study distinguishes between the different aspects of CER. Environmental subsidies are more inclined to improve the disclosure of environment-related concepts and systems and have less impact on pollution emissions and governance. We conduct an in-depth analysis in the following sections.

4.2 Heterogeneity analysis

This study conducted a subsample regression considering the large heterogeneity of firms in the sample. We adopt two classification bases to distinguish between industries and property rights: state-owned and non-state-owned. In Panel A, we regress according to the sample of state-owned and non-state-owned firms, and the classification is based on the list of state-owned listed firms provided by CSMAR. Although the CER level of Chinese firms is significantly higher than that of non-state-owned firms, the regression results show that environmental subsidies have a stronger incentive to improve the CER of non-state-owned firms, consistent with Lee et al. (2017). For state-owned firms, the coefficient of Subsidy is less significant. When disclosure is the dependent variable, the coefficient is significantly negative. Owing to the natural political ties from state-owned equity, state-owned firms can obtain more long-term debt financing and policy preferences. Non-state-owned firms are more likely to cater to policies and adopt

corresponding political strategies (Zhang and Zhang, 2005). Therefore, non-state-owned firms are more likely to use government subsidies to improve CER performance. Panel B in Table 4 presents the regression results for distinguishing industries according to the classifications and codes of listed companies. Notably, the regression coefficients of the different subsamples are not comparable due to different samples. However, environmental subsidies had a higher regression coefficient for chemical and energy industries, agriculture, and services. In contrast, the regression coefficients of firms in the food and commodity industries, metals, and mining industries were not significant. The coefficient of the electronics and machinery manufacturing industry is significantly negative. Therefore, we believe that because firms in the chemical and energy industries have relatively higher pollution levels and greater environmental governance pressure, environmental subsidies incentivize such firms to improve their CER. Finally, in Panel C, we conduct a subsample regression according to the regional division criteria of Eastern, Central, and Western China provided by the National Development and Reform Commission. The results indicate that environmental subsidies play a more significant role in the eastern region. They effectively improve the environmental performance of enterprises in Western China, but the effect of environmental subsidies in Central China is not significant.

4.3 The moderating role of social responsibility and corporate governance

CSR may be related to entrepreneurship, and responsible entrepreneurs are more willing to actively implement technological innovation, achieve green development, and fulfill social and environmental responsibilities (Chen et al., 2021). Some studies illustrate the relationship between corporate governance structures and CSR or the sustainability of firm development (Aras and Crowther, 2009; Wang, 2016). Referring to Qiu and Yin (2019), this study calculates firms' social responsibility and corporate governance scores using the CSMAR database and PCA, which are represented as S and G respectively. In the regression, we regard $Subsidy$ and the interaction of $Subsidy$ and S or G as endogenous variables according to the IV variable selection method of interaction provided by Rajan and Zingales (1998), whereas $IV\_Subsidy$ and the interaction of $IV\_Subsidy$ and S or G are regarded as IV. Column 1 of Table 3 shows that the regression coefficient of CSR on CER is significantly positive and that of social responsibility and environmental subsidies is also significantly positive. Therefore, CSR can be considered to have a moderating effect in Model one; the higher the level of social responsibility, the more it can use environmental subsidies. Column 2 of Table 5 shows that the interaction between G and $Subsidy$ is not significant. Therefore, even if the corporate governance factor can improve the CER (because the coefficient of G in Column 2 is significantly positive), we cannot infer that corporate governance factors have a moderating effect. In Column 3, all variables are entered into the regression equation, and the conclusion remains the same.

4.4 Mechanism analysis

As environmental R&D investment can improve CER performance, we speculate a mediating mechanism between environmental subsidies and environmental R&D investment. After collecting the R&D input data of each firm and taking logarithmic processing after flattening in 2010, this study determines the mediating mechanism of R&D investment through a step-by-step regression method. Based on the regression results in Table 6, we find that the regression coefficient of environmental subsidies for R&D inputs in Column 1 is significantly negative, the coefficients of R&D inputs and environmental subsidies in Column 3 are significantly positive, and the coefficients of Subsidy in Column 3 are larger than those in Column 2. As the direct effect (i.e., the coefficient of $Subsidy$ in Column 3) is the opposite of the indirect effect (the coefficient of $Subsidy$ in Column 1 multiplied by the coefficient of $RDInput$ in Column 3), no mediating effect of R&D investment is found at this time, but a suppressing effect (MacKinnon et al., 2002). Environmental subsidies crowd out firms' R&D spending, which may be related to shortsighted management decisions caused by shareholder debt constraints (Wu et al., 2022).

5 Conclusion and discussion

China is in a transition period of industrial structure optimization and upgradation, and improving the performance of CER is a challenge for Chinese firms in the transformation process. To reasonably guide firms to optimize resource allocation and use idle resources, a series of economic means, represented by environmental subsidies and taxes, have entered the public view and play an important role. Based on the background of the gradual improvement of China's environmental subsidy system and the rising social influence of the CER concept, this study collected samples of listed firms in China from 2010 to 2020 using the CSMAR database. Through IV-2SLS regression, this study examines whether environmental subsidies have a significant positive effect on CER. We found that significantly increasing environmental subsidies has indeed improved the performance of firms in CERs, but it has no significant impact on pollution emissions and controls. In the analysis, we distinguish between industries and property rights. Environmental subsidies can play a critical role in the more seriously polluting chemical and energy industries and

non-state-owned firms with greater survival pressure. The effect of environmental subsidies in western and eastern China is significant but not in the central region. We also find that a firm's sense of social responsibility can play a moderating role in the path of environmental subsidies to improve CER performance. Finally, through mechanism analysis, we find a crowding-out effect between environmental subsidies and private R&D investment.

The empirical results can provide policy guidance. When formulating an environmental subsidy mechanism, the government must follow the principle of adapting to local conditions. Simultaneously, policymakers can further strengthen the supervision of corporate behavior by the public and media to play a coupling effect with environmental policies and promote firms to improve environmental performance. Finally, the government should actively promote the diversification of environmental subsidy mechanisms to ensure that subsidies and environmental R&D investments have complementary effects. The limitations of this study are as follows. Due to the lack of data related to environmental subsidies and environmental performance, more sample sizes have been lost, so there will be certain errors in estimating the effect of environmental subsidies on Chinese listed firms. However, there is still room for improvement in this study's calculation method for the CER performance. However, there are few indicators related to the environmental behavior of Chinese firms in the existing database, and there is no agreement on the estimation of CER performance in empirical studies. With the deepening of the concept of CER and the improvement of the relevant database, the measurement dimensions of CER will be further expanded.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

GC conceived and designed the research method; RZ conceived and designed the research method with GC and provided financial support; BW analyzed the data, wrote, and finalized the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that this research was conducted without any commercial or financial relationships construed as potential conflicts of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.972328/full#supplementary-material

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