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The effect of economic incentives on corporate environmental investment: Evidence from Chinese manufacturing listed firms

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Abstract

Different from most studies that analyze command-and-control policies, our paper quantitatively evaluates the effectiveness of one type of economic incentive – environmental subsidies for stimulating corporate environmental investment. Using a representative sample of Chinese manufacturing listed firms, we find that environmental subsidies provided by the government significantly increase corporate environmental investment. The effect of environmental subsidies is also higher for smaller firms and private firms. Moreover, we also find that environmental subsidies have a significant and positive effect on both cleaner production and end-of-pipe investment, with the effect on cleaner production being greater. Further exploration reveals that government subsidies are a signal of endorsement that contributes to increments in firms' innovation and financial capacity, which encourages an increase in corporate environmental investment.

Keywords: Economic incentives; Environmental subsidies; Corporate environmental investment

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1 Introduction

Since the late 1970s, China has experienced rapid economic growth. During that time, pollution has been a major concern. China ranked 120th in the 2018 Environmental Performance Index jointly published by the Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network. In response, during the past decade, various governmental interventions were implemented, and the central government included pollution control in their governing goals.[1] The current paper aims to empirically evaluate these interventions.

According to the Porter hypothesis (Porter and Linde, 1995), environmental spending could generate large amounts of positive externalities (spillover effects) since it can increase productivity and innovation in the long run. It may serve to offset the negative externalities of pollution (Chen and Ma, 2021). Therefore, local governments should encourage corporate environmental investment. A wide array of pollution control policies are considered effective solutions, including command-and-control, persuasiveness-and-encouragement, and economic incentives (Chang et al., 2021; Bai and Chen, 2022). Among them, economic incentives (e.g., tax incentives, government subsidies, and various regimes of tradable permits) are currently being implemented in different regions and settings around the globe. Different from most scholars exploring the effect of tax incentives or environmental regulations on corporate environmental investment (e.g., Zhang et al., 2020; Sun et al., 2021), we investigate the effect of environmental subsidies on corporate environmental investment, especially in the context of a large emerging market.

Theoretically, the net effect of environmental subsidies on corporate environmental investment is ambiguous. It depends on subsidies' additionality and crowding-out effect. The former indicates that environmental subsidies increase the funds available to firms to combat pollution and increase corporate environmental investment. First, environmental subsidies are required to be used only for environmental protection (Khan et al., 2013). Therefore, environmental subsidies can be directly used as environmental investments. Second, government environmental subsidies can solve market failure. Corporate environmental investment has positive externalities such that private investments tend to be insufficient. Finally, firms that receive environmental subsidies have more cash, which helps them increase

[1] For example, in the 13th Five Year Plan, the Ministry of Ecology and Environment of People's Republic of China lays down the strategy and pathway for 2016–2020, setting peak targets for major pollutant emissions.

their environmental investments, such as increasing green technology R&D (Huang et al., 2019) and purchasing more pollution control equipment.

However, environmental subsidies may crowd out corporate environmental investment. Even when governments allocate public resources to projects that would not have been possible without public support, eligible companies may simply use available public financial resources to squeeze out investments they initially plan to make, thereby undermining the argument that public assistance has an “additional” effect (Marino et al., 2016). For example, government R&D subsidies could support private R&D projects that would have been undertaken even without subsidies and crowd out private R&D investment (Zuniga-Vicente et al., 2014; Choi and Lee, 2017).

Using a panel data sample of Chinese manufacturing listed firms from 2008 to 2020, our study investigates the causal effect of environmental subsidies on corporate environmental investment. The empirical results reveal that environmental subsidies provided by the government significantly increase corporate environmental investment. Moreover, this effect is also higher for smaller firms and private firms compared to their respective counterparts. We find that the positive impact of environmental subsidies on cleaner production investment is greater than that on end-of-pipe investment. We further document two mechanisms. They are innovation and financial capacity. Environmental subsidies increase corporate environmental investment by promoting corporate green innovation (e.g., increased innovation investments and number of patents relating to Environmentally Sound Technologies) as well as increasing financial capacity (e.g., improved credit capacity and reduced corporate financial constraints).

A similar work to ours is Garcia-Quevedo et al. (2022), who find that subsidies are a key determinant of investment in cleaner production and end-of-pipe technologies. The current study complements theirs from several perspectives. First, Garcia-Quevedo et al. (2022) focus on comparing the drivers of cleaner production technology and end-of-pipe technology. Different from theirs, our paper focuses on one type of economic incentive—the environmental subsidy—and quantitatively evaluates the effect on corporate environmental investment. Second, Garcia-Quevedo et al. (2022) do not discuss the mechanism behind their results. In contrast, the current study not only documents the causal relationship between the two but also investigates the mechanism behind it. We find that environmental subsidies increase corporate environmental investment by promoting green innovation activities and improving firms’ financial capacity. Third, the measurements of corporate environmental investment in these two studies are different and thus complement each other. Garcia-Quevedo et al. (2022) adopt investment in cleaner production or end-of-pipe technology to measure green innovation investments. In contrast, we subtract the environmental subsidies received from corporate environmental investment to avoid the tautology effect. This could help us better capture the role of environmental subsidies in promoting corporate environmental investment.

Our paper contributes to the large body of literature that investigates corporate environmental investment. According to the Porter hypothesis mentioned above, investing in environmental protection can positively affect firm productivity (Shadbegian and Gray, 2005) and innovation (Dang et al., 2019). Moreover, corporate environmental investment also attracts foreign investment in the U.S. (Keller and Levinson, 2002) and China (Di, 2007). Additionally, some scholars investigate its determinants. Financial constraints are an important factor that affect corporate environmental investment (Zhang et al., 2019). Environmental regulations, such as the Clean Air Act Amendments of 1990 in the U.S. (Becker, 2005) and pollution regulations in China (Ji et al., 2017) substantially affect corporate environmental investment. Recent papers further identify several potential determinants, including stake-holder factors, managerial strategy, and international factors (Shabbir and Yaqoob, 2019; Daddi et al., 2019). The current paper not only provides empirical evidence that treats the economic incentive as one additional key determinant of corporate environmental investment. However, it also complements theoretical works that analyze the impact of subsidies on corporate environmental investment (Renström et al., 2021).

Our paper also devotes to the literature that discusses the impacts of various environmental control policies. Tax incentives, environmental regulations, and subsidies are three commonly utilized tools by the government (Qia et al., 2022; Fan et al., 2021; Greenstone and Hanna, 2014; Chen et al., 2017; Varela-Candamio et al., 2018). These tools are specifically designed to create motivations for environmental protection and generate a substantial impact. Subsidies are a vital economic incentive and rank high among instruments frequently applied in environmental policymaking. The current study adds evidence to this area that evaluates the effectiveness of subsidies (Arguedas and Soest, 2009; Zúñiga-Vicente et al., 2014; Bronzini and Piselli, 2016; Costa-Campi et al., 2017; Chen et al., 2017; Mateut, 2018). Respectively, they serve as incentives for more R&D, investment, and environmentally friendly actions. To our knowledge, the current paper highlights the minimal studies that empirically evaluate the government economic incentive on corporate environmental investment in the context of a large emerging market and demonstrate two unique mechanisms.

The rest of the paper is organized as follows. Section 2 presents the institutional background and descriptive evidence on environmental subsidies. Section 3 presents the statistical description of the data and our empirical strategy. Section 4 displays the estimation results. Section 5 provides robustness checks and discusses mechanisms. Section 6 concludes the paper.

2 Institutional background

Environmental subsidies are offered as a certain amount of financial support to qualified firms. They are widely used in China to encourage firms to reduce emissions, implement energy conservation strategies, and innovate green technologies (Xu et al., 2021).

The Chinese government has established a series of policies regarding the management of environmental subsidies during the past several decades. In 1984, the State Council implemented regulations that local governments must use at least 80% of the emission fees paid by enterprises to fund subsidies to support enterprises in environmental protection activities. The rest is to be held by local Ecology and Environment Bureaus for other environmental protection purposes. This is to make sure that funds for environmental protection are not allowed to be diverted to other unrelated purposes. Management of the funds' use was further enhanced in 1990.[2]

The central government and local governments are jointly responsible for granting environmental subsidies. Applications submitted by firms are subsequently approved by the provincial government and the central government. The Ministry of Finance is responsible for budget and fund management, while the Ministry of Ecology and Environment is mainly responsible for the supervision and management of emission reduction projects. Subsidized projects are generally expected to be completed within 12 months of approval.

Environmental subsidies became increasingly popular between 2006 and 2020. During the 11th Five-Year Plan period (2006-2010), China further increased its concern about environmental protection. In 2007, the Ministry of Ecology and Environment and the Ministry of Finance jointly issued the Interim Measures for the Management of Special Funds for Emission Reduction of Major Pollutants, which allowed Chinese provincial governments to

[2] http://policy.mofcom.gov.cn/claw/clawContent.shtml?id=37807, accessed on December 18, 2022.

develop local environmental subsidy policies and establish a national fund for emission reduction of key pollutants. During the 12th Five-Year Plan period (2011-2015), the government was committed to strengthening environmental protection and increasing the budget for environmental protection, which led to an increase in environmental subsidies. In 2017, the State Council issued a notice on the comprehensive work plan for energy conservation and emission reduction in the 13th Five-Year Plan (2016-2020). This document emphasizes the need to improve financial and tax incentive policies, increase financial support for emission reduction efforts and reward firms that have done a better job of it.

Unfortunately, we are unable to provide prefectural/provincial-level data on environmental subsidies because the government does not disclose them. Instead, following the relevant literature (e.g., Xu et al., 2021), we focus on firm-level data on environmental subsidies. Specifically, the dataset investigated in the study records how much environmental subsidies the listed firm received each year. Table 1 presents descriptive statistics of firm-level environmental subsidies in our sample. Furthermore, in Table 2, we aggregate firm-level subsidies by province and present the average number by region across the sample period. The five provinces that received the most environmental subsidies were Hebei, Inner Mongolia, Jiangxi, Guangxi, and Anhui Provinces. The five provinces that received the lowest environmental subsidies were Hainan, Jiangsu, Heilongjiang, Guizhou, and Zhejiang Provinces. We further divide the provinces into three regions, East, Middle and West, and show the average environmental subsidy by region in Figure 1. In addition, we find that the middle region has the highest average environmental subsidy. This may be because most cities are resource-based cities with high industrial pollution emissions and more severe environmental conditions, which leads to higher subsidies in the middle region. Finally, we present the annual average level of environmental subsidies in Figure 2. During the 12th Five-Year Plan period (2011-2015), the annual average environmental subsidy has a growth rate of 8.7%. However, due to the slowdown of the economy and the COVID-19 shock, the annual level of environmental subsidies during the 13th Five-Year Plan period (2016-2020) was reduced by 34% compared to the last period.

Table 1 Descriptive statistics of environmental subsidies

Variable	Obs.	Mean	S.D.	Min	Max
Environmental subsidy	20,741	1,726,762	5,307,350	0	2,147,315,456

Monetary values are in RMB.

Table 2 Mean of environmental subsidies by province

Province	Environmental subsidies	Province	Environmental subsidies
Hebei	6,224,811	Sichuan	1,779,877
Inner Mongolia	5,991,081	Gansu	1,627,575
Jiangxi	5,439,759	Tianjin	1,320,653
Guangxi	4,735,264	Shandong	1,297,344
Anhui	4,050,644	Shanghai	1,178,710
Hunan	3,001,141	Ningxia	1,159,758
Xinjiang	2,990,738	Chongqing	960,724
Jilin	2,891,742	Fujian	598,394
Liaoning	2,611,867	Shaanxi	507,983
Henan	2,594,757	Tibet	417,964
Hubei	2,543,582	Zhejiang	316,547
Beijing	2,142,303	Guizhou	312,876
Guangdong	2,132,568	Heilongjiang	267,858
Yunnan	2,109,100	Jiangsu	251,216
Qinghai	1,952,847	Hainan	174,625
Shanxi	1,794,954		

Monetary values are in RMB.

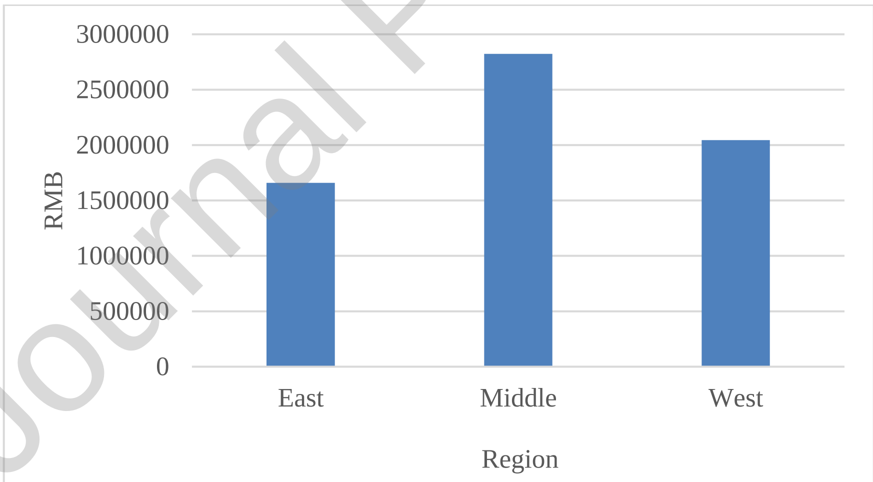

Figure 1 Mean of environmental subsidies by region[3]

[3] The eastern region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan and Liaoning provinces. The middle region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan, Jilin and Heilongjiang provinces. The west region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Ningxia, Xinjiang and Qinghai provinces.

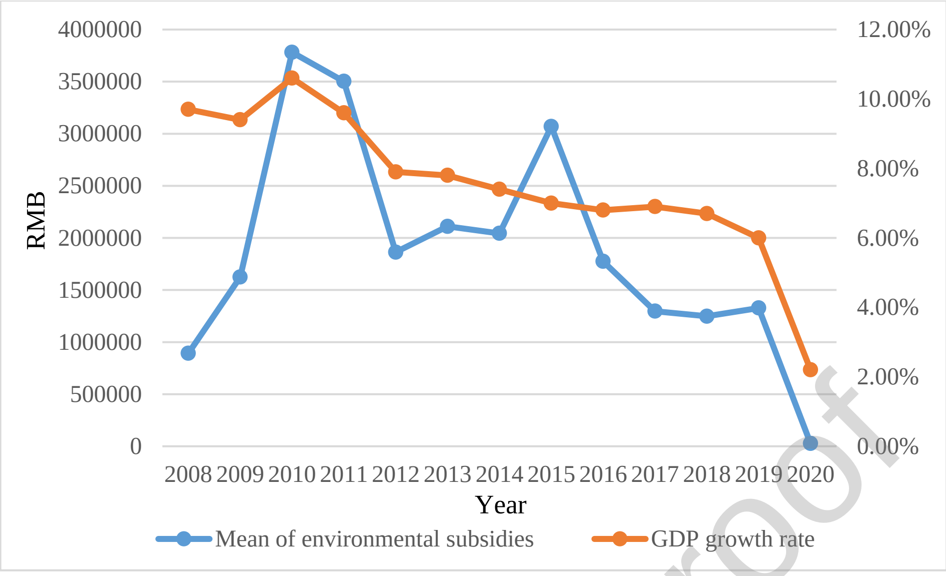

Figure 2 Mean of environmental subsidies by year

3 Data and empirical strategy

3.1 Data

The main empirical sample is drawn from the CSMAR database. This dataset includes information on all listed manufacturing firms in China between 2008 and 2020. It is a nationwide representative sample of all manufacturing firms. Our sample is quite large, with 20742 observations.

Before proceeding, the following observations are dropped from the main sample. (1) We exclude firms without accurate information on ownership. (2) We exclude firms that have missing variables used in our estimation or invalid values (such as reporting zero employees). (3) All continuous variables estimated are winsorized at the top and bottom 1% levels to reduce the impact of outliers.

3.2 Empirical strategy

3.2.1 Dependent variable

Corporate environmental investment is the dependent variable in this study.[4] It refers to a company's effort to reduce its environmental impact (Wang et al., 2022; Zhu et al., 2022).

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[4] The connotation of corporate environmental investment is consistent with firm investment in pollution abatement, which all refers to a company's effort to reduce its environmental impact, includes invest in both end-of-pipe and cleaner production technologies. However, the names of the two are different in the Chinese Private Enterprise Survey and Chinese listed companies, which will not be interfered with the object of this paper. It is modified as "corporate environmental investment", which is more appropriate with previous studies (Wang et al., 2022; Zhu et al., 2022).

Therefore, corporate environmental investment in our article includes not only end-of-pipe but also cleaner production technologies (Wei et al., 2017). Furthermore, to avoid the tautology of environmental subsidies on corporate environmental investment, we subtract the amount of environmental subsidies received from investment to construct the dependent variable (Marino et al., 2016).

3.2.2 Interested explanatory variable

In the current analysis, we attempt to explore the effect of one type of economic incentive—environmental subsidies—on corporate environmental investment. Environmental subsidies are offered as a certain amount of financial support to qualified firms. They are widely used by different levels of government in China to encourage firms to reduce emissions, implement energy conservation strategies, and innovate green technologies (Xu et al., 2021). Firms receive different subsidies from the government, and we define an environmental subsidy based on the key words of its description. [5] Finally, we aggregate all environmental subsidies a firm receives in one year.

The benchmark estimation function is formulated as follows:

$$Investment_{it} = \beta_0 + \beta_1 Subsidy_{it} + \gamma X_{it} + \zeta_i + \eta_t + \vartheta_j + \varepsilon_{it} \qquad (1)$$

where *i* is firm, *t* is year and *j* is ownership status. $Subsidy_{it}$ denotes the natural logarithm of the number of environmental subsidies firm *i* receives in year *t*. The parameter of interest is β_1, which captures the effect of environmental subsidies on corporate environmental investment. X_{it} is a series of control variables that influence corporate environmental investment, and their details are given below. ζ_i, η_t and ϑ_j represent firm, year and ownership fixed effects, respectively, to control for the unobserved heterogeneous effects across different firms, years and ownership statuses. ε_{it} represents the error term clustered at the firm level.

3.2.3 Control variables

We include several determinants of corporate environmental investment that are routinely examined in the literature (e.g., Murovec et al., 2012; Costa-Campi et al., 2017): (1) firm size

[5] We select a series of key words that indicate the relation to environmental subsidies. They include: energy saving and emission reduction, environmental governance, pollution prevention and control, maintenance expenses, sewage charges, pollutant discharge fees, green fees, green technology innovation, environmental recovery and treatment margin, environmental protection equipment purchasing, environmental regulation input, ecological construction, ecological engineering, ecological management, clean production, comprehensive utilization, environmental protection, comprehensive pollution improvement, technological transformation, circular economy, etc.

(Size). Firm size is represented using the natural logarithm of the number of employees. (2) firm age (Age), which is equal to the survey year minus the registered year. (3) firm leverage (Lev), which is measured using the ratio of total debt to total assets. (4) cash holding (Cash), which is represented using the ratio of cash and cash equivalents balance to total assets. (5) return on assets (ROA), which is equal to the ratio of earnings before interest and tax to total assets.

Two firm owners' characteristics are also included in our regression: (1) the CEO's age (CEO_age), measured using the natural logarithm of the CEO's age. (2) the CEO's educational attainment (CEO_edu). This ranges from 1 to 3.[6]

3.2.4 Potential mechanisms

In this section, we present several variables that are potential mechanisms: (1) R&D investment (LnRD), which is the natural logarithm of the firm's investment in R&D plus one (Xu et al., 2021). (2) Green innovation ability (Lnpatent), which is the natural logarithm of the number of firms' green innovations plus one (Xu et al., 2021). (3) Financial capacity (Lnloan), the natural logarithm of the sum of short loans and long loans the firm receives plus one (Liu et al., 2019). (4) Financial constraints (SA). Following Hadlock and Pierce (2010), we use the SA index to proxy for corporate financial constraints.

3.2.5 Descriptive statistics

Table 1 exhibits the descriptive statistics of our sample. The average level of corporate environmental investment in our sample is 33 million RMB.[7] The average subsidy the firm receives is 1.73 million RMB. Approximately 73.7% of firms receive no subsidy.[8]

With regard to firms' characteristics, the average number of employees is 2521, and the average age of firms in our sample is 16 years. The survey also provides several variables about

[6] 1 indicates that the CEO's educational attainment is a bachelor's degree or below; 2 indicates that the CEO's educational attainment is a master's degree; 3 indicates other cases.

[7] Furthermore, we use the average of the dollar and euro exchange rates over the sample period (2008-2020) as the conversion rate used in this paper. 1 Euro is converted to approximately 8.27 RMB and 1 USD is converted to approximately 6.59 RMB. Therefore, 33 million RMB approximately equal to 3.99 million Euro or 5 million USD.

[8] Firms receiving environmental subsidies account for 26.3% of the total sample. Ren et al. (2021) shows that 42.8% of Chinese listed manufacturing companies obtain environment subsidies during 2011 and 2015. The difference between ours and theirs is reasonable. This is because, first, our sample period begins as early as 2008 when few companies received environmental subsidies in earlier years. Second, Ren et al. (2021) drop all firms listed after 2011 and investigate a sample of 712 listed firms with 3,560 observations. In contrast, the sample size of our study is 5.8 times as many as theirs, and the sample period is longer than theirs (13 years vs. 5 years) as well.

R&D decisions. In our sample, the average R&D investment for each firm is 18.3 million RMB, and the average number of green patents each firm holds is 1.115. We next include a few variables that describe firms' financial capacity. The average of all loans that each firm receives is 1430 million RMB.

Table 3 Descriptive statistics

Variable	N	Mean	SD	Min	Max
Investment	17,587	6.033	7.827	0	20.34
Subsidy	20,741	3.498	5.941	0	17.23
Size	20,523	6.754	1.541	2.398	10.28
Age	20,742	2.801	0.357	1.609	3.466
Lev	20,741	0.403	0.207	0.0510	0.976
Cash	20,741	0.167	0.136	0.00800	0.659
ROA	20,741	0.0570	0.0700	-0.251	0.254
CEO_age	20,561	3.962	0.143	3.526	4.290
CEO_edu	20,742	1.465	0.612	1	3
LnRD	17,988	17.79	1.417	13.72	21.63
Lnpatent	18,282	0.230	0.586	0	3.045
Lnloan	20,742	16.06	7.818	0	23.76
SA	20,741	-3.783	0.244	-4.398	-3.163

4 Empirical results

4.1 Main results

Table 4 presents the results of our benchmark estimation. Firm fixed effects, year fixed effects and owner fixed effects are included. Robust standard errors are applied and clustered at the firm level. The results show how government environmental subsidies affect corporate environmental investment. Notably, we subtract environmental subsidies from corporate environmental investment, which helps to alleviate the endogeneity problem to some extent.

In Column (1), we only control for fixed effects and do not include any control variables. The coefficient of *Subsidy* is significantly positive at the 1% level, suggesting that environmental subsidies have a positive effect on corporate environmental investment. Furthermore, the control variables are included step by step in Columns (2) - (4). The results are consistent. For other controls, firm size and firm ROA both have significantly positive effects on corporate environmental investment. This indicates that a 1% increase in subsidy is associated with a 0.36% increase in corporate environmental investment.

Table 4 The effect of economic incentives on corporate environmental investment: benchmark results

	(1)	(2)	(3)	(4)
	Investment	*Investment*	*Investment*	*Investment*
Subsidy	0.3659***	0.3631***	0.3616***	0.3609***
	(0.0163)	(0.0163)	(0.0162)	(0.0163)

Size		0.1496**	0.1321*	0.1352*
		(0.0753)	(0.0761)	(0.0765)
ROA			1.8860**	1.6749*
			(0.8603)	(0.8612)
Age		1.2393	0.7875	0.8233
		(1.0544)	(1.0788)	(1.0912)
Lev			0.9511	0.9327
			(0.6137)	(0.6136)
Cash			-0.8756	-0.9510
			(0.5796)	(0.5814)
CEO_age				-0.4661
				(0.6221)
CEO_edu				-0.1694
				(0.1651)
_cons	5.4145***	0.9607	2.0012	4.0005
	(0.0297)	(2.9500)	(3.0477)	(3.7034)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes	Yes
R^2	0.6829	0.6846	0.6851	0.6858
N	16992	16804	16803	16654

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

4.2 Heterogeneity

In this section, we explore the heterogeneity of the effect, and the results are presented in Tables 5, 6 and 7. We first divide our sample into four quartiles based on firm size. The results are presented in Columns (1) to (4) of Table 5, and our baseline result still holds in all four subsamples. Environmental subsidies promote corporate environmental investment, but the coefficient of *Subsidy* gradually decreases from Column (1) to Column (4). This indicates that as firms become larger, the effect of environmental subsidies on corporate environmental investment diminishes. This conclusion is consistent with the literature. For example, Zwick and Mahon (2017) find that smaller firms are more responsive to investment when investment opportunities arise. Small firms also face stronger financial constraints (Hadlock and Pierce, 2010) and are in greater need of environmental subsidies to provide funding for their environmental investments, reflecting in a larger sensitivity to environmental subsidies. Moreover, being socially responsible helps firms build good relationships with the government, and political connections are more useful for smaller firms (Zhou, 2013).

Table 5 The heterogeneity effect of firm size

	(1) *Q1*	(2) *Q2*	(3) *Q3*	(4) *Q4*
Subsidy	0.3728***	0.3418***	0.3091***	0.2634***
	(0.0380)	(0.0333)	(0.0327)	(0.0260)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Year FE	Yes	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes	Yes
R^2	0.7287	0.7366	0.7318	0.7552
N	4082	4070	3989	3833

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

Second, we examine the heterogeneity effect of environmental subsidies on corporate environmental investment across ownership statuses. Firms in our sample are divided into three groups based on their ownership status: SOEs (state-owned enterprises) controlled by the central government, SOEs controlled by local governments, and non-SOEs. The results are shown in Table 6. We show that the coefficients of subsidy are significantly positive for all categories. In addition, the effect of environmental subsidies on corporate environmental investment is stronger for non-SOEs than for SOEs. This could be due to several facts. First, SOEs are inherently more likely to receive government environmental subsidies given their political halo. SOEs may have become so accustomed to environmental subsidies that the incentive effect is not as pronounced as for non-SOEs. Second, compared with SOEs, non-SOEs are more likely to face the problem of financial constraints. Environmental subsidies ease corporate financial constraints and provide funds for environmental investments. Third, established literature demonstrates that SOEs, with their inherent political attributes, need to take more social responsibility and have larger investments in environmental protection (Zhu et al., 2016). Meanwhile, as investment in environmental protection increases, the marginal investment cost likewise rises; in other words, the return that a firm can obtain for making one unit of environmental investment declines (Färe et al., 2016). Therefore, compared to SOEs that already have large environmental investments, private firms have a greater marginal benefit of environmental investments and respond more pronouncedly to economic incentives.

Table 6 The heterogeneity of firm’s ownership

	(1) *Central SOEs*	(2) *Local SOEs*	(3) *Non SOEs*
Subsidy	0.3086***	0.3147***	0.3893***
	(0.0407)	(0.0299)	(0.0218)
Controls	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes
R^2	0.6422	0.6951	0.6889
N	2059	3158	11365

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

Third, as mentioned above, the corporate environmental investments in our article include both end-of-pipe and cleaner production technologies. Therefore, we further distinguish between these two categories based on the definition of cleaner production by the United Nations Environment Programme (2006) and the Cleaner Production Promotion Law of the People's Republic of China.[9] Specifically, we identify cleaner production investment by a series of keywords, including clean, wind power, energy saving, photovoltaic, hydrogen, retrofit, new energy, recovery, recycling, etc. The end-of-pipe investment is then obtained by subtracting cleaner production investment from corporate environmental investment. Similarly, end-of-pipe investment is obtained by subtracting government environmental subsidies from cleaner production investment. The results are presented in Table 7. We find that environmental subsidies have a significant and positive effect on both cleaner production and end-of-pipe investment and that the effect on cleaner production investment is greater than that on end-of-pipe investment.

Table 7 Heterogeneity: environmental subsidies on cleaner production and end-of-pipe investments

	(1) *Cleaner production*	(2) *End-of-pipe*
Subsidy	0.6553***	0.3859***
	(0.0255)	(0.0184)
Controls	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
Owner FE	Yes	Yes
R^2	0.6506	0.7059
N	15179	16228

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

5 Robustness checks and mechanisms

5.1 Robustness checks

In this section, we conduct a series of robustness checks, such as excluding other policy interferences, replacing the independent variable, and modifying the database. In sum, these tests prove that our results are robust.

First, we exclude other policy interferences. We take other environmental policies in China into consideration, including (1) green credit policy; (2) environmental protection law;

[9] https://www.mee.gov.cn/ywgz/fgbz/fl/201904/t20190428_701287.shtml, accessed on December 18th, 2022.

(3) environmental tax law; and (4) air pollution control policy. The green credit policy was implemented in 2012. It was designed to place credit restrictions on heavily polluting sectors. The environmental protection law and environmental tax law were implemented in 2015 and 2018, respectively, and both strengthened environmental regulation. The air pollution control policy was announced in September 2013. By 2017, the PM10 concentration needs to decrease by 15–25% in Beijing, Tianjin, Hebei, the Yangtze River Delta and the Pearl River Delta. Following the literature (Tu et al., 2020; Yao et al., 2021; Xie et al., 2022), to further examine the potential interfering effects of policies (1), (2) and (3), we treat heavily polluting sectors as the treatment group and other sectors as the control group; to examine the potential interfering effect of policy (4), we regard Beijing, Tianjin, Hebei, the Yangtze River Delta and the Pearl River Delta as the treatment group and other cities as the control group. We generate four dummy variables *POST* based on the implementation time of each policy. Another four dummy variables *TREAT* are generated, and the values equal one for qualified firms in each policy described above.

For each policy evaluated, we include the interaction term of the corresponding *POST* and *TREAT* as an additional control variable. The results are presented in Columns (1) – (4) of Table 8. The coefficients of *Subsidy* all remain positive and significant, indicating that our main conclusions are not influenced by these environmental policies. Moreover, the environmental tax law and air pollution control policy both have positive and significant effects on corporate environmental investment. This is consistent with previous literature (Peng et al., 2021; Liu et al., 2022).

Table 8 Removing policy interference

	(1) *Green credit*	(2) *Environmental protection law*	(3) *Environmental tax law*	(4) *Air pollution control*
Subsidy	0.3608***	0.3612***	0.3632***	0.3607***
	(0.0163)	(0.0163)	(0.0163)	(0.0163)
Other policy	-0.1886	0.1526	0.5649**	0.6255**
	(0.2878)	(0.2847)	(0.2696)	(0.2905)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes	Yes
R^2	0.6858	0.6858	0.6860	0.6860
N	16654	16654	16654	16654

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

Next, we replace the independent variable and examine the effect of all government subsidies (environmental subsidies and other subsidies) on corporate environmental investment. Similarly, we subtract government subsidies from corporate environmental investment to avoid the tautology effect. The results are presented in Column (1) of Table 9 below. We show that government subsidies increase corporate environmental investment. In addition, to make full use of the sample information, we do not subtract government subsidies from corporate environmental investment and directly examine the impact of government subsidies on corporate environmental investment. The results are presented in Column (2) of Table 9. We show that the coefficient of *Subsidy* is significantly positive, suggesting that government subsidies have a positive effect on corporate environmental investment.

Third, to ensure that environmental subsidies truly work and that the estimated effect is not a "tautological effect", we rerun the regression on the subset of firms with nonzero investment in environmental protection. The results are presented in Column (3) of Table 9. The coefficient of *Subsidy* is significantly positive, suggesting that the role of environmental subsidies in promoting corporate environmental investment remains among the subset of firms that invest in environmental protection.

Fourth, we transform our data into a balanced panel and rerun the baseline regression. The results are presented in Column (4) of Table 9. We also rerun the regression using environmental subsidies per capita and corporate environmental investment per capita to replace the original dependent and independent variables, respectively. The results are represented in Column (5) of Table 9. Our main findings still hold.

Table 9 Robustness tests

	(1)	(2)	(3)	(4)	(5)
Subsidy	0.4412***	0.0876***	0.3660***	0.3707***	0.4166***
	(0.0506)	(0.0265)	(0.0167)	(0.0211)	(0.0204)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes	Yes	Yes
R^2	0.8686	0.6137	0.5460	0.6496	0.6738
N	2727	19738	10875	7625	16657

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

Finally, the relationship between environmental subsidies and corporate environmental investment may suffer from reverse causality and omitted variable bias. For example, the government may choose firms that invest in environmental protection to offer subsidies to reflect the government's goal of environmental protection. In this case, subsidies cannot lead to corporate environmental investment, but rather corporate environmental investment attracts subsidies. As such, the issue of reverse causality arises and leads to biased coefficients. Another concern is omitted variable bias. Potentially, there exists another factor that simultaneously correlates to environmental subsidies and corporate environmental investment. Thus, excluding it also causes biased estimates. Firms in certain industries (such as those of "Made in China 2025")[10] and state-owned enterprises are more prone to invest in the environment and receive subsidies.

Before addressing these endogeneity concerns, we verify the presence of endogenous explanatory variables. The traditional Hausman test does not apply in this case due to the presence of heteroskedasticity. Therefore, we employ the Durbin-Wu-Hausman (DWH) test, which provides more robust results than the traditional Hausman test. The DWH result shows chi2 (1) = 109.33 (p = 0.0000), indicating the presence of endogenous explanatory variables in the regression. Therefore, we employ instrument variables to address the issue of endogeneity. Based on Nakamura and Steinsson (2014), we choose a reasonable instrumental variable to address these endogeneity concerns. It is constructed as follows. First, we calculate the average ratio of the firm's environmental subsidies to the city average environmental subsidy where the firm is located during the sample period. Second, the interaction term between the average ratio and the environmental subsidy of the city where the firm is located in the current year is used as the instrumental variable. The results are represented in Table 10. Column (1) reports the first-stage results. The positive coefficient of IV confirms our expectation, and the F value is greater than 10. The second-stage results are presented in Column (2), and they confirm our previous finding that environmental subsidies have a positive effect on corporate environmental investment.

The above IV is valid because, first, it satisfies the correlation requirement. Environmental subsidies received are highly correlated with the instrumental variable. Second, it also satisfies the requirement of exogeneity. This instrumental variable is composed of the weights of the firms and the environmental investments of the cities where the firms are located. Omitted variables (mostly firm-level unobservable factors) can neither influence the ratio nor determine the situation in the city where the firm is located. Therefore, omitted variables are not directly related to the instrumental variable.

[10] http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm, accessed on December 18th, 2022.

We further verify the exogeneity of our instrumental variable using three empirical methods. First, following Conley et al. (2012), we include both the endogenous variable and the instrumental variable in the regression. The estimated coefficient (0.3655) in Table 10, Column (3), remains almost unchanged compared to the baseline results (0.3609). Meanwhile, the coefficient of the IV significantly decreases compared to Column (2) and is not significantly different from zero. These results indicate that the instrument variable affects the dependent variable (investment) only through the explanatory variable (subsidy). This suggests that the IV in our study does not directly influence corporate environmental investment but rather affects it through environmental subsidies.

Second, we also employ an indirect test method based on previous literature (Wooldridge, 2002). We regress the residuals from the second-stage regression on the IV to examine the significant correlation between the residuals and the IV. If the regression coefficient is insignificant, it confirms the consistency of the IV with the exogeneity hypothesis. The results, shown in Column (4), indicate that the coefficient of the IV is not significant, confirming that the IV selected satisfied the exogeneity requirement for instrumental variables.

At last, we additionally employ the local to zero (LTZ) method. Although the IV we construct may not be entirely exogenous, we conduct robustness tests on its exogeneity by relaxing the assumption of exogeneity. This approach provides an accurate result (Conley et al. 2012; Lal et al. 2023). The paper further tests exogeneity using the local to zero approach proposed by Conley et al. (2012), and the regression results in Column (5) once again show a significantly positive impact for the subsidy, indicating near-exogeneity[11]. These findings confirm that the IV selected in this study satisfies the exogeneity hypothesis. In summary, while our IV may not be perfectly exogeneous, this issue does not substantially impact the conclusions of the article.

Table 10 Instrument variable

	(1)	(2)	(3)	(4)	(5)
			Exogeneity test		
	First stage	Second stage	Including IV and Subsidy	Indirect test method	LTZ
IV	0.3479***		-0.0128	-0.0052	
	(0.0874)		(0.0137)	(0.0102)	
Subsidy		0.3287***	0.3655***		0.9555***
		(0.0344)	(0.0168)		(0.2024)
DWH	109.33***				

[11] The LTZ method does not allow for the inclusion of fixed effects in the regression and the results do not report R^2.

K-P Wald F	15.84				
Controls	Yes	Yes	Yes	Yes	No
Firm FE	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	No
Owner FE	Yes	Yes	Yes	Yes	No
R^2		0.0720	0.6855	0.1219	
N	16265	16265	16265	16265	16682

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

5.2 Mechanism

In this section, we explore two potential mechanisms through which environmental subsidies affect corporate environmental investment. The first is innovation. Theoretically, environmental subsidies can alleviate market failure by reducing the cost of innovation and increasing the number of patents relating to environmentally sound technologies by increasing firms' incentives to innovate (Choi and Lee, 2017). For example, by designing game theoretic models, Wang et al. (2017) show that environmental subsidies can promote cleaner production innovation. Furthermore, because such R&D investment usually promotes large volumes of technology innovation that will raise energy efficiency and clean energy production, it is also included in the scope of corporate environmental investment. Tian et al. (2020) empirically document that corporations' R&D investment has a positive impact on corporations' environmental investment and improves firms' environmental performance.

In Table 11, we investigate this mechanism by replacing the dependent variable. In Column (1), we explore the impact of environmental subsidies on firms' total R&D investment. The result confirms that environmental subsidies decrease R&D costs and thus encourage R&D investments (Bronzini and Piselli, 2016; Mateut, 2018). For robustness, we also examine an alternative measurement, the number of green patents (Column 2). Along with total R&D investment, both measures generate consistent estimates. This indicates that environmental subsidies positively affect corporate environmental investment through innovation.

The second potential mechanism is financial capacity. From the perspective of signaling theory, receiving environmental subsidies helps firms build a better image (Nie et al., 2016) and indicates that the activity carried out by them is supported by the government. This reduces information asymmetry and helps firms acquire necessary resources (Zou and Adams 2008; Zeng et al., 2021). Financial institutions such as banks are more willing to lend money to such firms to reduce the risk of uncollectible accounts. As discovered by Zhang et al. (2019), financial constraints hinder environmental investment behaviors because environmental investment does not contribute directly to profit and is recognized as a cost. Therefore, environmental subsidies could improve corporate financial capacity and ease financial constraints, which in turn increase corporate environmental investment.

The results are presented in Table 11. In Column (3), we regress the natural logarithm of the sum of all loans the firm receives on subsidy, all controls and fixed effects inherited from the benchmark regression. The significant coefficient of subsidy indicates that receiving subsidies significantly increases the firm's financial capacity, through which corporate environmental investment could also be augmented. In Column (4), we further verify the impact of environmental subsidies on financial constraints that is proxied by the SA index. Following Hadlock and Pierce (2010), the SA index is a negative value, and a larger SA index (closer to zero) indicates greater financial constraints. The results show that the significantly negative coefficient of subsidies indicates that receiving subsidies significantly decreases firms' financial constraints.

Table 11 Mechanism: Innovation capacity and financial capacity

	(1) R&D investment	(2) Green patents	(3) Financial capacity	(4) Financial constraints
Subsidy	0.0030^{**}	0.0012^{*}	0.0156^{*}	-0.0006^{***}
	(0.0015)	(0.0007)	(0.0083)	(0.0001)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Owner FE	Yes	Yes	Yes	Yes
R2	0.8478	0.6566	0.6766	0.9559
N	17087	17641	19751	19751

Notes: Standard errors are reported in parentheses; * Significant at the 10% ** Significant at the 5% *** Significant at the 1%.

6 Conclusion

In response to the deteriorating environment, the Chinese central government has implemented various pollution control policies. This paper contributes to the literature that quantitatively estimates the effectiveness of one specific type of economic incentive – subsidies. It complements the relevant literature since previous studies concentrate on the effects of various environmental regulations and tax incentives. This study also contributes to the literature that evaluates the determinants of corporate environmental investment.

Using a representative sample of Chinese manufacturing listed firms, the empirical results reveal that environmental subsidies—a type of economic incentive—substantially increase corporate environmental investment. The effect of subsidies is also greater for smaller firms and private firms. Moreover, we also find that environmental subsidies have a significant and positive effect on both cleaner production and end-of-pipe investment and that the effect on cleaner production is greater. We further explore the mechanisms and find that environmental subsidies promote corporate environmental investment by increasing firms' innovation and financial capacity.

Our study provides useful implications regarding the use of environmental subsidies that should be valuable to policymakers and firm managers. First, local governments should increase the scope and scale of environmental subsidies. Although there may exist a crowding-out effect on corporate environmental investment, the findings of this paper confirm the overall positive effect. Investment in environmental protection only accounts for 1.15% of the total GDP in China. This leaves much room for further increments compared to developed countries. In addition, the current coverage of environmental subsidies is not wide, and the government should increase the size and scope of environmental subsidies to stimulate corporate environmental investment.

Second, technological innovation is the key to achieving green development, and local governments should increase their support for firms to carry out green innovation. It not only reduces the difficulty of obtaining funds for firms to carry out green innovation but also increases corporate environmental investment by alleviating their financial constraints.

Third, the findings of this paper emphasize the important role of small firms and non-SOEs in environmental protection. The heterogeneity results show that small and non-SOEs are more sensitive to economic incentives due to their higher financial constraints and innovation costs. Therefore, governments can utilize this and design policies in favor of small and non-SOEs to improve their accessibility to innovation funds and ease their financial constraints.

Finally, one perverse effect of subsidies is that they prevent polluting firms from exiting (and stop polluting). This is the main disadvantage of subsidies compared to taxation. Therefore, in addition to environmental subsidies, other economic incentives should also be used, such as environmental tax incentives, value-added tax deductions (green equipment credits), and corporate income tax deductions.

References

Alam, M. S., Atif, M., Chien-Chi, C., & Soytaş, U. (2019). Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. *Energy Economics*, 78, 401-411.

Arguedas, Carmen, and Daan P. van Soest. "On reducing the windfall profits in environmental subsidy programs." *Journal of Environmental Economics and Management* 58.2 (2009): 192-205.

Bai, Y., & Chen, S. (2022). Empirical study on the impact of environmental regulation on enterprise environmental investment. Environ. Resour. *Ecol. J*, 6(02).

Becker, Randy A. "Air pollution abatement costs under the Clean Air Act: evidence from the PACE survey." *Journal of Environmental Economics and Management* 50.1 (2005): 144-169.

Bronzini, Raffaello, and Paolo Piselli. "The impact of R&D subsidies on firm innovation." *Research Policy* 45.2 (2016): 442-457.

Chang, D., Gao, D., Xu, X., Wang, X., Ju, Y., & Shen, X. (2021). Top-runner incentive scheme in China: a theoretical and empirical study for industrial pollution control. *Environmental Science and Pollution Research*, 28(23), 29344-29356.

Chen, Y. H., Wen, X. W., Wang, B., & Nie, P. Y. "Agricultural pollution and regulation: How to subsidize agriculture?." *Journal of Cleaner Production* 164 (2017): 258-264.

Chen, Y., & Ma, Y. (2021). Does green investment improve energy firm performance?. *Energy Policy*, 153, 112252.

Cheng, Z., Luo, L., Wang, S., Wang, Y., Sharma, S., Shimadera, H., ... & Hao, J. (2016). Status and characteristics of ambient PM2. 5 pollution in global megacities. *Environment international*, 89, 212-221.

Choi, J., & Lee, J. (2017). Repairing the R&D market failure: Public R&D subsidy and the composition of private R&D. *Research Policy*, 46(8), 1465-1478.

Conley, T. G., Hansen, C. B., & Rossi, P. E. (2012). Plausibly exogenous. *Review of Economics and Statistics*, 94(1), 260-272.

Costa-Campi, Maria Teresa, Jose Garcia-Quevedo, and Ester Martínez-Ros. "What are the determinants of investment in environmental R&D?." *Energy Policy* 104 (2017): 455-465.

Daddi, T., Iraldo, F., Testa, F., & De Giacomo, M. R. (2019). The influence of managerial satisfaction on corporate environmental performance and reputation. *Business Strategy and the Environment*, 28(1), 15-24.

Dang, Tri Vi, Youan Wang, and Zigan Wang. "The Effects of Mandatory Pollution Abatement on Corporate Investment and Performance: Theory and Evidence from a US Regulation." *Financial Management Association International* (2019).

Danielova, Anna, and Sudipto Sarkar. "The effect of leverage on the tax-cut versus investment-subsidy argument." *Review of Financial Economics* 20.4 (2011): 123-129.

Di, Wenhua. "Pollution abatement cost savings and FDI inflows to polluting sectors in China." *Environment and Development Economics* 12.6 (2007): 775-798.

Fan, Q., Qiao, Y., Zhang, T., & Huang, K. (2021). Environmental regulation policy, corporate pollution control and economic growth effect: Evidence from China. *Environmental Challenges*, 5, 100244.

Färe, R., Grosskopf, S., & Pasurka, C. (2016). Technical change and pollution abatement costs. *European Journal of Operational Research*, 248(2), 715-724.

Garcia-Quevedo, J., Martinez-Ros, E., & Tchórzewska, K. B. (2022). End-of-pipe and cleaner production technologies. Do policy instruments and organizational capabilities matter? Evidence from Spanish firms. *Journal of Cleaner Production*, 340, 130307.

Greenstone, Michael, and Rema Hanna. "Environmental regulations, air and water pollution, and infant mortality in India." *American Economic Review* 104.10 (2014): 3038-72.

Hadlock, C. J., & Pierce, J. R. (2010). New evidence on measuring financial constraints: Moving beyond the KZ index. *The review of financial studies*, 23(5), 1909-1940.

Hu, H., Qi, S., & Chen, Y. (2023). Using green technology for a better tomorrow: How enterprises and government utilize the carbon trading system and incentive policies. *China Economic Review*, 78, 101933.

Huang, Z., Liao, G., & Li, Z. (2019). Loaning scale and government subsidy for promoting green innovation. *Technological Forecasting and Social Change*, 144, 148-156.

Ji, Xiang, Guo Li, and Zhaohua Wang. "Impact of emission regulation policies on Chinese power firms' reusable environmental investments and sustainable operations." *Energy Policy* 108 (2017): 163-177.

Keller, Wolfgang, and Arik Levinson. "Pollution abatement costs and foreign direct investment inflows to US states." *Review of Economics and Statistics* 84.4 (2002): 691-703.

Khan, A., Muttakin, M. B., & Siddiqui, J. (2013). Corporate governance and corporate social responsibility disclosures: Evidence from an emerging economy. *Journal of business ethics*, 114(2), 207-223.

Lal, A., Lockhart, M., Xu, Y., & Zu, Z. (2023). How much should we trust instrumental variable estimates in political science? Practical advice based on over 60 replicated studies. arXiv preprint arXiv:2303.11399.

Liu, G., Yang, Z., Zhang, F., & Zhang, N. (2022). Environmental tax reform and environmental investment: A quasi-natural experiment based on China's Environmental Protection Tax Law. *Energy Economics*, 109, 106000.

Liu, X., Wang, E., & Cai, D. (2019). Green credit policy, property rights and debt financing: Quasi-natural experimental evidence from China. Finance Research Letters, 29, 129-135.

Marino, M., Lhuillery, S., Parrotta, P., & Sala, D. (2016). Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure. *Research Policy*, 45(9), 1715-1730.

Mateut, S. "Subsidies, financial constraints and firm innovative activities in emerging economies." *Small Business Economics* 50.1 (2018): 131-162.

Murovec, Nika, Renata Slabe Erker, and Igor Prodan. "Determinants of environmental investments: testing the structural model." *Journal of Cleaner Production* 37 (2012): 265-277.

Nakamura, E., & Steinsson, J. (2014). Fiscal stimulus in a monetary union: Evidence from US regions. *American Economic Review*, 104(3), 753-92.

Nie, P. Y., Chen, Y. H., Yang, Y. C., & Wang, X. H. "Subsidies in carbon finance for promoting renewable energy development." *Journal of Cleaner Productio*n 139 (2016): 677-684.

Peng, F., Peng, L., Mao, J., & Lu, P. (2021). The Short-Run Effect of a Local Fiscal Squeeze on Pollution Abatement Expenditures: Evidence from China's VAT Pilot Program. *Environmental and Resource Economics*, 78(3), 453-485.

Porter, Michael E., and Claas Van der Linde. "Toward a new conception of the environment-competitiveness relationship." *Journal of Economic Perspectives* 9.4 (1995): 97-118.

Qia, Y., Zhang, J., & Chen, J. (2022). Tax incentives, environmental regulation and firms' emission reduction strategies: Evidence from China. *Journal of Environmental Economics and Management*, 102750.

Renström, Thomas I., Luca Spataro, and Laura Marsiliani. "Can subsidies rather than pollution taxes break the trade-off between economic output and environmental protection?." *Energy Economics* 95 (2021): 105084.

Requate, Till, and Wolfram Unold. "Environmental policy incentives to adopt advanced abatement technology: Will the true ranking please stand up?." *European Economic Review* 47.1 (2003): 125-146.

Shabbir, M. S., & Yaqoob, N. (2019). The impact of technological advancement on total factor productivity of cotton: a comparative analysis between Pakistan and India. Journal of Economic Structures, 8(1), 1-16.

Shadbegian, Ronald J., and Wayne B. Gray. "Pollution abatement expenditures and plant-level productivity: a production function approach." *Ecological Economics* 54.2-3 (2005): 196-208.

Song, J., Zhang, H., & Su, Z. (2021). Environmental subsidies and companies' environmental investments. *Economic and Political Studies*, 9(4), 477-496.

Sun, Z., Wang, X., Liang, C., Cao, F., & Wang, L. (2021). The impact of heterogeneous environmental regulation on innovation of high-tech enterprises in China: mediating and interaction effect. *Environmental Science and Pollution Research*, 28(7), 8323-8336.

Tian, J. F., Pan, C., Xue, R., Yang, X. T., Wang, C., Ji, X. Z., & Shan, Y. L. (2020). Corporate innovation and environmental investment: The moderating role of institutional environment. *Advances in Climate Change Research*, 11(2), 85-91.

Tu, W. J., Yue, X. G., Liu, W., & Crabbe, M. J. C. (2020). Valuation impacts of environmental protection taxes and regulatory costs in heavy-polluting industries. *International Journal of Environmental Research and Public Health*, 17(6), 2070.

United Nations Environment Programme (2006). Environmental Agreements and Cleaner Production: Questions and Answers.

Varela-Candamio, Laura, Nuria Calvo, and Isabel Novo-Corti. "The role of public subsidies for efficiency and environmental adaptation of farming: A multi-layered business model based on functional foods and rural women." *Journal of Cleaner Production* 183 (2018): 555-565.

Wang L, Su Y, Huang H, et al. Director's network location and corporate environmental investment in the carbon neutrality age. *Business Strategy and the Environment*, 2022.

Wang, C., Nie, P. Y., Peng, D. H., & Li, Z. H. (2017). Green insurance subsidy for promoting clean production innovation. *Journal of cleaner production*, 148, 111-117.

Wei, F., Ding, B., & Kong, Y. (2017). Female directors and corporate social responsibility: Evidence from the environmental investment of Chinese listed companies. *Sustainability*, 9(12), 2292.

Wooldridge, J. M. (2002). Econometric analysis of cross section and panel data MIT press. Cambridge, ma, 108(2), 245-254.

Xie, G., Yang, Y., Jiang, K., & Chen, Z. (2022). The effect of the new Environmental Protection Law on corporate financialization in China. *Environmental Science and Pollution Research*, 1-16.

Xu, J., Wang, X., & Liu, F. (2021). Government subsidies, R&D investment and innovation performance: analysis from pharmaceutical sector in China. *Technology Analysis & Strategic Management*, 33(5), 535-553.

Xu, X., Zhang, W., Wang, T., Xu, Y., & Du, H. (2021). Impact of subsidies on innovations of environmental protection and circular economy in China. *Journal of Environmental Management*, 289, 112385.

Yao, S., Pan, Y., Sensoy, A., Uddin, G. S., & Cheng, F. (2021). Green credit policy and firm performance: What we learn from China. *Energy Economics*, 101, 105415.

Zeng, Y., Guo, P., & Li, B. (2021). The impact of government subsidies on company debt financing: New evidence from Chinese listed companies. *Emerging Markets Finance and Trade*, 57(7), 1843-1858.

Zhang, D., Du, W., Zhuge, L., Tong, Z., & Freeman, R. B. (2019). Do financial constraints curb firms' efforts to control pollution? Evidence from Chinese manufacturing firms. *Journal of cleaner production*, 215, 1052-1058.

Zhang, Y., Li, X., Jiang, F., Song, Y., & Xu, M. (2020). Industrial policy, energy and environment efficiency: evidence from Chinese firm-level data. *Journal of environmental management*, 260, 110123.

Zhou, W. (2013). Political connections and entrepreneurial investment: Evidence from China's transition economy. *Journal of business venturing*, 28(2), 299-315.

Zhu X, Liu R, Chen J. Corporate environmental investment and supply chain financing: The moderating role of environmental innovation. *Business Strategy and the Environment*, 2022.

Zhu, Q., Liu, J., & Lai, K. H. (2016). Corporate social responsibility practices and performance improvement among Chinese national state-owned enterprises. *International Journal of Production Economics*, 171, 417-426.

Zou, H., & Adams, M. B. (2008). Debt capacity, cost of debt, and corporate insurance. *Journal of financial and quantitative analysis*, 43(2), 433-466.

Zúñiga-Vicente, J. Á., Alonso-Borrego, C., Forcadell, F. J., & Galán, J. I. (2014). Assessing the effect of public subsidies on firm R&D investment: a survey. *Journal of economic surveys*, 28(1), 36-67.

Zwick, E., & Mahon, J. (2017). Tax policy and heterogeneous investment behavior. *American Economic Review*, 107(1), 217-48.

Appendix

We believe that our dataset is representative. It is an unbalanced panel consisting of 20742 observations. More details about the density of observations across province and industry is presented in Table A1. It shows that the density of firms in Guangdong, Zhejiang and Jiangsu all exceed 10%; together they account for 39.61% of all observations. The three most numerous industries in the sample are computer, communications and other electronic equipment manufacturing, chemical raw materials and chemical products manufacturing industry and pharmaceutical manufacturing industry, respectively. And the sum of them reached 34.27% of the total sample size.

Table A1 The density of observations across province and industry

	Part A			Part B	
Province	Observations	Density	Code of industry[12]	Observations	Density
Shanghai	1287	6.20%	C13	490	2.36%
Yunnan	227	1.09%	C14	421	2.03%
Inner Mongolia	192	0.93%	C15	443	2.14%
Beijing	1136	5.48%	C17	424	2.04%
Jilin	261	1.26%	C18	312	1.50%
Sichuan	760	3.66%	C19	81	0.39%
Tianjin	276	1.33%	C20	77	0.37%
Ningxia	117	0.56%	C21	127	0.61%
Anhui	719	3.47%	C22	323	1.56%
Shandong	1516	7.31%	C23	116	0.56%
Shanxi	238	1.15%	C24	106	0.51%
Guangdong	3169	15.28%	C25	168	0.81%
Guangxi	199	0.96%	C26	2198	10.60%
Xinjiang	251	1.21%	C27	1983	9.56%
Jiangsu	2421	11.67%	C28	257	1.24%
Jiangxi	314	1.51%	C29	661	3.19%

[12] C13 to C20 respectively refer to Agri-food processing industry, food manufacturing, wine, beverage and refined tea manufacturing, textile industry, the Textile clothing and apparel industry, the leather, fur, feathers and their products and footwear industry, the Wood processing and wood, bamboo, rattan, palm, grass products industry. C21 to C25 respectively refer to furniture manufacturing industry, paper and paper products industry, printing and recording media reproduction industry, education, industry, sports and entertainment goods manufacturing industry, petroleum processing, coking and nuclear fuel processing industry. C26 to C33 respectively refer to chemical raw materials and chemical products manufacturing industry, pharmaceutical manufacturing industry, chemical fiber manufacturing industry, rubber and plastic products industry, non-metallic mineral products industry, ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry, metal products industry.C34 to C43 respectively refer to general equipment manufacturing industry, special equipment manufacturing industry, automobile manufacturing industry, railroad, ship, aerospace and other transportation equipment manufacturing industry, electrical machinery and equipment manufacturing industry, computer, communications and other electronic equipment manufacturing industry, instrument manufacturing industry, other manufacturing industries, comprehensive utilization of waste resources industry, metal products, machinery and equipment repair industry.

Hebei	456	2.20%	C30	904	4.36%
Henan	613	2.96%	C31	382	1.84%
Zhejiang	2626	12.66%	C32	742	3.58%
Hainan	122	0.59%	C33	585	2.82%
Hubei	691	3.33%	C34	1157	5.58%
Hunan	614	2.96%	C35	1753	8.45%
Gansu	176	0.85%	C36	1046	5.04%
Fujian	702	3.38%	C37	509	2.45%
Tibet	84	0.40%	C38	1936	9.33%
Guizhou	199	0.96%	C39	2927	14.11%
Liaoning	454	2.19%	C40	351	1.69%
Chongqing	257	1.24%	C41	221	1.07%
Shaanxi	342	1.65%	C42	40	0.19%
Qinghai	107	0.52%	C43	2	0.01%
Heilongjiang	216	1.04%			

Highlights

- We document that environmental subsidies — one type of economic incentive —significantly increase corporate environmental investment.
- This effect is positive on both cleaner production and end-of-pipe investment, with the former being greater.
- The effect is higher for smaller firms and for private firms compared to their respective counterparts.
- The increase in corporate environmental investment is realized through increased firms' innovation and financial capacity.