Pol. J. Environ. Stud. Vol. 34, No. 6 (2025), 8469-8481
DOI: *10.15244/pjoes/194588* ONLINE PUBLICATION DATE: 2025-01-16

Original Research

Air Pollution and Corporate Green Investment: Evidence from Chinese Industrial Companies

Ling Zou[1], Jiejing Ma[1, 2]*

[1]School of Accounting, Jiangxi University of Finance and Economics, Nanchang, Jiangxi 330013, China
[2]School of Business, Jishou University, Jishou, Hunan 416000, China

Received: 14 July 2024
Accepted: 13 October 2024

Abstract

Air pollution influences the investment decision-making behavior of micro-enterprises within a region. This study empirically investigates the impact of regional air pollution on corporate green investment using a sample of Chinese A-share industrial listed companies from 2014 to 2022. The findings indicate that worsening air pollution prompts companies to undertake green investments. Environmental pressure from air pollution influences corporate green investment through three channels: local government environmental regulation, media attention, and public environmental supervision. Heterogeneity analysis reveals that the promoting effect of air pollution on corporate green investment is more significant in regions with lower marketization levels, heavily polluted industries, state-owned enterprises, companies with lower government subsidies, and those with lower institutional shareholding. This study uncovers the micro-mechanism through which air pollution impacts economic development, providing theoretical support and empirical evidence for local governments to formulate pollution control policies and achieve low-carbon economic development.

Keywords: air pollution, green investment, government environmental regulation, media attention, public environmental supervision

Introduction

Air pollution is a significant challenge for developing countries worldwide, severely impacting production and economic development [1, 2]. Since the reform and opening up, China has achieved remarkable economic progress, but extensive development has also led to severe air pollution problems [3, 4]. Air pollution exerts a significant negative impact on health, economic development, and social stability in China. According to recent data, air pollution has become the second-largest health risk factor in the country, contributing to approximately 1.24 million premature deaths and causing economic losses amounting to 54 billion dollars annually. Severe air pollution events, such as haze, not only endanger public health but also reduce productivity and disrupt transportation systems. Furthermore, air pollution strains the healthcare system, diminishes residents' disposable income, and curtails spending power, thereby impeding economic growth and deposable social [4]. In summary, air pollution represents a critical public health hazard in China and poses substantial challenges to economic development and social stability. In recent years, China

*e-mail: majiejing517@126.com
Tel.: +86 18474329017; Fax: +86 0743-8564580

has consistently implemented air pollution control and ecological environmental protection measures, achieving some overall improvements. However, air pollution still presents numerous challenges and pressures, and environmental protection remains a long-term task [5]. According to the China Ecological and Environmental Status Bulletin, in 2023, nearly 40.1% of 339 prefecture-level and above cities exceeded air quality standards. In the first half of the year, the national average PM2.5 concentration increased by 6.2% year-on-year; there were a total of 1,980 days of severe pollution, with the average proportion of severe and above pollution days at 1.6%. Additionally, there were 5 instances of haze and 17 instances of sandstorm weather, with the average number of haze days at 20.5 days and the number of sandstorm occurrences being the highest since 2011. Given the severity of the air pollution situation, the 2024 National Ecological Environmental Protection Work Conference emphasized the need to "increase supervision and assistance for improving air quality in key regions and strengthen overall supervision", implementing stricter control measures to promote continuous improvement in air quality and achieve low-carbon economic development.

Companies are major contributors to environmental issues such as air pollution, and they are also key targets for pollution control efforts. Existing research has identified air quality as a significant factor influencing the behavior of corporate decision-makers and stakeholders. On the one hand, air pollution increases corporate compliance costs [3], causes talent loss [2], raises operational risks, and significantly negatively impacts corporate fixed asset investment [6]. Air pollution not only reduces corporate innovation [7], corporate performance [8], corporate environmental performance [9], and shareholder responsibility performance [10], but also increases the risk expectations of capital market participants and the uncertainty of corporate operations [11]. On the other hand, exposure to severe air pollution prompts corporate managers to implement green management practices to fulfill corporate social responsibility and enhance social responsibility levels [12-14], thereby improving the quality of environmental information disclosure [4, 15, 16], enhancing employee treatment [1], and increasing the corporate capital-labor ratio [17]. Clearly, air pollution has diverse impacts on the business and investment behaviors of micro-enterprises. However, few studies have examined its impact on corporate green investment behavior.

Corporate green investment behavior is directly linked to the effectiveness of environmental protection and low-carbon economic development [18]. Green investment refers to the necessary investments aimed at reducing greenhouse gas and air pollutant emissions without significantly lowering the production and consumption of non-energy products [19]. Although green investment helps curb industrial waste emissions, control environmental pollution, and establish a green corporate image, purchasing environmental protection equipment and investing in green technologies require substantial financial resources from enterprises. The direct returns are uncertain, leading to significant risks for companies undertaking green investments [20]. Therefore, green investment is more of a "passive behavior", with companies lacking the motivation and intrinsic drive to engage in it [21]. As China continues to improve air quality and strengthen environmental supervision, will companies be compelled to make green investments to reduce pollution and achieve a green transformation? How will environmental regulations play a role in this relationship? These questions deserve further exploration.

Given this, we investigate the impact of air pollution on corporate green investment using a sample of Chinese A-share industrial listed companies from 2014 to 2022. The main contributions are as follows:

Firstly, we contribute to the research on the economic consequences of air pollution. Air pollution is a significant issue in China and globally, attracting widespread attention and discussion across all sectors of society. The academic community has conducted extensive research on its negative economic consequences [7, 8, 10, 22]. In recent years, both the Chinese government and the public have taken numerous actions to address air pollution. Whether regional air pollution can prompt companies to implement positive business and investment activities has become an increasingly important and urgent issue. Existing literature has highlighted the positive impact of air pollution on employee treatment [1], corporate capital-labor ratios [17], environmental information disclosure [4, 15, 16], and corporate environmental performance [9]. These aspects can encourage companies to implement green management practices, fulfill corporate social responsibility, and enhance social responsibility levels [12-14]. We systematically examine the impact of air pollution on corporate green investment behavior from the perspectives of formal and informal environmental regulation, finding that air pollution positively influences corporate green investment, thereby contributing to the existing literature on the economic consequences of air pollution.

Secondly, we provide a new perspective and empirical evidence for researching the factors influencing corporate green investment from the perspective of regional air pollution, an important external natural environment factor. Existing literature suggests that public appeal [23], institutional environment [24], political connections [25], environmental emissions charges [26], capital leverage [27], environmental protection tax [21], environmental law [28], economic growth targets [20], corporate managers' experience [29], and carbon trading policies [30] can largely explain corporate green investment behaviors. By focusing on the external natural environment that corporations depend on, we expand and enrich the research on the factors influencing green investment.

Finally, our conclusions provide valuable practical insights for relevant government departments to effectively tackle pollution and for enterprises to accelerate green transformation. We reveal the important mechanisms by which air pollution positively affects economic development at the micro-enterprise level, offering reliable empirical support for the impact of air pollution on corporate green investment and its heterogeneity. The findings deepen the understanding of how air pollution affects microenterprise development mechanisms. The conclusion not only helps to better understand corporate green investment behavior but also provides decision-making references for government departments to enhance environmental governance capabilities and achieve a win-win situation of economic development and environmental protection.

Theoretical Analysis and Research Hypothesis

Air pollution exerts direct pressure on corporate green investment. According to environmental pressure theory, external factors influence corporate behavior, compelling companies to take action. Regional air pollution directly impacts public health and quality of life [14, 22]. Serious air pollution events, such as haze and industrial emissions, cause respiratory and cardiovascular diseases, attracting significant attention from the government and public, with extensive media coverage [31]. Legitimacy theory posits that corporate behavior can only be sustainable if it adheres to legal regulations, aligns with social norms, and meets public expectations. As major producers, companies generate negative externalities that affect society, the economy, and other enterprises. In pursuing economic growth and increasing financial revenue, companies lack intrinsic motivation for environmental governance, relying more on external pressure to compel them to take environmental protection measures [24]. We argue that air pollution can attract attention and supervision from local governments, the media, and the public to corporate production and operation activities, thus prompting companies to increase green investment.

Firstly, air pollution can promote corporate green investment by strengthening local government environmental regulations. Air pollution is an environmental issue of great concern to the central government, with related policies clearly outlining the governance responsibilities of local governments, motivating local officials to engage in governance [16, 32, 33]. In China, ecological and environmental authorities maintain continuous oversight of cities by implementing dynamic air quality monitoring systems at the municipal level and disseminating air pollution data in real-time. To prevent local governments from resorting to short-term strategies, such as temporary production cuts or shutdowns in response to assessments, the central government mandates that local governments address pollution through long-term mechanisms. With the introduction of scientific and transparent assessment indicators for air pollution control and the heightened emphasis on air pollution prevention and control in performance evaluations, local officials in severely polluted areas are increasingly incentivized to enforce long-term environmental regulations on enterprises. Indicators such as environmental protection and energy conservation have become important criteria in evaluating the performance of local cadres [20, 34]. When air pollution worsens, local officials, aiming to maintain their reputation and promotion opportunities, will strengthen environmental regulation, passing more governance pressure onto enterprises within their jurisdictions and increasing the cost of environmental violations. This heightens the risk of companies being penalized and scrutinized for poor environmental performance [10, 35]. This compels companies to overcome previous shortsighted environmental management strategies and increase investment in green development to alleviate environmental pressure and reduce risks.

Secondly, the media, acting as an information intermediary and supervisor, serves as a significant external pressure source for enterprises to engage in green governance by overseeing corporate legitimacy issues [36]. The media possesses strong capabilities in extracting and processing information, integrating, and reporting on issues of public concern comprehensibly. Given the profit-driven nature of media reports, they tend to prioritize news that captures public attention. In the context of the central government's strong emphasis on air pollution control, the media have greater incentive and opportunity to report on related issues, thereby enhancing their role in pollution monitoring. Air quality is a topic of widespread public interest, and the news media play a "sensationalizing" role in air pollution matters. Negative news coverage can attract public attention and criticism, increasing the likelihood of government regulatory intervention, thus affecting corporate operations and damaging the corporate image and reputation [37]. Media coverage exerts significant public pressure on the involved companies [38], increasing the reputational cost of corporate environmental pollution behaviors. Consequently, companies are compelled to take measures to protect their corporate image, bolster their reputation, and promote green development through investments in sustainable practices, such as green behaviors and management.

Finally, air pollution can promote corporate green investment through public environmental supervision. The public is a crucial stakeholder, and companies must continually meet public expectations and demands in their operations. As direct victims of environmental pollution, the public is motivated to exercise its supervisory role [39]. Institutional theory asserts that social groups can substantially influence corporate behavior, with the pressure for environmental legitimacy emerging as a key driver of green corporate

governance. Air pollution negatively affects the public physiologically and psychologically, arousing attention and anger from the news, media, and local communities. Persistent health and economic inequalities caused by prolonged exposure to air pollution have prompted the local public to demand higher air quality and actively monitor the polluting activities of firms in their region. This heightened scrutiny significantly increases the likelihood of detecting corporate environmental violations and raises the cost of such violations [40]. To protect their interests, the public is highly sensitive to corporate polluting behavior and uses the Internet and other platforms to voice environmental protection concerns and monitor corporate polluting practices [41]. The local public can file complaints and lawsuits with government departments to demand stricter regulations and penalties for polluting companies and expose corporate violations to the news media, increasing the likelihood and the cost of corporate misconduct being discovered [23]. Under the pressure of public opinion and moral condemnation, corporate image and operations suffer. To maintain environmental legitimacy and shape a green corporate image, companies are motivated to increase green investment, achieve green production, and build green core competitiveness [6, 19].

Based on the above theoretical analysis, we propose the following research hypothesis:

H1: All else being equal, air pollution prompts corporate green investment.

Research Design

Sample Selection and Data Sources

To address the evolution and intensification of air pollution issues, China's Ministry of Environmental Protection introduced a new Air Quality Index (AQI) in 2013, following the newly issued "Ambient Air Quality Standards". As 2014 marked the first year of systematic air pollution monitoring, we selected the period from 2014 to 2022 as the sample study period, focusing on A-share listed companies in high-pollution industrial sectors. We match the daily air quality data of each prefecture-level city to the company level based on the city of registration for each company. The sample selection criteria are as follows: (1) exclude financial industry data; (2) exclude samples with missing relevant variables; (3) exclude ST and ST* samples. The results are a final sample consisting of 15,547 company-year observations.

The data on corporate air pollution is sourced from the CNRDS database, while the data on green investment and other financial data is sourced from the CSMAR database. Green investment data is manually collected from the "Construction in Progress" detail accounts in the annual reports of listed companies, filtering out amounts related to green environmental protection projects. The data on urban GDP per capita comes from the China Urban Statistical Yearbook. To control the influence of extreme values, we winsorize the upper and lower 1% of continuous variables.

Variable Definition

Dependent Variable: Green Investment (GI)

According to the definition of green investment by [18], all capital expenditures related to environmental protection are included in the corporate green investment. Following the methods of [19], we download the financial statement notes on the construction in progress of A-share industrial listed companies from the CSMAR database. Using text analysis and machine learning, we extract investment expenditure items related to pollution prevention, ecological environment management, and green production, such as desulfurization and denitrification, sewage treatment, energy conservation, dust removal, waste gas and waste residue treatment, environmental management, ecological restoration, and cleaner production. The annual amount of green investment by enterprises is then aggregated. To improve the readability of the regression coefficients and account for the relatively small amount of green investment after scaling, we standardize the scale of green investment based on total assets at the end of the year and then multiply it by 100 to measure the corporate green investment (*EI*). A larger value indicates a higher level of corporate green investment, and vice versa.

Independent Variable: Air Pollution (AQI)

Drawing on the research of [2] and [8], we use the average air quality index (AQI) in each region to measure the air pollution level. The AQI is constructed based on six air pollutants: ozone (O_3), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter with aerodynamic diameters less than 10 mm and 2.5 mm (PM10 and PM2.5). A higher AQI indicates poorer air quality, i.e., more severe air pollution.

Control Variables (Controls)

Referring to previous literature, we primarily select control variables from the levels of enterprise financial status, corporate governance, and regional characteristics. First, for corporate financial status, we include financial leverage (*Lev*), firm growth (*Growth*), profitability (*ROA*), cash flows from operating activities (*Cflow*), firm size (*Size*), and firm age (*Age*). Second, for the internal corporate governance, we include board size (*Board*), percentage of independent directors (*Indep*), and shareholding concentration (*Shrcr*). Third, for the external regional characteristics, we control regional economic development (*per GDP*). Additionally, to mitigate the impact of unobservable variables on

the conclusions, we control for firm (*Firm*) and year (*Year*) fixed effects in the regression. The specific variable definitions are detailed in Table 1.

Model Design

To investigate the impact of air pollution on corporate green investment, we construct the following baseline regression model:

$$GI_{it} = \alpha_0 + \alpha_1 AQI_{it} + \alpha_2 Controls + Firm_i + Year_t + \varepsilon_{it} (1)$$

where *GI* is the green investment of company *i* in year *t*, *AQI* is the average value of the air quality index of the city where company *i* is located in year *t*, *Controls* are the control variables, $Firm_i$ is the firm fixed effect, $Year_t$ is the time fixed effect, and ε_{it} is the error term. The parameter α_1 reflects the impact of air pollution on corporate green investment. To ensure the robustness of the conclusions, all regressions use robust standard errors with clustering at the firm level.

Empirical Results and Analysis

Descriptive Statistics

Table 2 presents the descriptive statistics of the main variables. The mean value of corporate green investment (*GI*) is 8.5570, with a standard deviation of 10.3088, a maximum value of 53.4301, and a minimum value of 0.0000. This indicates a significant disparity in green investment among the sample companies, suggesting an overall low level and substantial room for improvement. The mean value of air pollution (*AQI*) is 64.9608, the median is 61.4536, with a standard deviation of 21.0152, and the minimum and maximum values are 32.0904 and 121.2493, respectively. This shows significant differences in air pollution levels among the sample cities. The statistical distribution of other variables is reasonable and highly consistent with the existing literature.

Analysis of Baseline Regression Results

Table 3 presents the test results of the baseline regression model. As shown in column (1) of Table 3, the regression results, which only control for year and firm fixed effects, indicate that the coefficient of air pollution (*AQI*) is 0.0339, significant at the 10% level. In column (2), after adding firm-level control variables, the coefficient of air pollution (*AQI*) is 0.0368, significantly positive at the 5% level. In terms of economic significance, a one standard deviation increase in the AQI leads to an average increase of 2.3906 units (=0.0368*64.9608) in green investment by firms. Considering that the mean value of green investment in the sample is 8.5570, this implies that an increase of one standard deviation in the AQI results in approximately a 27.94% (=2.3906/8.5570) rise in green investment, underscoring the substantial economic impact of air quality on corporate environmental behavior. This suggests that the worsening of air pollution prompts companies to increase green investment, thereby verifying the research hypothesis H1. Regional air pollution increases the external environmental pressure faced by companies, compelling them to increase green investment to promote the development of a low-carbon economy. Simultaneously, companies are incentivized to alleviate external pressures and pursue long-term growth opportunities through green investments.

Table 1. Definition of variables.

Variable type	Variable name	Symbol	Variable definitions
Dependent variable	Green investment	GI	(Amount of green investments* 100)/total assets
Independent variable	Air pollution	AQI	Air quality index (AQI)
Control variables	Financial leverage	Lev	Asset-liability ratio
	Firm growth	Growth	Revenue growth rate
	Profitability	ROA	Net profit margin on total assets
	Cash flows from operating activities	Cflow	Net cash flow from operating activities/total assets
	Board size	Board	Ln (number of board members)
	Percentage of independent directors	Indep	Number of independent directors/ number of board of directors
	Firm size	Size	Ln (total assets)
	Firm age	Age	Ln (current year - year of listing of the enterprise + 1)
	Shareholding concentration	Shrcr	The shareholding ratio of the largest shareholder
	Regional economic development	perGDP	Ln (level of GDP per capita by region)

Table 2. Descriptive statistics.

Variable	N	Mean	Std. Dev.	Min	Median	Max
GI	15547	8.5570	10.3088	0.0000	4.9075	53.4301
AQI	15547	64.9608	21.0152	32.0904	61.4536	121.2493
Lev	15547	0.3866	0.1831	0.0599	0.3801	0.8523
Growth	15547	0.1698	0.3316	-0.4896	0.1162	1.9155
ROA	15547	0.0461	0.0571	-0.1928	0.0439	0.2052
Cflow	15547	0.0562	0.0630	-0.1272	0.0536	0.2414
Board	15547	2.1059	0.1947	1.6094	2.1972	2.6391
Indep	15547	0.3770	0.0530	0.3333	0.3636	0.5714
Size	15547	22.2397	1.2442	20.1259	22.0481	26.3891
Age	15547	1.9644	0.9385	0.0000	2.0794	3.4340
Shrholder	15547	33.9263	14.4547	8.8300	31.8600	74.9900
perGDP	15547	11.5816	0.4373	10.3527	11.6746	12.2068

Table 3. Baseline regression results.

Variable	(1)	(2)
	GI	GI
AQI	0.0339* (1.89)	0.0368** (2.07)
Lev	–	6.4203*** (4.03)
Growth	–	-1.7081*** (-6.99)
ROA	–	0.8818 (0.41)
Cflow	–	-4.9257*** (-3.14)
Board	–	-0.2718 (-0.24)
Indep	–	-1.0511 (-0.32)
Size	–	2.6111*** (5.84)
Age	–	0.6259* (1.74)
Shrholder	–	0.0422* (1.76)
perGDP	–	0.9562 (1.41)
Firm/Year	Yes	Yes
_cons	6.35*** (5.46)	-66.63** (-5.17)
N	15547	15547
Adj R2	0.4404	0.4532

Note: t-values are in parentheses and***,**, and* indicate significance at the 1%, 5%, and 10% levels, respectively. Same as below.

Robustness Tests

Replacing the Measurement Method of the Independent Variables

Referring to the method of [26], we use the logarithm of the green investment amount to re-measure green investment and conduct regression analysis on model (1). As shown in column (1) of Table 4, the coefficient of air pollution (*AQI*) is significantly positive, further supporting the research conclusions.

Lagging the Independent Variable by One Period

Considering the lag effect of air pollution, to reduce the problem of bidirectional causality and exclude the interference of endogeneity, we introduce green investment lagged by one period into the model and conduct the regression again. As shown in column (2) of Table 4, the coefficient of air pollution (*AQI*) is positive at a 5% significant level, verifying the robustness of the core conclusions.

Replacing the Measurement Methods of the Dependent Variable

Referring to the methods of [9] and [10], we use the average PM2.5 to measure the air pollution and reconducts regression analysis. PM2.5 refers to particulate matter with an aerodynamic diameter of less than or equal to 2.5 micrometers, which can adhere to various toxic and harmful substances and remain in the atmosphere for a long time, being a major factor causing air pollution. As shown in column (3) of Table 4, the coefficient of air pollution (*AQI*) is significantly positive, confirming the robustness of the results.

Table 4. Robustness test.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
					Phase I AQI	Phase II GI
AQI	0.0020* (1.76)	0.0525** (2.47)	0.0330* (1.70)	0.0365* (1.92)	–	0.1734** (2.24)
Rain	–	–	–	–	-0.0725*** (-26.82)	–
Controls	Yes	–	Yes	Yes	Yes	Yes
Firm/Year	Yes	–	Yes	Yes	Yes	Yes
_cons	13.37*** (22.17)	-72.17*** (-4.85)	-65.04*** (-5.08)	-68.92*** (-5.10)	–	–
N	15547	12344	15547	13506	7159	7159
Adj R2	0.8795	0.4685	0.4628	0.4627	–	–
KP F-statistic	–	–	–	–	719.35	–
Centered R2	–	–	–	–	–	0.0108

Adding Control Variables

To avoid the impact of omitted variables, we further control for other factors that may affect corporate green investment, including dual positions (*Dual*), Tobin's Q value (*TobinQ*), whether audited by the Big Four International Accounting Firms (*Big4*), and the regional GDP growth rate (*Gdp*), and re-run the sample regression. As shown in column (4) of Table 4, the coefficient of air pollution (*AQI*) is positive and significant at the 10% level, consistent with the main regression results.

Instrumental Variable Method (2SLS)

To mitigate reverse causality and other endogeneity issues, we adopt the approach of [12], using urban rainfall (*Rain*) as an instrumental variable for air pollution. Rainfall is theoretically an effective instrumental variable for air pollution because, on the one hand, as a major meteorological factor affecting air pollution, urban rainfall helps reduce air pollution levels and improve air quality, thus meeting the relevant conditions. On the other hand, urban rainfall is determined by meteorological conditions and geographical factors, having no direct relationship with corporate economic activities, thus satisfying the homogeneity assumption of an instrumental variable. Columns (5) and (6) of Table 4 report the results of the two-stage least squares (2SLS) regression based on instrumental variables. The first stage results (Column (5)) show that rainfall (*Rain*) is significantly and negatively correlated with air pollution (*AQI*), consistent with expectations. The F-statistic is 719.35, far exceeding the critical value of 16.38 at the 10% level, indicating no weak instrumental variable problem. The second stage results (column (6)) show that after using the instrumental variables for estimation, air pollution (*AQI*) remains significantly positively correlated with corporate green investment (*GI*), further validating the robustness of the baseline model regression results.

Further Analysis

Mechanism Analysis

Based on existing research and theoretical analysis, air pollution triggers formal environmental regulation by the government and exerts pressures through informal regulation from the media and the public. These factors collectively drive companies to increase green investments, implement green differentiation strategies, reduce environmental compliance costs, enhance environmental legitimacy, and pursue "green" profits. To test these mechanisms directly, we examine the impact of air pollution on government environmental regulation, media attention, and public environmental supervision. Following the approach of [42], we measure local government environmental regulation (*GER*) by calculating the ratio of the frequency of the words related to environmental protection and governance (such as "green," "environment," "PM2.5," "environmental protection," "pollution," "wastewater," "energy saving," and "recycling") in municipal government work reports to the total word count, multiplied by 100. This data is manually collected from government work reports on local government websites. Drawing on [37], media attention (*Media*) is measured by the natural logarithm of the total number of news articles about listed companies in both online and print financial news titles and content. This data comes from the China Research Data Service Platform (CNRDS). Following the methods of [43], public environmental supervision (*Public*) is measured

Table 5. Mechanism analysis.

Variable	(1)	(2)	(3)
	GER	Media	Public
AQI	0.0018*** (3.34)	0.0018* (1.67)	0.0074*** (8.52)
Controls	Yes	Yes	Yes
Firm/Year	Yes	Yes	Yes
_cons	1.79*** (4.52)	2.58*** (3.23)	3.44*** (5.70)
Adj R2	0.6172	0.7236	0.9756
N	15396	15050	15526

by the natural logarithm of the average daily search index for keywords like "environmental pollution", "air pollution", and "smog" on the Baidu search engine. The data is gathered using Python tools to scrape and compile search engine data from Baidu.

The results of the mechanism analysis are shown in Table 5. The coefficients for air pollution (*AQI*) and government environmental regulation (*GER*), media attention (*Media*), and public environmental supervision (*Public*) are all significantly positive. This indicates that air pollution prompts local governments to regulate and attracts attention and supervision from the news, media, and the public. As air pollution intensifies, companies face greater external environmental regulation pressure [8]. This supervision includes formal environmental regulation set by laws and regulations, as well as informal environmental supervision from the media and the public. To cope with increased operational costs and reduced profit levels due to external regulation, companies must undergo green transformation and achieve low-carbon development. Stakeholder theory and legitimacy theory suggest that, under stakeholder supervision, companies alleviate conflicts and adhere to legitimacy standards to gain recognition and support by implementing green investments [44]. Therefore, proactive green investment to reduce pollutant emissions is crucial for companies to gain social recognition and legal status. The environmental legitimacy pressure exerted by stakeholders, primarily the government and supplemented by the media and the public, is a key factor in driving corporate green investments. In other words, local government environmental regulation, media attention, and public environmental supervision are the mechanisms through which air pollution impacts corporate green investment.

Heterogeneity Analysis

Marketization Level

We use the marketization index developed by [45] to measure the marketization level of different regions. A higher marketization index indicated a higher marketization level of the local economy. The full sample is divided into low and high-marketization level groups based on the median marketization level of the region where the companies are located, and regression analysis is performed accordingly. The results are shown in columns (1) and (2) of Table 6. The regression analysis for the low marketization level sample shows that the coefficient of air pollution (*AQI*) is significantly positive. In contrast, in the high marketization level sample, the coefficient of air pollution (*AQI*) is positive but not significant. Additionally, the Fisher combination test is used to test the significance of the difference in coefficients between groups, and the results show that the empirical P-value is significant at the 1% statistical level. This indicated that the level of marketization, to some extent, weakens the positive effect of air pollution on corporate green investment. This may be because, in regions with higher marketization levels, relevant environmental laws and regulations are more comprehensive, and government environmental regulation and public environmental awareness are also higher [26]. Local companies place greater emphasis on environmental protection and low-carbon development, and the level of green economy and environmental governance is relatively mature. In contrast, in regions with lower marketization levels, local governments focused more on economic growth, and environmental protection laws and standards are relatively lax. The penalties for corporate pollution behavior are also lighter or even overlooked [28]. Additionally, local companies are more likely to engage in extensive and low-end activities with harmful gas emissions, reducing their motivation to undertake proactive environmental governance. Therefore, in regions with lower marketization levels, severe air pollution issues compel the government to strengthen the enforcement of environmental regulations, effectively leveraging government and public environmental supervision, thereby forcing companies to increase their green investments.

Heavily Polluting Industries

To examine the differences between industries, we classify listed companies into non-heavily polluted industry groups and heavily polluted industry groups based on the categories outlined in the "Listed Companies Environmental Verification Industry Classification and Management Directory" (Environmental Affairs Office Letter [2008] No.373). As shown in columns (3) and (4) of Table 6, the coefficients of air pollution (*AQI*) for non-heavily polluted industries are not significant. However, for heavily polluted industries, the coefficient of air pollution (*AQI*) is significantly positive at the 5% level. Moreover, the difference in coefficient between the groups is significant at the 1% level (empirical p-value of 0.004), indicating that air pollution has a more pronounced effect on promoting green investment in heavily polluting

Table 6. Heterogeneity analysis.

Variable	Marketization level		Heavily polluting industries		Firm ownership	
	(1)	(2)	(3)	(4)	(5)	(6)
	low	high	non	heavily	non-SOE	SOE
AQI	0.0505** (1.66)	0.0086 (0.35)	0.0181 (0.89)	0.0572** (1.97)	0.0188 (0.83)	0.0536* (1.85)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm/Year	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-35.79 (-1.63)	-69.18** (-3.24)	-26.75* (-1.82)	-106.70*** (-5.56)	-52.77*** (-3.65)	-92.38*** (-3.31)
r2	0.620	0.582	0.539	0.539	0.525	0.603
N	7555	7295	9427	6114	10977	4532
Empirical p-value	0.008***		0.004***		0.000***	

Note: Coefficient difference p-values were calculated by autosampling (Bootstrap) 1000 times.

industries compared to non-heavily polluting industries. This is primarily because companies in heavily polluting industries, such as iron and steel, chemicals, and cement, have higher pollution emissions and are major sources of air pollution, attracting more attention and scrutiny from the government, media, and public [15]. On the one hand, governmental departments enforce strict environmental regulations and policies on heavily polluting industries. To avoid hefty fines, production restrictions, or even shutdowns, these companies are more inclined to invest in green initiatives to comply with regulatory requirements. On the other hand, the air pollution issues of heavy-polluting companies are more prominent, leading to negative media coverage and public dissatisfaction [20]. This societal pressure forces companies to take measures to improve their environmental performance to maintain their corporate image and social reputation. Therefore, when air pollution worsens, heavily polluting companies are more likely to engage in green investments in response to stricter regulation and social pressure.

Firm Ownership

Based on firm ownership, we divide the sample into non-state-owned (non-SOE) and state-owned (SOE) enterprise groups. The grouped regression results are shown in columns (5) and (6) of Table 6. The coefficient of air pollution (*AQI*) for the non-SOE enterprise group is positive but not significant, whereas the coefficient for the SOE enterprise group is significantly positive. Additionally, there is a significant difference in the coefficients between the groups (p-value = 0.000). This indicates that air pollution has a more pronounced effect on promoting green investment in SOE enterprises compared to non-SOE enterprises. This may be because SOE enterprises generally have closer political ties with local governments and are expected to play a leading role in environmental protection in the eyes of the public, thus bearing more social responsibility [46]. When facing air pollution issues, SOE enterprises encounter greater regulatory pressure and stricter assessment requirements within the same institutional environment, making them more sensitive to environmental legitimacy [16]. Additionally, the environmental performance of SOE enterprises directly impacts the political reputation and promotion opportunities of their management. To maintain a political reputation and gain legitimacy recognition, SOE enterprises are more motivated to invest in green initiatives, possibly allocating more funds for environmental protection and adopting additional environmental measures. Moreover, compared to non-SOE enterprises, SOE enterprises have more funds and resources, enabling them to better bear the costs of green investment and quickly implement environmental measures.

Government Subsidies

We divide the sample into low and high-government subsidy groups based on the median government subsidies and then conduct group regressions sequentially. Government subsidies are measured by the logarithm of government subsidies received by enterprises for their daily operations. The results shown in columns (1) and (2) of Table 7 indicate that, in the low government subsidy group, the coefficient of air pollution (*AQI*) is significantly positive. However, in the high government subsidy group, air pollution (*AQI*) has a negative but not significant effect on corporate green investment and passes the test of difference in coefficients between groups. This suggests that the positive impact of air pollution on green investment is more pronounced in enterprises receiving lower government subsidies compared to those receiving higher subsidies. A possible reason is that industrial enterprises are typically major contributors to local

Table 7. Heterogeneity analysis.

Variable	Government subsidies		Institutional shareholding	
	(1)	(2)	(3)	(4)
	low	high	low	high
AQI	0.0584*** (3.10)	-0.0513 (-1.14)	0.0474* (1.85)	0.0189 (0.71)
Controls	Yes	Yes	Yes	Yes
Firm/Year	Yes	Yes	Yes	Yes
_cons	-69.47*** (-4.65)	-79.44*** (-3.34)	-33.54** (-2.33)	-8.26 (-0.64)
r2	0.592	0.608	0.600	0.553
N	9573	5438	7421	7573
Empirical p-value	0.000***		0.072*	

Note: Coefficient difference p-values were calculated by autosampling (Bootstrap) 1000 times.

GDP growth, and government subsidies are a crucial means of supporting these enterprises in the market. Government subsidies can enhance the cash flow of enterprises, thereby promoting their investment activities [47]. Generally, industrial enterprises that significantly contribute to local economic growth tend to receive more government support, and the government prefers to subsidize well-performing enterprises. In contrast, enterprises receiving lower government subsidies lack direct financial support [19]. When air pollution worsens, these enterprises need to rely more on their efforts to respond to external regulations and societal expectations. Consequently, enterprises with lower government subsidies are more inclined to invest in green initiatives to demonstrate their environmental responsibility and responsiveness, improve their environmental image, and gain recognition from the government, the public, and investors.

Institutional Shareholding

The sample is divided into low and high institutional shareholding groups based on the median proportion of corporate institutional investors' holdings. The regression results, as shown in columns (3) and (4) of Table 7, indicate that in the low institutional shareholding group, the coefficient of air pollution (*AQI*) is significantly positive at the 10% level. However, in the high institutional shareholding group, the coefficient of air pollution (*AQI*) is not significant. Additionally, the between-group difference test is significant. This indicates that the positive effect of air pollution on green investment is stronger for companies with lower institutional shareholding. A possible explanation is that institutional investors, with their high level of professionalism, are more capable of supervising and managing enterprises. They possess advanced information analysis skills and rational decision-making mechanisms, paying close attention to policy trends and responding to the nation's green development strategy. Consequently, institutional investors tend to hold shares in companies that actively fulfill their environmental responsibilities [48, 49]. Thus, the higher the institutional shareholding, the more actively these investors participate in corporate governance, providing effective supervision that enhances the company's willingness to invest in green investments and improve environmental performance, thereby promoting long-term low-carbon development [11]. In contrast, companies with lower institutional shareholding, when faced with air pollution issues, rely more on external regulation and social pressure to drive green investment. Lacking strong internal oversight from institutional investors, these companies are more susceptible to external pressures from the government, media, and the public, prompting them to take environmental measures and engage in green investments.

Conclusions and Implications

Air pollution is the most widespread and significant environmental issue in China, with undeniable negative impacts on economic development and public health. Given the increasing governmental and public emphasis on ecological governance and green transformation, a critical question arises: Can air pollution and its mitigation compel enterprises to engage in green investments through environmental regulations, thereby achieving low-carbon economic development? This concern affects all sectors of society. We empirically examine the impact of air pollution on corporate green investment using a sample of China's A-share industrial listed companies from 2014 to 2022. The main findings are as follows: (1) Air pollution significantly promotes corporate green investment, and this conclusion remains robust after a series of robustness tests. (2) Further analysis of the underlying mechanism reveals that air

pollution can promote corporate green investment by enhancing formal environmental regulation through increased government environmental supervision and informal regulation through media attention and public environmental supervision. (3) Heterogeneity analysis shows that the positive effect of air pollution on green investment is more pronounced for enterprises in regions with lower marketization levels, in heavily polluting industries that are SOE, receive lower government subsidies, and have lower institutional shareholding. The findings reveal the mechanism by which air pollution, as a macro-external environment, impacts micro-enterprise green investment, supporting the theoretical expectation of the coercive effect of external environmental legitimacy pressure.

Based on the above conclusions, the implications are as follows:

First, governments, as leaders in environmental governance, should strengthen the management and supervision of enterprises to encourage green investment. Regulators should fully recognize the crucial role of enterprises in environmental governance. Enterprises are the primary creators of environmental problems, with regional air pollution essentially being the negative external economic consequence of their extensive development methods. The government should optimize supervisory mechanisms, guide enterprises to actively engage in green investment, and reduce the likelihood of illegal emissions through increased regulation and penalties, thereby forcing enterprises to upgrade and transform. By considering regional characteristics, industry specifics, and firm ownership, governments should formulate reasonable environmental regulatory plans to jointly promote green investment within their jurisdiction, improve regional air quality, and support low-carbon economic development.

Second, the role of the media in supervising air pollution control should be strengthened. Supervision mechanisms should be established and improved to fully leverage the media's environmental oversight function. The media should proactively shoulder social environmental responsibility, enhance reporting and guidance on corporate air pollution behaviors, and promote green development among enterprises. The media should continuously track corporate environmental governance issues, enhancing professionalism, accountability, and independence to ensure truthful reporting and proper guidance of public opinion. By encouraging enterprises to develop in the green sectors through both positive and negative guidance, the media can complement government regulation and help build a comprehensive environmental oversight system.

Third, public participation in environmental pollution governance should be enhanced, especially in guiding long-term supervision of corporate green investment decisions. The public is a driving force in promoting green economic development. The government should strengthen environmental protection education and awareness, mobilizing the public to participate in environmental protection and supervision. Public supervision can create pressure on companies, encouraging them to invest in green initiatives and reduce pollution. To improve the effectiveness of public oversight, the development of online platforms should be advanced, ensuring effective expression of public concerns and urging companies to take swift corrective actions.

Fourth, enterprises should fully leverage their role as mainstays of green governance by actively engaging in green investments and implementing low-carbon development strategies. As primary polluters, companies should enhance green management under the supervision of local governments and the media. They should remain sensitive to external air pollution issues and transform external environmental pressures into motivation for green investment and social responsibility. Enterprises should integrate green and low-carbon development into their production and operation, making strategic transformations to meet the shared interests of companies, governments, and the public, thereby gaining stakeholders' recognition. This approach can enhance corporate legitimacy and image, reduce pollution, achieve low-carbon transformation, and improve green competitiveness.

Acknowledgments

The authors acknowledge financial support from the Philosophy and Social Science Funds of Hunan Province [Grant No.22JD040], the Education Department Scientific Research Youth Project of Hunan Province [Grant No.22B0528].

Conflict of Interest

The authors declare no conflict of interest.

References

1. WANG L., DAI Y., KONG D. Air pollution and employee treatment. Journal of Corporate Finance, **70**, 102067, **2021**.
2. DONG R., FISMAN R., WANG Y., XU N. Air pollution, affect, and forecasting bias: Evidence from Chinese financial analysts. Journal of Financial Economics, **139** (3), 971, **2021**.
3. FU S., VIARD V.B., ZHANG P. Air Pollution and Manufacturing Firm Productivity: Nationwide Estimates for China. The Economic Journal, **131** (640), 3241, **2021**.
4. CHEN H., LIU S., YANG D., ZHANG D. Automatic air pollution monitoring and corporate environmental disclosure: a quasi-natural experiment from China. Sustainability Accounting, Management and Policy Journal, **14** (3), 538, **2023**.
5. NGUYEN T.H.H., ELMAGRHI M.H., NTIM C.G., WU Y. Environmental performance, sustainability, governance and financial performance: Evidence from heavily

polluting industries in China. Business Strategy and the Environment, **30** (5), 2313, **2021**.
6. FAROOQ U., ASHFAQ K., RUSTAMOVNA R.D., AL-NAIMI A.A. Impact of air pollution on corporate investment: New empirical evidence from BRICS. Borsa Istanbul Review, **23** (4), 876, **2023**.
7. WANG L., XING F., YU Y., DAI Y. Does severe air pollution affect firm innovation: evidence from China. Applied Economics Letters, **28** (7), 551, **2021**.
8. XUE S., ZHANG B., ZHAO X. Brain drain: The impact of air pollution on firm performance. Journal of Environmental Economics and Management, **110**, 102546, **2021**.
9. TRAN N.H., FU L., BOEHE D.M. How does urban air pollution affect corporate environmental performance? Journal of Cleaner Production, **383**, 135443, **2023**.
10. DING X., VUKOVIC D.B., SHAMS R., VUKOVIC N. Does air pollution affect corporate shareholder responsibility performance?: Analysis of regression discontinuity design based on the "Qinling-Huaihe" line. Environment, Development and Sustainability. **2023**.
11. KRUEGER P., SAUTNER Z., STARKS L.T. The Importance of Climate Risks for Institutional Investors. The Review of Financial Studies, **33** (3), 1067, **2020**.
12. ZHAO Z., LIU L., ZHANG F., YANG G. Does air pollution prompt corporations to implement green management? Evidence from China. Environmental Science and Pollution Research, **29** (6), 8933, **2022**.
13. LIU J., PAN X., QU Y., WANG C., WU W. Air pollution, human capital and corporate social responsibility performance: evidence from China. Applied Economics, **54** (4), 467, **2022**.
14. TAN Z., TAN J., CHAN K.C. Seeing is believing? The impact of air pollution on corporate social responsibility. Corporate Social Responsibility and Environmental Management, **28** (1), 525, **2021**.
15. LIN Y., HUANG R., YAO X. Air pollution and environmental information disclosure: An empirical study based on heavy polluting industries. Journal of Cleaner Production, **278**, 124313, **2021**.
16. SIMING Y., LINGLI X., PENG D., ZHAOHUI Q., QIANQIAN Z., TUANJIE Z. The impact of air pollution on corporate environmental information disclosure–Evidence from heavy pollution industries in China. Finance Research Letters, **59**, 104793, **2024**.
17. LIU B., WU J., CHAN K.C. Does air pollution change a firm's business strategy for employing capital and labor? Business Strategy and the Environment, **30** (8), 3671, **2021**.
18. EYRAUD L., CLEMENTS B., WANE A. Green investment: Trends and determinants. Energy Policy, **60**, 852, **2013**.
19. CHEN Y., MA Y. Does green investment improve energy firm performance? Energy Policy, **153**, 112252, **2021**.
20. ZHONG Q., WEN H., LEE C.-C. How does economic growth target affect corporate environmental investment? Evidence from heavy-polluting industries in China. Environmental Impact Assessment Review, **95**, 106799, **2022**.
21. LIU G., YANG Z., ZHANG F., ZHANG N. Environmental tax reform and environmental investment: A quasi-natural experiment based on China's Environmental Protection Tax Law. Energy Economics, **109**, 106000, **2022**.
22. SARMIENTO L. Air pollution and the productivity of high-skill labor: evidence from court hearings*. The Scandinavian Journal of Economics, **124** (1), 301, **2022**.
23. HU W.-Q., ZHAO J., ZHAO L. Does enhancing environmental regulation promote corporate green investment? Evidence from China. Energy & Environment, **34** (8), 3265, **2023**.
24. HAN S.-R., LI P., XIANG J.-J., LUO X.-H., CHEN C.-Y. Does the institutional environment influence corporate social responsibility? Consideration of green investment of enterprises - evidence from China. Environmental Science and Pollution Research, **29** (9), 12722, **2022**.
25. XU X., YAN Y. Effect of political connection on corporate environmental investment: evidence from Chinese private firms. Applied Economics Letters, **27** (18), 1515, **2020**.
26. HUANG L., LEI Z. How environmental regulation affect corporate green investment: Evidence from China. Journal of Cleaner Production, **279**, 123560, **2021**.
27. CHANG K., DING J., LOU Q., LI Z., YANG J. The impact of capital leverage on green firms' investment: New evidence regarding the size and age effects of Chinese green industries. Finance Research Letters, **38**, 101529, **2021**.
28. LIU S., LIU H., CHEN X. Does environmental regulation promote corporate green investment? Evidence from China's new environmental protection law. Environment, Development and Sustainability, **26** (5), 12589, **2024**.
29. SCHALTENBRAND B., FOERSTL K., AZADEGAN A., LINDEMAN K. See What We Want to See? The Effects of Managerial Experience on Corporate Green Investments. Journal of Business Ethics, **150** (4), 1129, **2018**.
30. CHEN L., LIU S., LIU X., WANG J. The Carbon Emissions Trading Scheme and Corporate Environmental Investments: A Quasi-natural Experiment from China. Emerging Markets Finance and Trade, **58** (9), 2670, **2022**.
31. MILLER M.R., NEWBY D.E. Air pollution and cardiovascular disease: car sick. Cardiovascular Research, **116** (2), 279, **2019**.
32. ZHANG B., CHEN X., GUO H. Does central supervision enhance local environmental enforcement? Quasi-experimental evidence from China. Journal of Public Economics, **164**, 70, **2018**.
33. ZHENG S., KAHN M.E., SUN W., LUO D. Incentives for China's urban mayors to mitigate pollution externalities: The role of the central government and public environmentalism. Regional Science and Urban Economics, **47**, 61, **2014**.
34. WANG L., KONG D., ZHANG J. Does the Political Promotion of Local Officials Impede Corporate Innovation? Emerging Markets Finance and Trade, **57** (4), 1159, **2021**.
35. GREENSTONE M., HE G., JIA R., LIU T. Can Technology Solve the Principal-Agent Problem? Evidence from China's War on Air Pollution. American Economic Review: Insights, **4** (1), 54, **2022**.
36. CHANG Y., HE Y., JIN X., LI T., SHIH C.M. Media Coverage of Environmental Pollution and the Investment of Polluting Companies. Asia-Pacific Journal of Financial Studies, **49** (5), 750, **2020**.
37. HE F., GUO X., YUE P. Media coverage and corporate ESG performance: Evidence from China. International Review of Financial Analysis. **91**, 103003, **2024**.
38. PAN X., CHEN X., YANG X. Examining the relationship between negative media coverage and corporate social responsibility. Business Ethics, the Environment & Responsibility, **31** (3), 620, **2022**.
39. TAO Y., WANG D., YE Y., WU H., ZHANG Y. The role of public environmental concern on corporate

social responsibility: Evidence from search index of web users. Energy Economics, **126**, 107041, **2023**.
40. INWALD J.F., BRUINE DE BRUIN W., YAGGI M., ÁRVAI J. Public Concern about Water Safety, Weather, and Climate: Insights from the World Risk Poll. Environmental Science & Technology, **57** (5), 2075, **2023**.
41. YU C., LONG H., ZHANG X., TAN Y., ZHOU Y., ZANG C., TU C. The interaction effect between public environmental concern and air pollution: Evidence from China. Journal of Cleaner Production, **391**, 136231, **2023**.
42. CHEN Z., KAHN M.E., LIU Y., WANG Z. The consequences of spatially differentiated water pollution regulation in China. Journal of Environmental Economics and Management, **88**, 468, **2018**.
43. ZHENG S., WU J., KAHN M.E., DENG Y. The nascent market for "green" real estate in Beijing. European Economic Review, **56** (5), 974, **2012**.
44. MOSS A., NAUGHTON J.P., WANG C. The Irrelevance of Environmental, Social, and Governance Disclosure to Retail Investors. Management Science, **70** (4), 2626, **2024**.
45. WANG X.L., ZHU H.P., FAN G. Marketization Index of China's Provinces: NERI Report. Beijing: Social Sciences Academic Press (China), Beijing, **2021**.
46. LEI X.-T., XU Q.-Y., JIN C.-Z. Nature of property right and the motives for holding cash: Empirical evidence from Chinese listed companies. Managerial and Decision Economics, **43** (5), 1482, **2022**.
47. SHAO K., WANG X. Do government subsidies promote enterprise innovation? - Evidence from Chinese listed companies. Journal of Innovation & Knowledge, **8** (4), 100436, **2023**.
48. CHI Y., HU N., LU D., YANG Y. Green investment funds and corporate green innovation: From the logic of social value. Energy Economics, **119**, 106532, **2023**.
49. JIN C., MONFORT A., CHEN F., XIA N., WU B. Institutional investor ESG activism and corporate green innovation against climate change: Exploring differences between digital and non-digital firms. Technological Forecasting and Social Change, **200**, 123129, **2024**.