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The Impact of Smart Ecological Monitoring on Corporate ESG Greenwashing Behavior

-- Quasi-Natural Empirical Evidence Based on Ecological Monitoring Data

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Abstract: As for the global green shift and corporations are doing their very own version, which is ESG greenwash, and that's becoming a bit like a distortion when companies disclose all other info rather than the financial stuff. Using enterprise samples used as data sources in this article from 2014-2025, we examine how the use of smart ecosystemic surveillance can help stop firms from engaging in ESG greenwashing and the causes behind it. It is discovered to the research, the smart ecological monitoring was implemented, which greatly reduced corporate ESG greenwashing behaviour. This conclusion also went through robustness checks such as parallel trends check and placebos, and alternate variants. Mechanism mainly goes through 3 channels, improve the transparency of corporates' info disclosure, reduce agency costs, and ease the fin constraint. And then heterogeneity analysis, we see that there is a big inhibitory effect coming from smart ecological monitering against ESG greenwashing. In that specific context, we could see that this happened much stronger with sov. Enterprise, the company located in a west part area, and non high tech type of business. It can show whether smart ecology supervision has a different effect in controlling corporate ESG information disclosing behavior based on the different background. The paper also brings more research materials for digital watching over in corporate e-society information disclosures; offers very helpful experience and real ways about improving e-soils and blueprints that use tech and push up the progress of cash venues.

Keywords: Smart Ecological Monitoring; ESG Greenwashing; Digital Regulation; Agency Cost; Information Disclosure Transparency; Financing Constraints.

1. Introduction

As the earth faces more serious weather problems caused by human activities, the green transition has become a hot topic both politically in government and in society, under such circumstances that the firms' ESG elements have turned into significant standards for evaluation in the capital markets as well as the support from the regulations and the public image. The 2024 Global Sustainable Investment Report released by the Global Sustainable Investment Alliance (GSIA), says that all the green investment money in the world goes past 45 trillion dollars, according to them. It will matter how companies look, it will impact what they do with the green investments on their finance expenses, it can impact what the company is valued at, the company's reputation socially, and how many customers it can sell to. However, as ESG awareness grows, the problem of corporate greenwashing has become increasingly serious. Some companies, by selectively disclosing environmental information, exaggerating their environmental investments, or concealing negative environmental behaviors, create a false image that conforms to green development standards, gaining policy benefits, investor favor, and competitive market advantages[1]. More and more companies recognize the importance of social responsibility, and both social responsibility and green innovation are beneficial to their future sustainable development, sending positive signals to society[2].

Greenwashing not only weakens a company's sustainable development capacity, reducing the efficiency of resource allocation in capital markets[3], but also undermines the effective operation of the green finance market [4]. Therefore, how to effectively govern corporate ESG greenwashing has become an urgent issue to be addressed in the global economy.

In this situation, digital change within government, as well as the implementation of smart ecological watching tools, gives way to proper methods of governance toward those sorts of companies making environmentally positive claims about themselves or their business practices. The tech systems that integrate IoT, big data, and AI to used with environmental things, like seeing if industries have polluted recently and tracking it. This greatly decreases information asymmetries among regulators and investors with regard to transparency and checkability in corporate environment information. It enhances the continuous regulation over a firm's environmental behavior and raises the danger of detecting fake efforts at eco-friendliness, so firms will be more likely to invest in actual green initiatives and innovation. Addressing the corporate reason that results in an effort by the firm to obtain benefit from either regulatory actions or the markets via false disclosures.

China's 14th Five-Year Plan and the report from the 20th National Congress both explicitly call for accelerating the development of a green, low-carbon economy and the construction of a beautiful China, while emphasizing the establishment of a modern environmental governance system. Smart ecological monitoring, with its characteristics of cross-departmental data integration and full-process intelligent regulation, provides crucial technological support for achieving these strategic goals. The system is not only an effective governance tool for corporate ESG information disclosure but also effectively limits the space for companies to embellish their environmental information through information sharing and risk warning mechanisms.

In existing research, scholars have widely discussed the economic and social impacts of government digital

environmental governance [5], covering aspects such as environmental policy compliance [6], carbon emissions trading[7], green energy incentives[6], and green tax reforms[8]. However, studies on the impact of smart ecological monitoring on corporate sustainable development and ESG greenwashing behaviors remain relatively scarce. On the other hand, existing research on corporate greenwashing mainly explores how companies, under pressure from environmental regulations, use false environmental statements or data manipulation to satisfy the green preferences of investors and consumers [9]. Although some studies have indicated that social media[10] and green certifications[11]have somewhat suppressed corporate greenwashing, the falsehood and complexity of corporate green information still make governance of this behavior a major challenge. Smart ecological monitoring provides a new solution for effectively governing corporate greenwashing by accurately identifying corporate environmental performance and behavior, combined with digital regulatory means. However, the exploration of the governance effects of smart ecological monitoring on corporate ESG greenwashing remains insufficient. Especially in the context of China's green transition, how to use this emerging technological tool to enhance the transparency of corporate environmental behavior and reduce false environmental performance remains a key issue to be addressed.

So then here is some work that looks into what it might be for smart eco monitoring, like if you increased the clarity on which information businesses had concerning nature, decreased some company expense stuff (like the kind that has managers doing less), relieved financial stressors on firms trying to do things, and stopped companies from doing fake-green environmental activities. Research based on some real information obtained from the CNPD database between 2014 and 2025 shows that the effect of smart ecological watching on making firms' ESG become greenish is much lower than usual. This conclusion is tested by doing a few other tests called robustness tests, such as doing another parallel trend test, doing a placebo test, and then using some different variables in the test. Smart ecological monitoring works on corporate ESG greenwashing via these means: first, it enhances corporate information transparency, as cross-departmental information sharing and big data technology strengthen the verifiability of ESG information, reducing the space for corporate greenwashing; second, it reduces corporate agency costs, as digital regulation forms external constraints that curb managers' motivation to pursue short-term economic benefits through false environmental behaviors; third, it alleviates corporate financing constraints, as smart ecological monitoring, by enhancing the authenticity and credibility of information, reduces companies' dependence on "greenwashing for financing." By heterogeneity testing, I can notice it appears quite clearly within SOEs and companies based in Western China, as well as non-HT firms - they each have their own unique rules as to how things get run over there.

It’s possible to get something from me that goes here like such: At first there is some digital regulation device that calls smart ecology observing combined along with company green washing along with non-fiscal statement misinformation, which leaves out what is found by people researching if those who want to be known as being "ecological" will use these devices more widely for just making sure companies keep things within a given range when talking about money versus how their other stuff works (which has already been studied by those doing environmental control), but where nobody has really looked into exactly what effect the smart technology would actually have when it comes straight down to getting that company to tell everyone honestly all at once. This enriches the research on the interaction between government digital governance and corporate non-financial behavior; second, through empirical testing, the study clearly identifies the threefold mechanism of "information disclosure improvement – agency cost reduction – financing constraint alleviation," revealing the internal logic of how smart ecological monitoring, through digital regulatory means, suppresses corporate ESG greenwashing, providing specific and verifiable mechanisms to understand how governments can use digital tools to influence corporate green information disclosure behaviors; third, based on smart ecological monitoring, It gives us great ways to help growing economies make their company’s ESG info better, more trustworthy and open up new roads of progress by going electronic, it will tell companies how to not do what looks like being environmentally kind just so people think they’re really nice to earth and it can also fix how things run as green managers get stronger.

2. Mechanism Analysis

2.1. The Direct Impact of Smart Ecological Monitoring on Corporate ESG Greenwashing

The central issue in corporate ESG greenwashing lies in information asymmetry: companies either present a selective impression using only certain sustainability information or make exaggerated claims about their sustainability efforts. External stakeholders are often unable to verify these claims cost-effectively to determine their truthfulness (Lyon & Maxwell, 2008). Smart Ecological Monitoring is a new application of digital governance that completely challenges this assumption. The nationwide unified data platform established by Smart Ecological Monitoring connects and cross-verifies data from various departments, such as environmental, tax, business, and social security, ensuring that the environmental investments claimed by companies align with their actual pollution levels, tax incentives, and other relevant factors. This system closes the information gap where companies could otherwise use false data to mislead stakeholders about their environmental efforts.

And this monitoring system can also do things like get real-time information about companies and then send danger messages about problems with how much stuff they should share when they tell people what their business does to nature. Such as in case the eco score differs a lot from the emission discharge amount released on the ground by a firm, the monitoring system will instantly show this discrepancy and sound an alarm. This raises the likelihood of being found out and increases costs. In addition to that, a smart eco monitoring platform lessens local regulators’ discretion by standardization of the regulatory process, so that it reduces collusion of the firm and the supervisory body, which aims at hiding or covering up green washing behavior, thereby improving the effectiveness of direct monitoring.

Regarding information disclosure, smart ecological monitoring enhances corporate transparency, especially in the environmental sector. Corporate environmental investments, social responsibility expenditures, and other data need to be

verified against actual tax records and environmental data for consistency. Any inconsistencies can be quickly captured and addressed. This mechanism effectively eliminates the space for greenwashing in information disclosure, enhancing the credibility of corporate social responsibility reports, enabling stakeholders to make more accurate decisions. Benchmark regression results show a significant negative correlation between the implementation of smart ecological monitoring and the degree of corporate ESG greenwashing, proving that digital regulation can directly suppress corporate greenwashing behaviors. The core impact comes from the fundamental disruption of the information asymmetry environment, where transparent data collection and verification mechanisms effectively expose the false elements in corporate disclosures, significantly reducing companies' motivations and actions related to greenwashing.

2.2. The impact mechanism of Smart Ecological Monitoring on Corporate ESG Greenwashing

2.2.1. The Mediating Role of Information Disclosure

The essence of the company's ESG greening is to make use of the disclosure chance in an information-transparent environment. At the heart is this: the firm takes advantage of info imbalances, it tries to fool the outside world, it says all sorts of non-pecuniary stuff, it puts a nice spin on its eco/social efforts, or it quietly hides anything it doesn't like to do where the environment and community are concerned; the overall impression is better [12]. Most particularly, worldwide, disclosing the importance of ESG within CSR reporting. It is companies that do not report just in finance as they improve the amount of ESG information made known, which is to divulge other types of facts to interested parties [13]. This behavior can also be interpreted as a signaller[14]. Intelligent ecological monitoring is promoting this procedure of openness, causing companies' statements regarding environmental, social, and governance (ESG), truer, more correct, and lessening the emergence of greenwashing.

Smart ecological monitoring basically gets rid of this kind of problem by using new digital technology and really improves how companies give out information. Using AI and Big Data for improving a corporation's ESG and pushing sustainability: some trends are popping up. Smart ecological monitoring, through artificial intelligence technology, can analyze corporate environmental data in real-time and identify potential greenwashing behaviors, increasing transparency and compliance in the environmental sector [15] [16]. This technological advancement not only improves the quality of information disclosure but also promotes sustainable investment globally, providing technological support for enhancing the long-term competitiveness of companies[17].

2.2.2. The Mediating Role of Agency Costs

Agency theory provides the theoretical foundation for understanding the potential motivations and operational mechanisms behind corporate ESG greenwashing [18, 19]. Often, companies have a misalignment with their shareholders when it comes to greenwashing behaviors. [20]. From the perspective of agency theory, companies may engage in greenwashing as a response to stakeholders' concerns about environmental issues, thereby demonstrating their commitment to sustainability and business direction [21]. However, they overlook the harm such actions may cause to the long-term stability of the company's operations and the legitimate interests of minority shareholders[22].

Smart ecological monitoring, through strengthening external supervision, effectively reduces the second type of agency costs between major shareholders and minority shareholders, thus curbing opportunistic behaviors driven by greenwashing. From the perspective of external constraints, the smart ecological monitoring system can monitor key data such as the company's environmental behavior, fund flows, and social responsibility expenditures in real-time, ensuring consistency with records from tax authorities, environmental protection departments, and other regulatory bodies. This cross-departmental collaborative regulation breaks down the information barriers in traditional regulatory mechanisms, enhancing the external supervisory pressure on companies.

Looking at what's happening inside ourselves there is another way that we could make more complete and true the amount or the way the information flows from us so that people who own even fewer pieces can get better at looking for ways the truthiness is on the level with how this business did things by taking on its environmental-social-responsibility (ESR) test results into consideration as well as why they have been going after those dollars they took out already. With the cross-departmental verification functions provided by the system, shareholders can clearly understand the actual state of the company's environmental performance and social responsibility fulfillment, thereby enhancing their ability to supervise major shareholders and management. This increased information transparency prevents management from easily manipulating external perceptions through false information or selective disclosure, thereby reducing the space for gaining short-term benefits through greenwashing.

The deterrent effect of external regulation and the constraints of internal supervision create a dual effect, jointly promoting the alignment of major shareholders' interests with the company's long-term development goals. Through the implementation of the smart ecological monitoring system, companies' ESG behaviors increasingly focus on creating long-term value, reducing motivations for short-term opportunism, and guiding companies towards more socially responsible development.

2.2.3. The Mediating Role of Financing Constraints

As per Signal Theory, firms engage in ESG Disclosures so as to give off a signal pertaining to their sustainable development abilities towards the Capital Market, so they can be recognized by the providers of funding[23]. But because of unequal information, giving out money doesn't work well, figuring out if the ESG is really true or just fake news, so they cannot tell how much future growth and problems a place might have [24]. For companies with financing restrictions, ESG greenwash turns into a "back-door"- through making up a nice picture of ESG, a business can lessen the worry about lenders' views, improve the chances of borrowing, and make more financial support available. This is a greenwashing for the sake of financing, and we can look at that as a bit of a distortion around the time that there was an imbalance where not all the same data was accessible[25].

The smart ecological monitoring system optimizes the efficiency of corporate information transmission by providing real-time environmental data collection, cross-departmental information sharing, and big data analysis. It addresses the root causes of corporate financing constraints, thus weakening the motivation for greenwashing. Specifically, first, the system relies on big data technology to cross-verify

corporate information, significantly improving the credibility of the information and greatly reducing the cost for funding providers to distinguish between genuine and false signals. Rather than relying solely on ESG disclosures, funding providers can verify the company's real operating condition and sustainable development capabilities through cross-departmental data, reducing the misleading effect of false ESG signals.

Second, verified real ESG performance, which has been certified through smart ecological surveillance, starts appearing more convincing as an indicator of whether someone has got funding. In contrast with greenwashing behavior having no strong backing, when the ESG effort is based on compliance and true investment efforts are taken, it is more aptly rewarded by those in power, and thus, more long-term sustainable means of funding will be had, thus lessening stress from funding acquisition on an entity over time. If companies are able to obtain reasonable funding with regard to these true and actual financial data points, they'll have much lower motivation or even be completely uninterested in greenwashing just for their money. And this kind of thing stops the greenwashing motivation altogether at the motivation level.

Hypothesis 1: The implementation of the smart ecological monitoring system can suppress corporate ESG greenwashing behavior.

Hypothesis 2: The implementation of the smart ecological monitoring system can suppress corporate ESG greenwashing behavior by enhancing the level of corporate information disclosure.

Hypothesis 3: The implementation of the smart ecological monitoring system can suppress corporate ESG greenwashing behavior by reducing corporate agency costs.

Hypothesis 4: The implementation of the smart ecological monitoring system can suppress corporate ESG greenwashing behavior by alleviating corporate financing constraints.

3. Research design

3.1. Data Sources and Processing

This study treats ecological environmental monitoring as a quasi-natural experiment. The data includes pilot regions explicitly mentioned in the Ministry of Ecology and Environment's "Ecological Environment Smart Monitoring Innovation Application Pilot Work Plan" (hereinafter referred to as the "Plan") issued between 2014 and 2025. Specifically, the experimental group consists of 13 provinces and 16 municipal districts that were included in the pilot program as outlined in the Plan. These regions implemented the pilot policies for ecological environment smart monitoring innovation after the issuance of the Plan in February 2022, thus being the objects of policy intervention. Regions that were not included in the pilot program are selected as the control group. In this setting, the DID (Difference-in-Differences) value for the experimental group in the year of policy implementation and thereafter is set to 1. In contrast, the DID value for the control group is set to 0. This creates a DID framework for the ecological environment smart monitoring pilot at the municipal level.

3.2. Model Setting

3.2.1. Benchmark Regression Model

To examine the effect of the smart ecological monitoring system on corporate ESG greenwashing, this study constructs a benchmark regression model based on the Difference-in-Differences (DID) method, a quasi-natural experiment approach. The model is as follows:

$$GW_{it} = \alpha_0 + \alpha_1 DID + \alpha_i X_{it} + \mu_i + \delta_i + \varepsilon_{it} \quad (1)$$

In the model, GW_{it} represents the degree of ESG greenwashing for company i in year t; DID is the core explanatory variable, which is the Difference-in-Differences (DID) term for the ecological environment smart monitoring pilot: if the location where the company stays has realized an Ecological Environment Smart Monitoring then Policy Dummy Variable DID = 1, if not so, then DID = 0; Xit represents a set of control variables, including company size, leverage ratio, profitability, and other company-level characteristics; μ represents the company-specific fixed effects, which control for time-invariant heterogeneous factors at the company level; δ_i represents the year fixed effects, which control for common shocks at the annual level; and εit is the random error term.

3.2.2. Mediating Effect Model

To see what's in between when it comes to how smart ecosystems monitor affects firms' green talk in their ESG statements, we'll establish a middleman model from top to bottom through a step process. The regression model for the mediator is defined like so:

$$Mediator_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_i X_{it} + \mu_i + \delta_i + \varepsilon_{it} \quad (2)$$

Where $Mediator_{it}$ stands for the mediator variable, this is the proxy variables representing the three core mediation pathways from this study: Quality of Information Disclosure (KV), Corporate Agency Costs (AC), and Corporate Financing Constraints (WW). All others are the same as (1).

3.3. Variable Description

3.3.1. Dependent Variables

Corporate ESG GW: GW means when a corp says they're committed to green stuff but no proof is there or maybe lies[26]. To measure how corporate greenwashing works here, let me gauge what I call a firm's mouthpiece green promises, along with doing business environmentally. As for [27]and [28]), first build a set of key phrases including words about being green, protecting nature, using less carbon dioxide, and keeping our surroundings healthy. For every one of those companies' reports that contain an annual part, go over them to see how often they show up these words and contrast it against the general average number of times in that certain industry and timeframe. If greater than the industry median, let Oral be equal to 1, else 0. And if there was any kind of eco fee during a firms annual data then make actual 1 but everything else would be 0. Following [29]), we use a proxy for corporate greenwashing (GW) as follows:

$$GW_{it} = \begin{cases} 1, \text{ if } Oral_{it}=1 \text{ and } Actual_{it}=1 \\ 0 \qquad\qquad o.w. \end{cases} \quad (3)$$

The meaning of the indicator variable being 1 is relatively straightforward, indicating that the company has engaged in excessive green marketing, but its actual environmental performance is very poor.

3.3.2. Independent Variables

Ecological Environment Smart Monitoring Pilot (DID): To promote the application of ecological environment smart monitoring, the Ministry of Ecology and Environment issued the "Ecological Environment Smart Monitoring Innovation Application Pilot Work Plan" (hereinafter, the "Plan") in February 2022. This Plan further enhances the ecological environment monitoring big data platform and establishes an intelligent and efficient ecological environment management information system. According to the "Plan," the principle of "national unified framework, local responsibility for construction" was adopted. Based on local willingness to participate, fundraising capabilities, and regional environmental issues, 13 provinces, including Shanxi, and 16 municipal districts, including Changzhou, were selected to be the first pilot areas. This pilot aims to use new technologies such as the Internet of Things, sensors, and artificial intelligence to empower monitoring and control operations, unlock the potential value of massive data, and strengthen the coordination and linkage between monitoring, environmental impact assessment (EIA), enforcement, emergency response, and other business activities. This will enhance the ability to perceive ecological and environmental changes, provide early warnings, conduct comprehensive assessments, and make intelligent decisions. This paper follows the work of [30], using a multi-period DID method for identification. DID as a dummy: Company i was operating within the trial zone of Ecological-Environment Intelligent Monitoring in the period of year t if i = 1, and equal to zero if it is not. Also, as existing researches do, take a start time to be at any first six months in the year, for if the "Ecological Environment Smart Monitoring" project has happened during those first six then the following year will be the next one.

3.3.3. Mediation Variables

(1)Corporate information disclosure(KV): [31], this paper takes on the same approach as [32] for measuring corporate info discloure. We have also made a thorough analysis about those linkages among disclosured info quality, gains and trade volume, Kim and Verrecchia (2001)realized that if a firm's info giving was more full, investors would place a lot less confidence in numbers coming from trading volumes and much more faith in stuff presented through disclosers, making what trade amounts do to returns be less strong. If there isn't enough information disclosure, then investors usually depend on how many times stocks go up or down, instead of depending only on the company's information, which makes it much more affected by whether the volume of people buying or selling the share goes up or down than before. We refer to the coefficient of trading volume on return as KV. The larger the KV index is, the worse the level of information disclose in a listed enterprise. And since with such great difference among each other regarding the available amount of traded securities, I think it would be kind of misleading to compare how closely related would the change in a trading volume correspond with a stock's return given that some other market participant might have access to many times as much securities than another does just because he was allowed to enter into this trading venue, hence to solve the problem, we use below formula for calculating KV index:

$$Ln|(P_t-P_{t-1})/P_{t-1}|=\lambda_0-\lambda(Vol_t/Vol_0-1)+\varepsilon \quad (4)$$

According to its formula, Pt represents the closing prices of shares on each day of trade, and Volt stands for the number of shares that have been bought or sold during one specific day of trade in the current market. Vol0 refers average daily trading volumes for an entire span under evaluation. Using the ordinary least squares (OLS) method, we get an estimated regression from the listed companies and then make the corresponding KV index without λ less than zero. A smaller λ means there's more proper information being disclosed, which is why a higher KV amount points towards a worse level of disclosing it.

(2)Agency costs (AC): This study uses the proportion of other receivables over total assets as an indicator for Type II agency costs associated with the control shareholders and the minority shareholders. First of all, the control shareholders take from listed firms is mostly what happens most time,, the smaller shares will get picked off. The other side is like, this appropriation, you could say a lot of it would go through, you could see the money coming in because it's from the same family, and some things, it's not like a true loan, just listed as another type of asset, like a temporary loan. In contrast to receivables from related party sales, other receivables from "temporary loans" are more hidden, so they have become an important way and sign for the control shareholder tunneling. So other receivables are pretty close to the amount of agency cost going on: the bigger the portion of other receivables, the bigger the agency cost.

(3)Financing constraints (WW): Following [33], here we compute the degree of financing difficulty utilizing multiple factors, including, for instance, the so-called WW index. It consists of many financial features like cash holdings or leveraged ratio, and dividend payout, etc It reflects how difficult a company has access to funding on the market. A larger number implies more intense financing constraints. We can derive WW index in such a manner:

$$WWindex=-0.091\times\frac{Cashflow}{Asset}-0.062\times DIVPOS+0.021\times\frac{DTLT}{Asset}-0.044\times Size+0.102\times ISG-0.035\times SG \quad (5)$$

From the equation, it is clear that DIVPOS is an indicator for whether or not the company distributes cash dividends as well, which has a value 1 for true, otherwise it is false and given a value of 0. DTLT = the long-term debt that the firm is liable to settle in the coming years, ISG is shorted by three letters and is equal to the change over the past three years on the same date each year; and SG also represents Sales Growth. When the WW index rises, the company suffers from more intense finance limitations.

3.3.4. Control Variables

This paper uses corporate ESG greenwashing (GW) as the dependent variable and the Pilot Project for Smart Monitoring of Ecological Environment (did) as the key independent variable to examine the impact of digital environmental regulation on corporate ESG greenwashing. To explore the underlying mechanisms, we further incorporate several mediating variables, including information disclosure quality (KV), corporate agency costs (AC), and corporate financing constraints (WW). Information disclosure quality is measured

by the KV index, corporate agency costs are proxied by the ratio of other receivables to total assets, and corporate financing constraints are captured by the WW index. In addition, we include a set of control variables to mitigate potential omitted variable bias, including firm operating efficiency (total asset turnover, ATO), cash flow position (cash flow ratio, Cashflow), asset structure (fixed assets ratio, FIXED), growth capability (operating revenue growth rate, Growth), governance structure (board size, Board), and tunneling problems arising from controlling shareholders (controlling shareholder fund appropriation, Occupy). Detailed definitions of all variables are provided in Table 1.

Table 1. Variable Definitions

Variable Category	Variable Name	Symbol	Description
Dependent variable	ESG greenwashing	GW	A dummy variable for corporate greenwashing. It equals 1 if, in the "Management Discussion and Analysis (MD&A)" section of the annual report, the frequency of terms related to environmental monitoring is higher than the median of firms in the same industry, and the firm is penalized for environmental issues in the same year; otherwise, it equals 0.
explaining variable	Pilot Project for Smart Monitoring of Ecological Environment	did	Constructing Digital Indicators for Regulating Corporate ESG Greenwashing through the Quasi-Natural Experiment of the Ecological Environment Smart Monitoring Pilot Project
Mediating variable	Information disclosure quality	KV	Information disclosure quality is measured using the KV index model.
	Corporate agency costs	AC	The ratio of other receivables to total assets.
	Corporate financing constraints	WW	Financing constraints are measured using the WW index model.
Control variable	Total asset turnover	ATO	The ratio of operating revenue to average total assets.
	Cash flow ratio	Cashflow	The ratio of net cash flow from operating activities to current liabilities.
	Fixed assets ratio	FIXED	The ratio of net fixed assets to total assets.
	Operating revenue growth rate	Growth	(Current period operating revenue-Previous period operating revenue)/ Previous period operating revenue ×100%
	Board size	Board	The actual number of directors on the board.
	Controlling shareholder fund appropriation	Occupy	The ratio of other receivables to total assets.

4. Empirical Analyses

4.1. Benchmark Regression Analysis

Table 2 presents the benchmark regression results for the impact of the Ecological Environment Smart Monitoring Pilot on corporate ESG greenwashing (GW). As shown in Column (1), in the absence of firm fixed effects, year fixed effects, and control variables, the coefficient on DID is −0.154, significant at the 1% level, indicating a significant negative association between the pilot policy and corporate ESG greenwashing.

Column (2) further incorporates firm fixed effects, year fixed effects, and firm-level control variables, including ATO and Cashflow. The coefficient on DID remains negative and statistically significant at the 1% level, with a coefficient of −0.151. The stability of both the sign and magnitude of the coefficient suggests that the baseline finding is robust to the inclusion of additional controls and fixed effects.

Taken together, the evidence from Table 2 suggests that the Ecological Environment Smart Monitoring Pilot significantly suppresses corporate ESG greenwashing, thereby supporting Hypothesis 1.

Table 2. Baseline regression results.

	(1)	(2)
	GW	GW
did	-0.154***	-0.151***
	(0.052)	(0.052)
ATO		0.023
		(0.058)
Cashflow		0.140
		(0.199)
FIXED		-0.693***
		(0.186)
Growth		-0.130***
		(0.029)
Board		-0.173*
		(0.101)
Occupy		-0.354
		(0.659)
_cons	0.057***	0.584***
	(0.010)	(0.226)
id	NO	YES
year	NO	YES
N	8454.000	8450.000
r2_a	0.446	0.448
id	NO	YES

*Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels.*

4.2. Robustness Checks

4.2.1. Parallel Trend Test

The result of a parallel trend on how ecological environment smart surveillance affects corporate ESG greenwashing is shown in Figure 1. Horizontal axis shows times: when the rule was introduced (pre_3 is three months prior, pre_2 two months, pre_1 just one month), the rules took effect (current), and it has been a month since the rules came into place (post_1). The vertical axis represents the estimate of dynamic effects for policy. Dots show coefficients; error bars show confidence intervals.

It is found that the effect estimates with dynamics from the periods before policy (pre_3, pre_2, pre_1) are all close to zero as well, their corresponding CI also includes zero, which means there was insignificant difference in the change of ESG greenwashing between treatment and control group before the policy has been implemented. This satisfies the parallel trend assumption required by the Difference-in-Differences (DID) model. During the policy implementation period (current), the dynamic effect estimate significantly decreases to a negative value, with the confidence interval not crossing zero, suggesting that the introduction of ecological environment smart monitoring immediately had a significant inhibiting effect on corporate ESG greenwashing once the policy was implemented. In the period after the policy implementation (post_1), the effect estimate slightly increases compared to the implementation period but remains below zero (with the confidence interval still not crossing zero), indicating that the inhibitory effect of smart ecological monitoring on corporate ESG greenwashing continues to exist after policy implementation, although the marginal effect has slightly weakened compared to the policy implementation period.

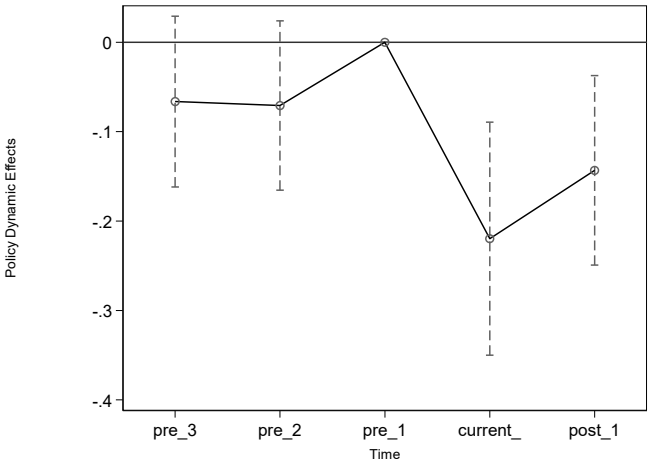

Figure 1. Parallel Trend Test

4.2.2. Placebo Test

So that we can reduce some of the impacts from random chance and things that aren't visible like stuff we forgot to include and stuff we can't even imagine, I am doing a test called a placebo test which tries to figure out if it is really the policy making company's environment smarter that makes them do worse at ESG greenwashing by accident or for some other reason, because some of my results seemed accidental. A placebo test with 500 random samplings simulation according to Figure 2 to see whether there are like random factors or hidden influences.

As for the result, it can be seen that according to what was simulated using Estimators from its Kernel Distribution, it seems that most estimations center themselves around 0; Moreover, only a few of those p-values will ever fall short statistically speaking. And this shows that if such policy shocks had been randomly assigned, there is no effect to be seen. Therefore it was a random factor or unobserved interference that didn't have an enormous effect on our results.

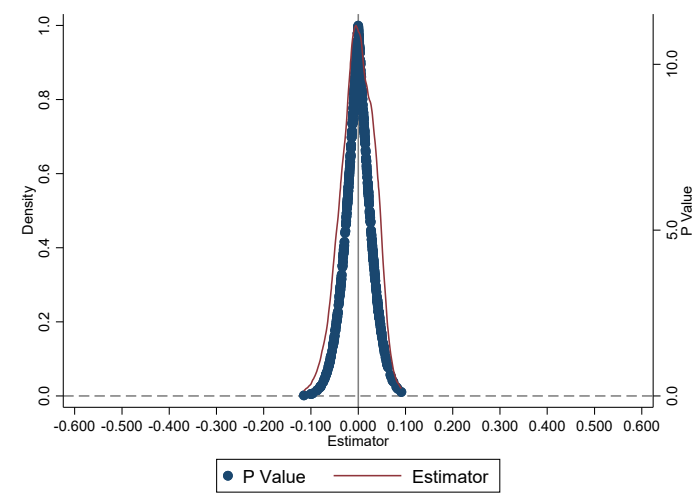

Figure 2. Placebo Test

With the combined estimate for the significantly negative DID coefficient found in our main regression, this placebo check also takes into account the influence of random factors as well as unobserved variables to exclude the conclusion we have reached as being affected by it. It verifies the strength of the outcome: Ecological environment smart supervision restrains firm ESG environmental greenish lies, which is proven via a strong effect seen during the baseline regression–meaning this was not some kind of false impression–hence the result holds true indeed as a proper policy effect.

4.2.3. PSM

As was done in previous works, we use the control variables as our matching variables and employ k-NN matching. Find the k nearest propensity scores for individuals from different groups. 1:1 nearest neighbor matching is used to get the sample. Nearest neighbor matching can help with the sample selection issue to some degree, which can lessen the bias in DID model estimation. Table 3 shows the outcomes: In Column (1), without controlling for company-specific and year fixed effects and without including control variables, the coefficient of the core explanatory variable is -0.159, and it is significantly negative at the 5% level, indicating that the implementation of the ecological environment smart monitoring policy has a significant inhibitory effect on corporate ESG greenwashing. In Column(2), after adding in control variables like ATO and Cashflow, the coefficient on DID is –0.166 but is still highly -1%. This shows that after controlling for confounding factors, the policy's inhibitory effect remains significant, further confirming the suppressive effect of ecological environment smart monitoring on corporate ESG greenwashing.

4.2.4. Replacing the Dependent Variable

To further test the robustness of the benchmark regression results, this study follows the method of Zhang(2022a)[34], measuring the corporate greenwashing score relative to industry peers, as defined in equation (6):

$$GW_{i,t}=\frac{ER_{i,t}-\overline{ER_{dis}}}{\sigma_{dis}}-\frac{ER_{i,t}-\overline{ER_{per}}}{\sigma_{per}} \quad (6)$$

This equation has the first term standing for the normalized Figure of the company's environmental ratings disclosure scores with respect to its counterparts in its respective sectors, as opposed to being the second one, which stands for the normalized number related to the company's actual environment performance and other members of the same kind within their industries. ERdis means mean value of envirnmental deilicationscore, ER_{per} means mean value of environmental performance score, σ dis means standard deviation of envirnmentaldeilication,σ per is the standard deviation of environmental performance. In other words, it is the Bloomberg Environmental Ratings that serve as our measure of environmental discloser ERdis as well as the Wind environmental rating serving as a true measure of how our environment fared ER_{per}.

And it was the results of the dependent variable with that measurement replaced are contained in Column (3) of Table 3. Core explanatory variables: DID coefficients, -1.223, significantly less than 0%, controlling for firm-specific fixed effects (id), year fixed effects (year), and controls. It means even after ESG greenwashing has changed, when we consider ecological environment smart monitoring on corporations' ESG greenwashing, there will be a very big and significant effect on ESG greenwashing, which makes the reference regressions much stronger.

Table 3. PSM and Alternative Dependent Variable.

	PSM		Alternative Dependent Variable
	(1)	(2)	(3)
	GW	GW	GW
DID	-0.159**	-0.166***	-1.223***
	(0.064)	(0.063)	(0.442)
ATO		-0.138***	20.225***
		(0.029)	(3.182)
Cashflow		0.129	-13.921***
		(0.195)	(1.479)
FIXED		-0.443***	-1.046***
		(0.080)	(0.202)
Growth		-0.165***	-5.414***
		(0.033)	(1.577)
Board		-0.440***	1.519**
		(0.062)	(0.713)
Occupy		-2.957***	-5.444***
		(0.540)	(0.589)
_cons	0.057***	1.256***	-31.287***
	(0.013)	(0.136)	(0.255)
id	YES	YES	YES
year	YES	YES	YES
N	8509.000	8505.000	8442.000
r2_a	0.066	0.082	0.421

*Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels*

5. Mechanism Analysis

This study successively verified three transmission paths: "improvement in information disclosure, reduction in agency costs, and alleviation of financing constraints". The regression results are shown in Table 4:

5.1. The Mediating Path of Information Disclosure

Column (1) presents the effect of environmental intelligent watch on company info disclosure (KV). For the core explanatory variables like DID, we observe the coefficient to be 0.043, which is highly significantly above 1%, hence there is a very large chance of improvement in corporation information disclosure post ecological environment smart monitoring implementation. Hypothesis 2 gets verified. From the point of view of mechanism logic, the ecological environment smart monitoring encourages the company's ESG information to go from "formal disclosure" to "real presence" by means of inter-departmental verifying of data, rules of disclosure constraining as well as so on. And this is just what I found out to me, the result allows us to find a link between the way we talk about our ESG things and all that information that companies want to get off their hands and put somewhere, because no one can say it didn't exist if someone finds out. It does show the transmission mechanism: more info disclosed, fewer opportunistic spaces for the corporation's ESG greenwashing, giving some support for how Ecolgy Envirnmt Smart Mltchngr Improves Corp's Info Dispblty Quallty And So On To Less ESS GRNWSHN, so it was found to have some connection here.

5.2. The Mediating Path of Agency Costs

In Column (2), the regression coefficient for the core explanatory variable DID on AC is -0.026, and this is highly statistically significant at the 1% level; i.e., firm's type-II agency costs fell by around one per cent following an increase in the use of ecological environment smart monitoring, thus validating Hypothesis 3. From a mechanism perspective, the digital regulation of ecological environment smart monitoring strengthens the tracking and constraint of controlling shareholders' appropriation of company funds, while improving internal information transparency to enhance minority shareholders' ability to supervise. This result validates the transmission mechanism "Ecological environment smart monitoring reduces agency costs, thereby reducing the motivation of controlling shareholders to use ESG greenwashing for personal gain," further supporting the effectiveness of this mediating path.

5.3. The Mediating Path of Financing Constraints

Column (3): The core explanatory variable DID has a regression coefficient of -0.012 on the WW financing constraints index, and it is significantly negative at the 1% level. This means that the implementation of ecological environment smart monitoring significantly alleviates corporate financing constraints, thus validating Hypothesis 4. Theoretically, it makes sense that ecological environment smart monitoring increases the truthfulness of company data, thus reducing the amount of effort required by funders to sift through noise and find valuable information, making loans easier for businesses that do not engage in greenwashing. This result confirms the transmission mechanism, showing that the pathway "Ecological environment smart monitoring → alleviates financing constraints → weakens the demand for greenwashing to obtain financing" holds.

Table 4. Mediation Mechanism Tests.

	(1)	(2)	(3)
	KV	AC	WW
did	0.043***	-0.026***	-0.012***
	(0.009)	(0.003)	(0.001)
ATO	-0.009	-0.070***	0.004**
	(0.014)	(0.005)	(0.002)
Cashflow	0.334***	-0.125***	-0.133***
	(0.048)	(0.016)	(0.007)
FIXED	-0.294***	0.070***	0.028***
	(0.044)	(0.014)	(0.007)
Growth	0.034***	-0.016***	-0.040***
	(0.007)	(0.002)	(0.001)
Board	-0.015	-0.018**	-0.013***
	(0.024)	(0.008)	(0.004)
Occupy	-0.664***	0.141***	0.060**
	(0.158)	(0.052)	(0.024)
cons	0.682***	0.225***	-1.042***
	(0.054)	(0.018)	(0.008)
id	YES	YES	YES
year	YES	YES	YES
N	8438.000	8285.000	7691.000
r2_a	0.269	0.780	0.814

*Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels.*

6. Heterogeneity Analysis

Table 5 shows the heterogeneity results for how well ecological environment smart monitoring does in terms of ESG GW across multiple perspectives. The main explanatory variable here was the policy effects of eco-environmental smart watching (DID). Specific analyses are as follows:

6.1. Heterogeneity Based on Corporate Ownership

In Column (1) for the State-owned enterprise group, DID is -0.242and is significant at 5% level. Column (2) non-state-owned enterprises group, the DID coefficient is also negative, it's equal to -0.221, and it passes the test of significance too. This means that the inhibitory effect of ecological environmental smart monitoring over ESG green washing can have an influence on both state-owned & non-state-owned companies statistically, yet there seems to be a stronger impact observed over state-owned businesses when compared with their private counterparts. This suggests that ecological environment smart monitoring has a more substantial inhibitory impact on state-owned enterprises, possibly because these companies are subject to stricter government regulation. The digital regulatory system, when combined with existing regulatory mechanisms, forms a synergistic effect that can more effectively constrain greenwashing behaviours in ESG disclosures. In contrast, non-state-owned enterprises have relatively lower transparency and compliance, and the policy's constraint effect is weaker[35].

6.2. Heterogeneity Based on Regional Distribution

In Column (5), for enterprises in the western region, the DID coefficient is -0.152. It is significantly negative, indicating a significant inhibitory effect of ecological environment smart monitoring on ESG greenwashing in Western region enterprises. In contrast, in Columns (3) and (4), for enterprises in the central and eastern regions, the DID coefficients are -0.209 and -0.291, respectively, with the

eastern region not passing the significance test. This suggests that the inhibitory effect of ecological environment smart monitoring is not significant in these regions.

The cause of this heterogeneity may be due to the relatively weak information infrastructure and regulatory systems in enterprises in the western region. Ecological environment smart monitoring, through cross-departmental data integration and real-time monitoring, effectively fills the information gap, thereby strengthening the constraint on greenwashing behaviours. In contrast, enterprises in the eastern and central regions already have higher transparency and better compliance, so the marginal effect of ecological environment smart monitoring is relatively limited.

6.3. Heterogeneity Based on Corporate Technological Attributes

In Column (7), for non-high-tech enterprises, the DID coefficient is -0.238 and is significantly negative, indicating a more significant inhibitory effect of ecological environment smart monitoring on non-high-tech enterprises. In contrast, in Column (6), for high-tech enterprises, the DID coefficient is -0.074, which does not pass the significance test, suggesting that the inhibitory effect on high-tech enterprises is not significant.

This result indicates that high-tech enterprises, which typically rely on innovation results and government support, tend to have more standardised ESG performance and weaker greenwashing motivations. Therefore, the policy's inhibitory effect is smaller. In contrast, non-high-tech enterprises are more likely to rely on ESG packaging to obtain financing or policy resources. Thus, the digital regulatory system of ecological environment smart monitoring has a more significant constraint effect on their greenwashing behaviour.

Table 5. Heterogeneity Analysis.

Items	(1) SOEs	(2) Non-SOEs	(3) Central region	(4) Eastern region	(5) Western region	(6) High-tech enterprises	(7) Non-high-tech enterprises
	GW	GW	GW	GW	GW	GW	GW
DID	-0.242**	-0.221*	-0.299*	-0.152	-0.202***	-0.074	-0.238***
	(0.098)	(0.113)	(0.156)	(0.109)	(0.068)	(0.091)	(0.088)
ATO	-0.245***	-0.036	-0.118	-0.117**	-0.146***	-0.105***	-0.153***
	(0.039)	(0.051)	(0.076)	(0.055)	(0.031)	(0.038)	(0.048)
Cashflow	-0.878***	0.822***	0.059	-0.287	0.244	-0.199	0.336
	(0.294)	(0.290)	(0.448)	(0.339)	(0.208)	(0.281)	(0.275)
FIXED	-0.540***	0.052	-0.461**	-0.420***	-0.476***	-0.148	-0.981***
	(0.103)	(0.162)	(0.193)	(0.138)	(0.087)	(0.105)	(0.139)
Growth	-0.069	-0.231***	-0.209***	-0.217***	-0.154***	-0.145***	-0.193***
	(0.051)	(0.046)	(0.075)	(0.059)	(0.035)	(0.046)	(0.046)
Board	-0.462***	-0.452***	0.034	-0.032	-0.480***	-0.422***	-0.405***
	(0.089)	(0.103)	(0.161)	(0.119)	(0.066)	(0.087)	(0.091)
Occupy	-3.037***	-2.422***	-3.351**	-2.766***	-2.985***	-1.855***	-4.240***
	(0.787)	(0.893)	(1.489)	(1.036)	(0.576)	(0.655)	(1.030)
cons	1.430***	1.094***	0.255	0.342	1.364***	1.115***	1.316***
	(0.199)	(0.221)	(0.356)	(0.265)	(0.144)	(0.192)	(0.196)
id	YES	YES	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES	YES	YES
N	4127.000	3794.000	1480.000	2617.000	7416.000	3980.000	4523.000
r2_a	0.121	0.104	0.150	0.129	0.080	0.084	0.120

*Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% levels*

7. Conclusion and Policy Recommendations

As for the Plan in 2014-2025, which is being made out of the treatment area in terms of the pilot areas for that time, I focus upon the policy shock created due to putting it into effect within this system for smart ecological surveillance, also observing how this influences the company's ESG, and also what those causes were. Conclusion. And first thing here we found that our smart eco monitoring systems did reduce a lot of corporate ESG and the greenwash of them. Robustness checks like parallel-trend test, placebo test, and alternative variable spec are done, and it's shown that smart ecological monitors can help make the info that firms release more visible, lessen info imbalance, and get more outside oversight. These changes effectively reduce managers' incentives to obtain short-term benefits through false or selective disclosures, thereby lowering the incidence of greenwashing. Second, the smart ecological monitoring system reduces greenwashing mainly through three channels: (i) improving the transparency and credibility of corporate disclosures, thereby strengthening external stakeholders'(e.g., investors' and regulators') trust in firms' environmental and social responsibility information; (ii) lowering agency costs within firms, which weakens managers' incentives to pursue short-term gains through greenwashing; and (iii) easing firms' financing constraints by enabling access to funding based on credible ESG signals, thereby reducing reliance on distorted ESG signals to obtain capital. Third, the heterogeneity analysis shows that the inhibitory effect of the smart ecological monitoring system varies across firm types. The effect is relatively more substantial for state-owned enterprises, firms with lower technological intensity, and firms located in western China. These firms tend to face larger gaps in disclosure capacity and regulatory infrastructure, and smart ecological monitoring can effectively mitigate these shortcomings, improve ESG performance, and reduce greenwashing. Based on these findings, this paper proposes the following policy recommendations:

(1) Strengthen cross-departmental collaborative

governance of ESG information under a digital regulatory framework. Based on the digital regulatory framework that is already being created from the smart ecological monitoring system that's already been implemented, the government should push the tax office, as well as the market regulation bodies, along with the Ecological Environment bureaus, towards making ESG-related records compatible and interchangeable with others, and also have an ESG checking process in place. For example, firms' tax declaration data can be cross-checked against ESG-disclosed indicators such as energy consumption and emissions reductions to reduce the room for greenwashing created by information asymmetry. In addition, ESG disclosure guidelines should be refined for different types of firms: for entities with stronger incentives to greenwash (e.g., non-high-tech firms), regulators should specify core ESG disclosure indicators—such as energy intensity and the share of environmental investment—and require corresponding supporting documentation; for western-region firms with weaker disclosure capacity, operational manuals for compliant ESG disclosure should be issued to improve standardisation and verifiability.

(2) Implement differentiated ESG supervision and targeted resource support based on heterogeneity. Given the relatively weak digital regulatory infrastructure in western China, resources should be increased—where appropriate—to expand the functions of the smart ecological monitoring system in these regions, such as ESG data collection and ESG compliance training, thereby narrowing regional gaps in regulatory capacity. For non-high-tech firms, regulators should increase the frequency of on-site verification of ESG information, with a focus on consistency between ESG disclosures and actual business practices. For state-owned enterprises, ESG disclosure quality can be incorporated as a supplementary indicator in the performance evaluation of responsible executives, strengthening internal governance constraints on ESG greenwashing.

(3) Establish an ESG information quality assurance mechanism that links regulatory enforcement with market incentives. The verification results of corporate ESG information generated through smart ecological monitoring should be tied to policy instruments such as financial institutions' credit decisions and eligibility for government subsidies. For instance, ESG verification approval can be set as a prerequisite for firms to obtain preferential interest rates on green credit, using market-based incentives to reduce greenwashing motives. At the same time, ESG greenwashing audits should be integrated with supervision of controlling shareholders' fund appropriation: for firms with distorted ESG disclosures and abnormal related-party fund flows, accountability mechanisms for controlling shareholders should be strengthened. Moreover, oversight channels for minority shareholders should be improved by allowing them to request regulatory re-examination of suspected issues in ESG disclosures, thereby alleviating Type II agency problems and reinforcing ESG information quality constraints from the perspective of internal monitoring.

Conflict of Interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

Author Contributions

Writing – original draft: Ruyu He; Writing – review & editing: Ruyu He;Supervision: Huan Huang.

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