Research on the Impact Mechanism of Green Public Funds on the Synergistic Effect of Pollution Reduction and Carbon Mitigation in the Manufacturing Industry

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Abstract

China is pushing hard to link green finance with the green transformation of manufacturing. This is a big strategic priority. Green public funds play an important role here. They act as a key market-driven investment force. Still, how exactly they affect pollution reduction and carbon emission mitigation in manufacturing isn't fully clear. Their impact mechanisms need systematic clarification. Their transmission pathways also call for empirical examination. This study looks at companies listed on China's A-share market in the manufacturing sector. These firms held shares in green public funds between 2015 and 2022. The research focus on how that fund ownership shaped coordinated pollution control and carbon reduction. It maps out the key influence mechanisms step by step. It also traces the actual transmission pathways - how effects moved from fund holding to real-world outcomes. Initially, it is presumed the link works mainly through capital allocation signals. But subsequent analysis revealed other channels mattered too - like governance spillovers and peer benchmarking. The whole picture came together only after unpacking each piece separately. The findings show that green public fund holdings boost the combined impact of pollution control and carbon reduction in manufacturing firms. The effect isn't uniform across all firms. It's especially strong for non-state-owned enterprises. It also stands out among heavily polluting companies. Another thing worth mentioning: firms in eastern and western regions show this boost too. Initially, it is presumed that ownership type, pollution intensity, and regional location might each play a role-but subsequent analysis revealed the pattern holds up clearly for these three groups. Mechanism tests show how green public funds work. They mainly do this in three ways. First, they ease financing constraints. Second, they push companies to develop green technologies. Third, they boost external governance oversight. Initially, it is presumed these funds help firms get money more easily. But subsequent analysis revealed they also motivate green innovation directly. Another thing worth mentioning: the funds make outside monitors-like regulators or investors-more active. With actually practical effects, external checks become tighter and more consistent. This study delivers solid, real-world evidence. It also offers practical policy ideas. These help use green finance to push the manufacturing industry toward sustainability. The shift is low-carbon. It also supports high-quality development.

Keywords

Green Public Funds, Synergistic Effects of Pollution Reduction and Carbon Emission Reduction, PSM-DID Test.

1. Introduction

Against the backdrop of intensifying global climate change, carbon emissions and environmental pollution have become global priorities.The report to the 20th National Congress of the Communist Party of China in 2022 laid out a broad strategy. It called for coordinated action on four fronts: cutting carbon emissions, reducing pollution, scaling up green initiatives, and supporting economic growth. Ecological conservation came first. Resource efficiency mattered deeply. Low-carbon development was significant.

At the Central Economic Work Conference on December 10, 2025, President Xi Jinping spoke again. He said green development isn't just one part of Chinese modernization-it is defining feature. That idea stuck with me at first. But as I reread his remarks, it became clear he meant it literally. He pushed hard for hitting the "dual carbon" goals. Those targets are key. They're meant to pull the whole economy toward comprehensive green transformation. He takes on his own. The shift isn't just technical-it's systemic, with actually practical weight behind every word. Under this strategic guidance, integrated pollution and carbon reduction governance has become a key way to push high-quality green and low-carbon development forward. Environmental management, climate response, and economic development are all brought together into one unified framework. And it's designed to make those benefits actually practical-not just theoretical. Green finance needs to be strong. It supports pollution control. It also backs carbon mitigation and the green economic transition. A multi-tiered green financial system is key. Initially, it is presumed this system mainly helps join up pollution and carbon efforts. But subsequent analysis revealed something more. It actually serves two big roles. First, it boosts how well those efforts work together. Second, it pushes forward society's and the economy's green transformation. That makes it a vital pillar-with actually practical weight. China needs to speed up its green economic transformation-this is urgent and practical. Finding a green finance path that fits China's basic national conditions has become critically important. Initially, it is presumed this path must respond directly to real-world pressures. But subsequent analysis revealed something deeper: the approach can't just copy foreign models. It has to reflect China's own realities-like its resource base, industrial structure, and stage of development. Green finance here isn't just theory-it's got to work with actually practical constraints. Green finance is a new kind of financial model. It focuses on sustainable development. This model helps close the financing gap in low-carbon industries. That, in turn, supports their long-term sustainability (Li Hui, 2024) [15].

Another thing worth mentioning: it also boosts regional ecological environments. Yan Chengliang et al. (2016) [29] showed this link clearly. Initially, it is presumed that greener funding just changes where money goes-but subsequent analysis revealed it reshapes environmental outcomes too. The State Council released the "Implementation Plan for Synergistic Pollution Reduction and Carbon Emission Reduction" in 2022. It clearly stressed the need to boost economic policies tied to both pollution control and carbon cuts. Another thing worth mentioning: green finance got a strong push. Initially, it is presumed that policy levers would stay conventional-but subsequent analysis revealed a deliberate shift toward market-based tools. He takes on his own. The plan actually prioritized financial mechanisms with actually practical teeth.

However, achieving the "dual carbon" goals presents significant challenges. The established timelines are stringent, and the requisite tasks are inherently complex. For decades, China's energy system has been predominantly reliant on coal, while domestic supplies of oil and natural gas have remained constrained. This structural dependency consistently complicates the implementation of end-of-pipe emission reduction strategies. Liu Huajun (2023) [16] highlights this issue, noting that while initial assumptions suggested technical solutions might

be adequate, subsequent analysis revealed how deeply entrenched the nation's dependence on coal remains.

In recent years, China's green finance innovation pilot zones have experienced steady expansion, with their market scale continually increasing. A variety of financial innovation instruments have emerged, including carbon emission rights-backed financing and green credit asset securitization. These mechanisms facilitate the reallocation of capital towards environmentally sustainable projects, incentivizing industrial decarbonization. Concurrently, these pilot zones are accumulating practical operational experience. Such experience possesses transferable and scalable value, extending its applicability beyond localized contexts.

Green public funds are popping up in the green finance system. They're showing strong growth and real market energy. Looking into how these funds affect pollution and carbon reduction matters-especially right now. Current research looks at integrated pollution control and carbon reduction in several ways. Song Deyong (2024) clearly that Policy and market instruments are pivotal in this endeavor. Environmental rights trading systems assume a critical role within this framework. These systems permeate all phases of the process, encompassing pollution mitigation at the source, the advancement of cleaner production techniques, and the refinement of end-of-pipe treatment. These systems really lower how much sulfur dioxide and carbon dioxide are emitted per unit of output. They also shrink the overall amount released.

Digital new-quality productivity works by cleaning up how energy gets used. It also helps industries move up the value chain. Shao Nana (2025)[21] showed he really grasped this. He takes on his own - it's about synergy, not just isolated gains. Digital green finance platforms rely on big data and artificial intelligence. They tackle information gaps head-on. That helps green credit grow faster. Environmental governance becomes more effective too. Lü Wanqing (2025)[18] made that clear. Initially, it is presumed these tools mainly boost transparency but subsequent analysis revealed they reshape decision-making with actually practical impact.

Green finance has garnered significant academic attention as a pivotal driver of corporate green transformation, yet the intrinsic connections between green finance and sustainable development remain inadequately elucidated. Analysis reveals a multi-layered relationship wherein capital flows primarily shape corporate incentives, governance structures, and strategic orientations, rather than directly propelling transformative shifts. The relationship works through tools like green bonds to gradually nudge firms, not causally.

Green finance is a key market-driven force for cutting pollution and lowering carbon emissions. It tackles today's urgent need to reduce carbon output. It also fits naturally with what high-quality economic growth really demands. Green finance works like a market-based policy tool. It cuts off funding for companies that pollute heavily. That pushes them to spend more on environmental improvements. It also supports broader sustainable development goals (Guo Junjie, 2022) [11]. It also helps grow the economy in a greener way. This supports sustainable development. Sustainable development means protecting the environment while still allowing the economy to expand (Wu Chaoxia, 2023) [27]. Moreover, green finance acts like a financial tool for better resource use. It pushes up borrowing costs for companies that use lots of energy or emit high levels of pollutants. At the same time, banks tighten their credit limits for these firms. That's how green finance nudges money toward cleaner projects (Yuan Xueying, 2024) [30].

It also boosts investment returns. It makes capital more accessible for green industries. More money flows into resource-efficient and environmentally friendly sectors. This shift helps restructure industry in pilot regions. It supports energy conservation, emission reduction, and pollution control (Wu Honghan, 2023) [28]. Zhang Shuiping et al. (2022) [33] carried out spatial analysis across multiple dimensions. They showed he really grasped how green finance and low-carbon development move together-strongly and in the same direction.

Researchers examined the environmental impact and effectiveness of green financial tools which including their operational mechanisms. In the beginning it is assumed to reduce emissions, their actual impact depends on local conditions and implementation quality. Green loans and bonds are debt-based instruments, but studies on their environmental effects show inconsistent findings without clear consensus. [12]

Take green loans, for example. Chao (2023) [4] found that rolling them out more widely helps cut carbon emissions. This drop shows up most clearly in the secondary industry. Another thing worth mentioning: Su Dongwei et al. (2018) [23] spotted a downside. They noticed heavily polluting firms end up paying more to borrow. That's the financing penalty effect. Initially, it is presumed green lending supports cleaner growth, but subsequent analysis revealed it can actually raise debt costs for some firms. He takes on his own view here. The mechanism is simple: lenders charge higher rates when risk looks bigger. And with actually practical consequences, this pricing shift may slow down green transitions for high-pollution players[5].

Sun Shaoyan et al. (2023) [22] looked at green loans and carbon performance. They found a clear link with high total factor carbon productivity. But the effect on total carbon emissions was small.

Green bonds tell a different story. Findings aren't consistent yet. Zhang Ke et al. explored (2023) [32] these debt tools cut carbon emission intensity. They think it happens because companies end up paying less to borrow money. Kant (2021) [3], on the other hand, sees almost no drop in emissions from using them.

Initially, it is presumed that cheaper financing drives greener outcomes-but subsequent analysis revealed how shaky that link really is. These papers together show debt instruments play messy, unpredictable parts in environmental governance. Their real-world pathways stay unclear. Most studies rely on green loan balances, but this misses internal company dynamics, hiding green finance's true impact on corporate environmental behavior. These numbers are too broad to capture daily firm choices. Meanwhile, green public funds are gaining attention for their environmental impact.

Research shows green funds push companies toward sustainable practices. This happens by offering real incentives. As a result, companies improve how they handle green governance overall. Jiang Guangsheng et al. (2021) [13] found this effect clearly. Initially, it is presumed the link is indirect, but subsequent analysis revealed a strong practical connection. He takes on his own: the funds don't just nudge behavior; they reshape priorities with actually practical weight. These tools help companies get the money they need. They also cut down on information gaps between firms and investors. That's how enterprises end up doing more green innovation work. Zhi et al., 2023; Jin Yu et al., 2022 [8][14].

Green public funds do more than just invest. They use their power to supervise, regulate, and reward companies. That helps stop firms from engaging in "greenwashing" (Zhou Min et al., 2024) [34].

Shareholder activism is part of how this works. Investors push for real environmental change-not just PR moves. Equity tools make this possible in a way debt tools simply can't. He takes on his own. Initially, it is presumed that ownership stakes give investors direct influence. But subsequent analysis revealed the real edge lies in voting rights, board access, and long-term alignment.

Green public funds effectively push companies to cut emissions in operation-specific ways. Research on pollution reduction and green finance has progressed, but significant gaps remain.

First, the connection between green finance and integrated pollution-carbon governance is unclear, with fuzzy synergistic mechanisms.

Second, studies over-rely on debt tools like green loans and bonds, using macro data that miss internal corporate dynamics and the equity-based role of green public funds.

Third, research on green public funds is narrow, focusing on single firms without broader governance frameworks, leaving their co-benefit pathways and synergy logic unmapped.

Specifically, this paper makes several distinct contributions.

First, it looks at coordinated pollution and carbon reduction governance from a wider angle. Green public funds sit right at the center of that new focus. Initially, it is presumed the field mainly centers on policy tools or tech solutions-but subsequent analysis revealed green public funds offer a different kind of leverage.

That shift in viewpoint matters. Most studies so far focus on debt-based tools which is green loans and green bonds. Equity-based green financial instruments receive comparatively less scholarly and market attention.

This study looks at shareholding data from listed companies. It explores how green capital shapes corporate governance through equity participation.The mechanism in this context diverges from the functional operations of debt instruments.

Second, it looks at how green public funds work on the ground in manufacturing. These funds help cut pollution and lower carbon emissions. They do this in three main ways. First, they ease financing constraints for firms. Second, they push companies to develop greener technologies. Third, they strengthen outside oversight. That oversight helps firms coordinate their emission reduction efforts better. Initially, it is presumed these mechanisms operate independently-but subsequent analysis revealed they actually reinforce each other. He takes on his own. The funds don't just throw money at problems. They create real pressure and support with actually practical effects.

Third, the study finds green public funds don't work the same way for every company. Their effects vary across three key areas: corporate ownership structure, pollution intensity, and geographical distribution. For example, non-state-owned enterprises respond more strongly. Heavily polluting firms also see bigger improvements. Companies in eastern and western regions benefit more clearly too. Initially, it is presumed these funds would lift all firms equally-but subsequent analysis revealed clear differences. He takes on his own-no blanket effect here. The pattern isn't uniform; it's shaped by who owns the firm, how much pollution it generates, and where it's located. With actually practical implications, the impact is stronger where market incentives or regulatory pressure are already more active[7].

This paper tries to make sense of how green public funds actually work.

It examines the reasons for differences among these funds and seeks practical methods to enhance pollution control and carbon reduction in manufacturing. In the Beginning, green public funds were assumed to function via conventional fiscal channels but analysis uncovered more complex mechanisms.

2. Theoretical Hypothesis

Pollution reduction and carbon mitigation are integrated as they share origins in energy and industry. Companies face financial constraints and weak oversight when pursuing green initiatives. Green public funds combine green finance and institutional investment, funding areas like energy conservation and clean energy to ease financing constraints and enhance long-term emission reduction capacity.

These funds use professional management and shareholder engagement to guide companies toward green technology R&D and improved efficiency. This kind of shareholder activism pushes companies to get involved in governance. It helps them keep an eye on how management operates. They also make sure pollution reduction and carbon mitigation measures actually happen.

This governance approach targets the root cause. It moves attention away from end-of-pipe treatments alone. Instead, it weaves those treatments into every stage of production. That shift changes how things connect across departments.Corporate synergy isn't just a quick fix but it really gets things working better. At first, just treating surface-level problems seemed enough; however, looking deeper showed we needed better coordination across the board.

As a result, here's the first hypothesis this paper puts forward.

H1: Green public funds boost enterprises' pollution reduction and carbon emission cuts-noticeably.

Financing constraints hold back companies. They make firms less willing to invest in R&D. They also shrink the scale of those investments. Green public funds are a type of green financial instrument. They share core features with other tools in this category. One main job they do is easing financing constraints. Peng Bin et al. (2017) [20] built the clean transformation model. It shows that more green institutional investors help cut corporate capital costs. Green public funds provide companies with direct funding and reducing reliance on bank loans and supporting long-term green projects. Their environmental focus attracts investors and may lower borrowing costs through a "green bonus," as a result that Hypothesis 2 was promoted.

H2:Green public funds can alleviate financing constraints, thereby encouraging companies to reduce pollution and carbon emissions.

Green innovation is a forward-looking strategy for tackling environmental challenges. It creates eco-friendly technologies. It also builds clean production processes. These directly cut pollutant and carbon emissions right at the source. That makes it a key pathway to hit two goals at once: pollution control and carbon reduction. Diaz-Garcia et al. (2015) [2] point this out. Initially, it is presumed these innovations mainly boost efficiency-but subsequent analysis revealed their real power lies in reshaping how things are made. He takes on his own. The synergy isn't automatic; it comes with actually practical design choices.

Green innovation initiatives take a long time to develop. They need lots of money upfront. Returns come in slowly. That's why traditional financial markets often hold back on support. Wang Xu et al. (2022) [26] point this out. Initially, it is presumed these projects should attract funding-but subsequent analysis revealed investors get cautious. He takes on his own: the wait feels too long, the costs too high, the payoff too distant. With actually practical support, things might shift.

Green mutual funds focus on sustainability. They also prioritize ecological protection and long-term value creation (Jiang Guangsheng et al., 2021) [13]. These priorities match up well with what green innovation projects need - steady, long-term funding.

They give businesses steady financial backing. This helps ease the money problems tied to green innovation work. Companies can move faster on environmental tech development. They also push ahead with clean production upgrades. All this boosts how well pollution and carbon reduction efforts actually work.

So what do these findings point to? Hypothesis 3 comes out of them.

H3: Green public funds can promote corporate green technological innovation, thereby helping companies reduce pollution and carbon emissions.

Institutional investors usually face strong external regulatory pressure. They also have solid supervisory skills. This helps them get involved in corporate governance effectively (Smith, 1996) [9].

They step in to reduce agency problems. How? By keeping a close eye on management decisions-actively and consistently (Brav, 2008) [1].

Initially, it is presumed that oversight alone might be enough. But subsequent analysis revealed something more: their real impact comes from sustained, hands-on involvement. He takes on

his own. Not just watching-they push back, ask questions, and shape choices. With actually practical oversight, they help align manager actions with shareholder interests.

Green mutual funds help companies cut carbon emissions. They also keep a closer eye on those businesses. This happens by pushing for clearer ESG disclosures and getting involved in corporate governance. The result? Stronger oversight from investors. Zhou Min et al., 2024 [34] found clear evidence of this effect. Initially, it is presumed that financial backing alone drives change-but subsequent analysis revealed supervision matters just as much. He takes on his own view: money plus oversight works better.

Studies show institutional investors hold stocks in ways that boost corporate social responsibility.

They also help companies do better on ESG overall. How well these supervisory effects actually work depends on two things. First, institutional investors need to hold a bigger share of the company. Second, those same investors have to act-pushing for change, asking questions, showing up at meetings. They don't just sit back and wait. Initially, it is presumed that higher ownership alone would drive change. But subsequent analysis revealed something else: ownership only matters when paired with active engagement. He takes on his own role-not as a passive holder, but as someone who pushes. With actually practical involvement, the effect becomes real.

So here's Hypothesis 4.

H4: Green public funds enhance corporate pollution and carbon reduction efforts by exerting supervisory and governance effects.

2.1. Model Building

To validate the aforementioned theoretical derivations and hypotheses, this study establishes the following model:

$$SPCR_{it} = \alpha_0 + \alpha_1 Greenshare + \alpha_2 Controls + \mu_i + \tau_t + \varepsilon_{it} \qquad \text{Equation(1)}$$

The core explanatory variable in Equation (1), Greenshare, represents the shareholding ratio of listed companies. The dependent variable SPCR measures the pollution reduction and carbon emission reduction level in manufacturing industries (%), μ_i represents the individual fixed effect at the enterprise level, τ_t represents the time-fixed effect. In the regression model, the coefficient of concern is α_1, which represents the impact of green public funds on the reduction of pollution and carbon emissions in the manufacturing industry. ε_{it} is the random error term.

$$WW_{it} = \gamma_0 + \gamma_1 Greenshare + \gamma_2 Controls + \mu_i + \tau_t + \varepsilon_{it} \qquad \text{Equation(2)}$$

$$Patent_{it} = \delta_0 + \delta_1 Greenshare + \delta_2 Controls + \mu_i + \tau_t + \varepsilon_{it} \qquad \text{Equation(3)}$$

$$INST_{it} = \varepsilon_0 + \varepsilon_1 Greenshare + \varepsilon_2 Controls + \mu_i + \tau_t + \varepsilon_{it} \qquad \text{Equation(4)}$$

Equations (2), (3), and (4) collectively form the model group of the path analysis, aiming to analyze the specific channels through which Greenshare affects SPCR. Among them, WW_{it}、$Patent_{it}$、$INST_{it}$ respectively represent financing constraints, green innovation, and supervision governance effects. The coefficient γ_1 reflects the impact of green public funds' holdings on financing constraints. The coefficient δ_1 reflects the impact of green mutual fund holdings on green innovation, while the coefficient ε_1 reflects the influence of green mutual fund holdings on institutional supervision.

2.2. Variable Selection

2.2.1. Explained Variable

This study uses the Synergistic Pollution Reduction and Carbon Emission Reduction (SPCR) index for manufacturing companies as the dependent variable. Following the approach of Lu Min et al. (2022) [17], we shift the analysis from the macro-regional level down to the micro-enterprise level. Based on carbon emission and pollution emission data from listed companies, we build a log-transformed interaction term between Pollution Emission Performance (PC) and the Carbon Reduction Index (CM) to measure how well a company performs in SPCR. This indicator captures the combined effect of cutting pollution and reducing carbon emissions. It also stays consistent in terms of governance mechanisms and pollution sources, which fits well with today's policy push for "integrated progress" in pollution reduction and carbon mitigation during the green transition.

To measure pollution emission performance (PC), we adopt the method proposed by Mao Jie et al. (2022) [19]. We pick key pollutant indicators from industrial wastewater and exhaust emissions, and then standardize them. Specifically, wastewater pollutants include chemical oxygen demand (COD) and ammonia nitrogen (NH_3), while exhaust pollutants cover sulfur dioxide (SO_2) and nitrogen oxides (NO_x). To make different pollutants comparable and remove unit differences, all emission amounts are converted into total pollution equivalent numbers (PE) using coefficients from the "Taxable Pollutants and Equivalent Value Table." The formula is as follows:

$$PE = \frac{COD}{1} + \frac{NH}{0.8} + \frac{SO_2}{0.95} + \frac{N0_X}{0.95} \quad \text{Equation(5)}$$

$$PC = Income/PE \quad \text{Equation(6)}$$

Here, Income means the money the company makes from its business operations.

As for the Carbon Reduction Index (CM), this study uses the approach suggested by Yi et al. (2022)[6]. It looks at how well companies are reducing carbon through three things: total CO_2 emissions, how fast emissions are growing, and carbon emission intensity. Since all three of these are measures that show a negative impact on the environment and they don't all carry the same weight which we use something called the entropy weighting method to decide how important each one is. Then we calculate a yearly overall carbon reduction score for each company.

2.2.2. Explanatory Variable

This study shines a spotlight on the Green Fund Holding Ratio (Greenshare) as the central explanatory variable. Following the lively methodology laid out by Wei Ping and Shu Hao (2018)[24], the specific processing steps dance along as follows: Step 1 – Identifying green public funds. We scoop up all funds that boast keywords like "green," "ecology," "new energy," "clean energy," "low-carbon," "energy conservation," "environmental protection," "carbon neutrality," "emission reduction," and "natural resources" in their names, investment objectives, or investment scope. Step 2 – Obtaining investment data for green public funds. Retrieve holding data from the end-of-period positions in annual fund reports through the CSMAR database. Match these green public funds with their stock holdings to obtain detailed equity investment records during the sample period. Step 3 – Matching corporate green fund holding ratios. Align the equity investment details of green public funds with the listed company database compiled by the CSMAR database, as illustrated in Equation (7).

$$\text{Greenshare}_i = \frac{\sum_j \text{GreenfundjHolding The number of stocks}_{ij} \text{ of listed companiesi}}{\text{Number of tradable A-shares}_i} \quad \text{Equation(7)}$$

2.2.3. Controlled Variable

This paper draws on the research frameworks of Yu Jian (2025) [31] and Wang Huaiming (2025) [25], controlling for the following variables: book-to-market ratio (MtB), defined as book value divided by market value; debt-to-asset ratio (Debt), calculated as total liabilities divided by total assets; fixed asset ratio (PPE,%), measured as net fixed assets divided by total assets; current ratio (CR), expressed as current assets divided by current liabilities; and asset intensity (Intensity), calculated as total assets divided by operating revenue.

2.3. Data Sources

In this study, we focus on A-share listed companies that put money into green public funds between 2015 and 2022. Our data mainly comes from the Guotai An (CSMAR) database. To clean up the sample, we followed a few steps: we left out companies with unusual trading activity, removed firms whose debt-to-asset ratios were below 0 or above 1, dropped businesses in the financial industry, and also filtered out any companies that had missing data we needed.

2.4. Descriptive Statistics

The descriptive statistical findings of this investigation are delineated in Table 1. The range of extreme values for the dependent variable, SPCR, is constrained, suggesting limited variability in pollution and carbon reduction levels across the sample firms, while the overall distribution remains relatively concentrated. Conversely, the extreme values for the core explanatory variable, Greenshare, exhibit substantial dispersion, indicative of pronounced disparities in green fund holdings among the firms: a subset possesses no green fund holdings whatsoever, whereas only a minority demonstrates elevated holding ratios. The extensive sample coverage effectively underpins the robustness of the research outcomes.

Table 1. Descriptive Statistics

variable	unit	sample number	mean	standard deviation	least value	crest value
SPCR	-	8,093	12.909	1.251	8.263	17.936
Greenshare	%	8,093	6.242	9.675	0.001×10-2	98.224
MtB	-	8,093	0.534	0.259	0.011	1.533
Debt	-	8,093	0.398	0.185	0.010	2.290
PPE	%	8,093	23.040	13.855	0.012	95.418
CR	-	8,093	2.441	2.684	0.106	60.417
Intensity	-	8,093	2.292	3.658	0.136	289.885

3. Analysis of Empirical Results

3.1. Reference Regression

The benchmark regression results on the impact of green public fund holdings on the synergistic effects of pollution reduction and carbon emission reduction in the manufacturing sector are presented in Table 2. To mitigate estimation errors arising from inherent firm differences and macroeconomic fluctuations, all regressions employed dual fixed effects for both firms and time. The results indicate that the regression coefficient of the core explanatory variable Greenshare remained largely unchanged in magnitude and significance level before and after incorporating control variables; the signs and significance levels of all control variables also aligned with theoretical expectations. A one percentage point increase in the shareholding ratio of green public funds corresponds to a 0.008% improvement in the

synergistic effectiveness of pollution and carbon reduction across manufacturing enterprises, demonstrating that green public funds significantly enhance coordinated progress in these areas and provide robust empirical support for our core hypothesis H1.

Table 2. Baseline Regression Results

Variables and Statistical Parameters	(1)	(2)
	SPCR	*SPCR*
Greenshare	0.008*** (0.001)	0.008*** (0.001)
MtB		0.162*** (0.058)
Debt		0.752*** (0.102)
PPE		-0.006*** (0.001)
CR		-0.027*** (0.007)
Intensity		-0.029*** (0.011)
constant term	12.866*** (0.006)	12.759** (0.066)
sample number	8,093	8,093
R2	0.916	0.925
individuality	YES	YES
time	YES	YES

Note: The values in parentheses represent standard errors adjusted for industry-level clustering: *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level; the same applies to subsequent tables.

3.2. Robustness Test

To ensure the robustness of the regression results in this paper, we employed the following methods for robustness testing.

3.2.1. PSM-DID test

To tackle the tricky issue of endogeneity arising from sample selection bias, this study adopts the Propensity Score Matching-Difference in Differences (PSM-DID) approach for robustness checks. We treat the policy shock-the rollout of the 2018 "Green Investment Guidelines (Trial)"-as an exogenous event. Firms that held green mutual funds above the annual industry average before the policy took effect were classified into the treatment group, while those below the average made up the control group. To wipe out systematic differences in firm traits between the two groups, a Logit model was used to estimate each firm's likelihood of falling into the treatment group, with control variables serving as matching covariates under a 1:1 matching ratio (see Table 3 for the PSM validity check). Before matching, the debt-to-asset ratio and fixed asset ratio showed notable gaps between groups. After matching, all t-tests on the covariates turned statistically insignificant, confirming that no lingering differences remained between groups once covariates were balanced-which backs the soundness of the PSM approach.

Table 3. PSM Validity Test

Variables and Statistical Parameters	Match or Not	mean		standard error (%)	t price
		Treatment Group	control group		
MtB	NO	0.490	0.494	-1.8	-0.29
	YES	0.489	0.496	-3.5	-0.55
Debt	NO	0.397	0.371	14.0	2.22**
	YES	0.397	0.394	-0.2	-0.03
PPE	NO	21.897	23.707	-13.0	-2.07**
	YES	21.880	21.744	1.0	0.16
CR	NO	2.380	2.690	-10.3	-1.64
	YES	2.350	2.384	-1.1	-0.21
Intensity	NO	2.720	2.462	2.8	0.45
	YES	2.712	2.401	3.4	0.52

Figure 1 shows the balance test results. Before matching, the differences between the control and treatment groups were really big; but after matching, all covariates in both groups had deviations under 10%. The deviations dropped noticeably before and after matching, reflecting the findings from Table 3 and showing the excellent quality of the matching.

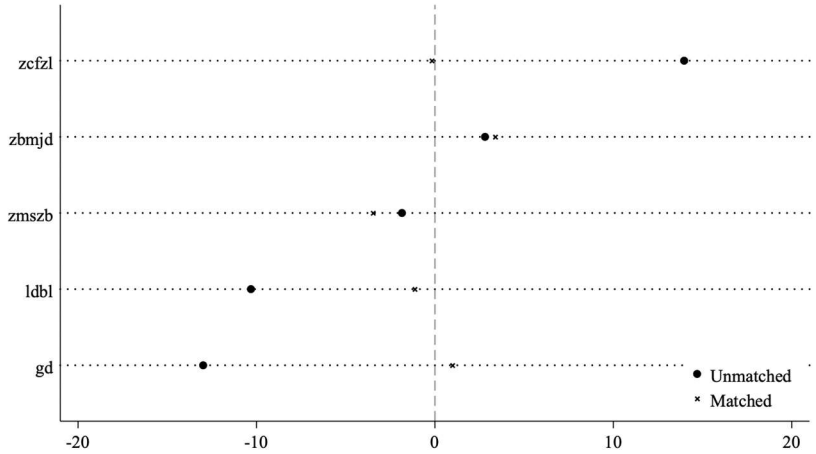

Figure 1. Balance Test

Table 4 presents the results of the PSM-DID regression. It indicates that the Greenshare coefficient remains significantly positive, which further supports the enduring positive impact of green mutual funds. This underscores the robustness of the study's key conclusions.

Table 4. PSM-DID Regression Results

Variables and Statistical Parameters	(1)	(2)
	benchmark DID	PSM-DID
Greenshare	0.007*** (0.001)	0.007*** (0.001)
constant term	12.627*** (0.006)	12.777*** (0.065)
sample number	8093	7252
R2	0.211	0.208
individuality	YES	YES
time	YES	YES

3.2.2. Placebo Test

To ascertain whether our findings might be influenced by unobserved confounding factors, we conducted a placebo test. The methodology involved randomly selecting an equivalent number of firms from the full sample to construct a pseudo-treatment group, mirroring the actual treatment group in size, while the remaining firms served as a pseudo-control group. We then re-estimated the primary regression model. This process of random assignment and estimation was iterated 500 times, generating 500 simulated difference-in-differences coefficients. The distribution of these coefficients is presented in Figure 2.

The results indicate that the vast majority of these simulated coefficients and their corresponding t-statistics are clustered around zero, markedly distant from the actual estimated results, and are largely statistically insignificant. This demonstrates that the observed effect of Greenshare on reducing manufacturing pollution and carbon emissions is robust and not attributable to unobserved confounding variables, thereby substantiating the validity of our primary findings.

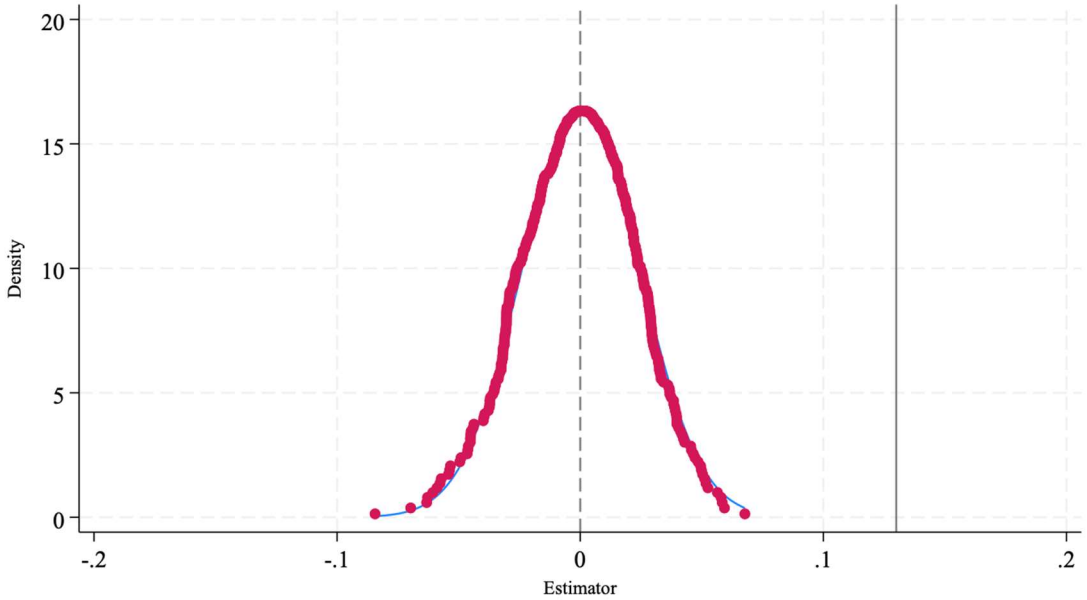

Figure 2. Placebo Test

3.2.3. Other Conservative Tests

(1) The dependent variable was replaced

Table 5. Robustness Test Results

Variables and Statistical Parameters	(1)	(2)	(3)	(4)
	PC	*SPCR*	*SPCR*	*SPCR*
Greenshare	0.008***		0.004***	0.008***
	(0.001)		(0.001)	(0.001)
Greenvalue		0.059***		
		(0.003)		
constant term	12.898***	11.634***	12.709***	12.693***
	(0.064)	(0.094)	(0.079)	(0.069)
controlled variable	control	control	control	control
fixed effect	YES	YES	YES	YES
sample number	8093	8093	4965	7151
R2	0.936	0.931	0.952	0.927

After swapping out the original SPCR for pollution emission performance (PC) and running a fresh regression analysis (take a look at column (1) in Table 5), the results showed that the coefficient for Greenshare was 0.008. It stayed significantly positive at the 1% level, matching what we saw in the baseline regression. This means that even when we change how we measure the dependent variable, our main takeaway doesn't budge: green fund holdings really do help companies cut down on pollution and carbon emissions. So, this gives us a preliminary thumbs-up that the findings are solid.

(2) Replacement of the explanatory variable

Given that a single indicator may be biased, this study replaces Greenshare with the natural logarithm of green public fund holdings (Greenvalue) for regression analysis (see column (2) in Table 5). The results show that the coefficient of Greenvalue is significantly positive at the 1% level. After altering the measurement of the explanatory variable, the promoting effect of green public fund holdings remains significant, and the baseline regression results remain robust.

(3) Exclusion of special samples

The COVID-19 pandemic from 2020 to 2022 may have exerted significant adverse impacts on corporate operations and environmental governance, while the policy frameworks and development conditions in municipalities directly under the central government were relatively unique. After excluding these two categories of samples, we conducted new regressions (see columns (3) and (4) in Table 5). The results show that the coefficient for Greenshare remains significantly positive at the 1% level, with the sign consistent with the baseline regression, confirming the core conclusion remains unchanged. This further demonstrates that the positive impact of green mutual fund holdings on pollution reduction and carbon mitigation in the manufacturing sector is stable and reliable.

3.3. Endogenous Processing

The robustness tests conducted earlier have demonstrated a relatively stable correlation between the holdings of green public funds and pollution reduction and carbon emission cuts in the manufacturing sector. However, a stable correlation does not imply a causal relationship. A key endogeneity issue in this study stems from reverse causality: green public funds tend to allocate more heavily to companies that excel in pollution reduction and carbon mitigation, which introduces bias into the estimation of regression coefficients.

Table 6. 2SLS Regression Results

Variables and Statistical Parameters	**(1)**	**(2)**
	stage Ⅰ	**stage Ⅱ**
	Greenshare	***SPCR***
IV	-0.340***	
	(0.015)	
Greenshare		0.006***
		(0.002)
controlled variable	control	
fixed effect	YES	
Cragg-Donald F	226.282	
Kleibergen-Paap F	537.127	
sample number	6673	

To address this issue, we employ an instrumental variable approach, utilizing the lagged value of the industry-average green fund shareholding ratio. This instrument is strongly correlated with the current key explanatory variable while remaining orthogonal to the contemporary

error term. This strategy mitigates potential reverse causality and reduces bias arising from omitted variables, thereby enhancing the reliability of our causal estimates.

The results of the two-stage least squares (2SLS) regression, presented in Table 6, indicate that green fund holdings continue to exert a significant positive effect on corporate pollution and carbon reduction performance. The core findings retain their robustness. Furthermore, both the weak instrument test and the overidentification test underscore the validity of the selected instrumental variables.

4. Scalability Analysis

4.1. Heterogeneity Analysis

This study uses instrumental variables to tackle endogeneity and clarify cause-and-effect relationships. It explores how green mutual fund holdings affect pollution and carbon reduction in manufacturing in different ways, shaped by ownership structure, pollution intensity, and where firms are located. Initially, the impacts were assumed to be similar, but they actually vary across firms. In practice, the same holding plays out differently, and context is key for real-world outcomes. Table 7 shows what came out of the analysis.

Table 7. Heterogeneity Analysis

Variables and Statistical Parameters	(1) State-owned enterprises	(2) Non-state-owned enterprises	(3) Enterprises with severe pollution	(4) Non-high-pollution enterprises	(5) east	(6) Central Region	(7) the west area
Greenshare	0.003***	0.009***	0.009***	0.007***	0.008***	0.005***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
constant term	13.682***	12.549***	13.078***	12.730***	12.638***	13.283***	13.160***
	(0.082)	(0.041)	(0.062)	(0.044)	(0.044)	(0.087)	(0.106)
controlled variable	control	control	control	control	control	control	control
individuality	YES	YES	YES	YES	YES	YES	YES
time	YES	YES	YES	YES	YES	YES	YES
sample number	2031	6062	3030	5063	5771	1349	973
R2	0.950	0.915	0.925	0.936	0.923	0.942	0.945
Adjusted R2	0.940	0.898	0.912	0.925	0.909	0.931	0.934

The analysis examined subgroup disparities across age, gender, educational attainment, and geographic region. Age exerted a significant influence on outcomes, with younger participants exhibiting more pronounced responses, whereas older adults demonstrated greater variability. Gender differences were observed: women attained higher scores on measures of empathy, while men displayed a stronger focus on task efficiency. Educational level also exerted a significant influence, as university graduates responded more consistently compared to high school graduates. Regional variation was pronounced, with urban samples adapting more rapidly to changes, and rural groups placing greater emphasis on long-term trust. Effect sizes varied across comparisons (Cohen's d ranging from >0.8 to approximately 0.3), underscoring the necessity for context-specific interventions. All comparative analyses employed the same statistical framework, utilizing fixed-effects estimation unless significant heterogeneity warranted the application of random-effects models.

Green public funds really help cut down on pollution and carbon emissions from companies. This effect is even stronger for non-state-owned firms and those that pollute a lot. Looking at

different regions, the impact is bigger in the east and west because they have better markets, policies, or more need to upgrade. But in the central region, it's weaker since green finance isn't as developed there. These differences show how the funds are customized for each area, playing specific roles to support a coordinated national move toward a greener future.

4.2. Path Analysis

This study looks at how green public funds help cut pollution and carbon emissions in manufacturing. It focuses on three key areas: financing constraints, green innovation, and regulatory oversight.

We wanted to understand the actual mechanisms behind this effect. Initially, it is presumed that green public funds mainly ease funding shortages for firms. But subsequent analysis revealed a more layered picture. They also push companies to invest in cleaner technologies. Another thing worth mentioning is how they strengthen government monitoring and enforcement.

The regression results appear in Table 8.

Table 8. Mechanism Analysis

Variables and Statistical Parameters	(1)	(2)	(3)
	WW	*Patent*	*INST*
Greenshare	-0.001***	0.033*	0.015***
	(0.000)	(0.018)	(0.001)
constant term	-1.018***	9.719***	3.579***
	(0.014)	(1.154)	(0.066)
controlled variable	control	control	control
fixed effect	YES	YES	YES
sample number	8298	4245	8353
R2	0.569	0.726	0.800

4.3. Green Innovation

Green innovation serves as a crucial driving force for enterprises to achieve synergistic effects in pollution and carbon emission reduction. Green innovation can enhance resource utilization efficiency, reduce energy consumption and emission intensity per unit of output. Meanwhile, green end - of - pipe treatment technologies directly reduce the total amount of pollutant emissions (Sun Xiaoting et al., 2024). Therefore, an improvement in the level of green innovation will directly translate into better performance of enterprises in pollution and carbon reduction.

Regarding the proxy variable for green innovation, considering that the authorization of green patents requires an approval process (usually with a lag of 1 - 3 years) and cannot truly reflect the current R & D investment and innovation achievements of enterprises (Liu et al., 2022), this paper chooses to construct the indicator (Patent) by taking the natural logarithm of the number of green patent applications plus one, which better aligns with the actual situation of enterprises' current innovation activities. Referring to Jiang Ke's (2022) method for testing the mediating effect, this paper verifies this path through the direct regression of the core explanatory variable and the mediating variable. The regression results in column (2) of Table 8 show that green mutual funds have a certain positive impact on green patent applications, indicating that they can effectively encourage enterprises to carry out green technology innovation, and Hypothesis H3 is established.

4.4. Supervision and Governance

Effective supervision and governance are important guarantees for enterprises to fulfill their environmental responsibilities. The supervision of independent directors, the inquiries of

institutional investors, and the requirements for information disclosure will force management to translate environmental protection commitments into actual actions (Cai Guilong et al., 2023)[10], thus providing a guarantee for enterprises to fulfill their responsibilities in pollution and carbon reduction.

Regarding the proxy variable for supervision and governance, this paper uses the shareholding ratio of institutional investors (INST) for measurement. As an important external governance force, the higher the shareholding ratio of institutional investors, the stronger their motivation and ability to supervise management (Jiang Guangsheng et al., 2021). As can be seen from column (3) of Table 8, the coefficient of Greenshare is positive and highly significant at the 1% level, indicating that the shareholding of green mutual funds significantly increases the overall shareholding level of institutional investors in the enterprise, forming a stronger external supervision force, and Hypothesis H4 is verified.

5. Conclusion

To adapt to the development trend of the domestic "dual carbon" goal, Chinese manufacturing enterprises not only need to reduce carbon emissions but also urgently need to reduce pollution emissions. Research has found that green finance serves the green transformation of enterprises and provides them with financial support. Strengthening the construction of the green financial system means the entry of a large number of investors, which provides public power for further supervision of the pollution and carbon emissions of manufacturing enterprises.

This research selects A-share manufacturing enterprises that have obtained "green public fund investment" from 2015 to 2022 as research samples to analyze the impact of green public fund holdings on the coordinated level of pollution and carbon reduction of enterprises. The research finds that green public fund holdings can significantly improve the coordinated level of pollution and carbon reduction of manufacturing enterprises. After further mechanism analysis, this paper concludes that green public funds mainly play a role in three aspects. First, green public funds help alleviate the financing constraints and barriers of enterprises; second, green public funds promote the green technological innovation of enterprises; finally, green public funds strengthen the supervision and governance of manufacturing enterprises through investors. Heterogeneity tests and analyses show that the positive effect of green public funds on pollution and carbon reduction in the manufacturing industry is more significant and powerful in non-state-owned enterprises, enterprises in the eastern and western regions, and heavily polluting enterprises. In this regard, this paper gives the following suggestions.

First, government regulatory departments should strongly support the development of green public funds, strengthen the supervision and review of relevant information, and direct government funds to "genuine" green transformation enterprises. The supervision policies and regulations issued by government regulatory departments should not only focus on the expansion of the scale of green funds but also take into account the quality of green fund development, so that limited funds can be invested in manufacturing enterprises that truly have a need for green transformation. Specifically, regulatory departments can re-examine, modify, and formulate more precise and transparent identification standards for green public funds, and at the same time strengthen the quality of their information disclosure. Through this measure, in order to obtain financial support, fund companies will pay more attention to the energy-saving and carbon-reducing effects of products and the green impact of clean production when designing products; financial institutions can also, in accordance with the general direction of the new policy, invest long-term funds such as insurance and social security in the field of pollution and carbon reduction in the manufacturing industry. Therefore, this

method not only strengthens the quality of the green transformation of manufacturing enterprises themselves but also provides strong economic support for their transformation.

Second, when formulating and improving policies, the government should pay attention to the different effects of green public funds on pollution and carbon reduction of enterprises and match the policies one by one. This research shows that green public funds mainly play a role by reducing financing constraints, promoting technological innovation, and strengthening external supervision. Therefore, policy design should also revolve around these three aspects. For example, for enterprises with relatively large financing constraints, to relieve the financial pressure on enterprises, the government can promote the cooperation of green public funds with financial tools such as green credit to provide economic support; for manufacturing enterprises with a foundation in green technological innovation, the government can provide R & D subsidies or tax incentives.

Third, as the policy - maker, the government should formulate policies for different situations according to the type of enterprises, the characteristics of industries, and regional differences. This research finds that green public funds have a better promoting effect on non - state - owned enterprises. This shows that market - oriented funds have a very good incentive effect on non - state - owned enterprises. Therefore, relevant departments can reduce some unnecessary administrative interventions based on this. In this way, green funds can better play the role of resource allocation. For some enterprises with relatively serious pollution, green funds should not simply avoid them. They can first evaluate the environmental performance of these enterprises, whether it is good or bad, and then formulate personalized policies to support enterprises in carrying out activities such as clean production, equipment renewal, and low - carbon transformation. For enterprises in the central and western regions, local governments can also combine the local industrial development and ecological protection needs to guide green funds to support the development of local manufacturing industries and help them achieve green upgrading. Local governments can also set up regional green funds to invest and guide funds, which can also help different regions jointly promote green transformation.

Fourth, the government should improve the enterprise environmental information disclosure system to reduce the investment judgment cost of green funds. The premise for green funds to play a guiding role is that fund institutions need to fully understand the real environmental situation of enterprises. However, at present, the information disclosure of many manufacturing enterprises in terms of pollution emissions, carbon emissions, and green technology investment is still incomplete, which greatly increases the difficulty of project screening. In this regard, regulatory departments need to continuously refine the environmental information disclosure rules for the manufacturing industry, unify the accounting standards for carbon emissions and pollutants, and build an enterprise environmental performance information database to provide data support for fund companies to accurately judge the actual situation of enterprise green transformation. At the same time, the competent department should also strongly support the development of third - party environmental evaluation institutions and achieve a market - oriented and objective evaluation of enterprise environmental performance with the help of third - party professional evaluations.

Fifth, regulatory departments should not only support the development of green funds but also strengthen risk control. As the scale of green public funds expands, more funds will enter green finance. This will promote the green transformation of the manufacturing industry. However, in this process, if regulatory departments do not play a role, "greenwashing" behavior may occur in the market. At this time, regulatory departments need to play a role. They can monitor the actual investment direction of green funds and regularly check the positions of enterprises in this process. In addition, fund companies can regularly disclose information on the environmental performance of their held enterprises, etc., so as to improve the transparency of

the operation of green funds and ensure that green funds flow to manufacturing enterprises with actual environmental benefits.

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