

Article

Informatization and Corporate ESG Performance: Evidence from Smart City Pilots in China

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Abstract

The value of informatization lies not only in expanding urban digital infrastructure, but also in reshaping firm behavior through improvements in the information environment. Using China's smart city pilot program as a quasi-natural experiment and a sample of Chinese A-share listed firms, this study examines whether urban-level informatization affects corporate ESG performance. The staggered difference-in-differences estimates show that smart city pilots significantly improve firms' ESG performance, and the result remains robust after a range of endogeneity checks and robustness tests. Mechanism analyses provide evidence consistent with the proposed external monitoring and internal governance channels. Specifically, smart city pilots are associated with stronger monitoring by capital-market participants and improved internal governance conditions, in line with investor attention theory and organizational information processing theory. The effect is more pronounced for firms whose executives have environmental backgrounds, firms in heavily polluting industries, and firms located in regions with stronger environmental regulation. Further tests show that ESG improvements induced by informatization increase both short-term profitability and long-term market valuation. These findings reveal how urban informatization promotes corporate ESG performance and show that ESG improvements can help firms align social value with economic value.

Keywords: informatization; corporate ESG performance; smart city pilots; stakeholders; multi-period difference-in-differences



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1. Introduction

With the expansion of digital infrastructure and the improvement of digital governance capacity, the level of urban informatization has increased substantially. Yet improvements in the urban information environment do not necessarily translate into better corporate sustainability practices. On the one hand, corporate ESG activities involve strong externalities and cover multiple objectives, including environmental governance, employee rights, social responsibility, and corporate governance. Their costs are often borne by firms in the current period, whereas their benefits may materialize gradually through reputational capital, access to resources, risk mitigation, and long-term value. On the other hand, corporate ESG performance reflects firms' overall outcomes in environmental responsibility, social responsibility, and corporate governance. Its improvement depends not only on firms' own governance willingness and capabilities, but also on external risks, the policy

environment, and the strength of stakeholder monitoring [1]. This raises an important question: can urban informatization, represented by smart city development, improve firms' ESG performance by reshaping the external information environment in which they operate? This question is also closely related to the literature on how reforms, social environments, and information design shape the decisions of economic agents. Changes in external institutional or information environments may alter decision constraints, information acquisition, and patterns of interaction, thereby generating economically meaningful behavioral responses [2]. In this sense, China's smart city pilot program provides a useful policy setting for examining how public digital infrastructure affects firm behavior as an exogenous shock to the information environment.

The theoretical rationale is that informatization is not merely an expansion of digital infrastructure, but also a change in the decision-making environment faced by firms. Existing studies show that corporate digital transformation can improve ESG performance [3], but this stream of research mainly focuses on how firms use digital technologies to improve operations, management, and sustainable development capabilities [4]. Unlike firm-level digitalization, smart city pilots first change public information infrastructure and information flows at the urban level. Their influence is not limited to a single firm's digital investment, but operates through the shared information environment in which firms, investors, governments, media, analysts, and institutional investors are jointly embedded [5]. Therefore, the effect of smart city development on corporate ESG performance should not be viewed simply as an external version of corporate digital transformation. Rather, it should be understood as a process through which public digital infrastructure reduces information frictions, improves monitoring conditions, and strengthens firms' governance capabilities.

Specifically, urban informatization shocks may affect corporate ESG performance by strengthening external monitoring and improving internal governance. From the perspective of investor attention theory [6], attention among capital market participants is a scarce resource, and information visibility and information acquisition costs shape both the direction of attention and the intensity of monitoring. By improving digital infrastructure, government data systems, and urban information platforms, smart city development increases the availability and dissemination efficiency of information related to firms' operations, environmental governance, and social responsibility. This enables media, analysts, and institutional investors to identify and evaluate corporate ESG behavior at lower cost [7,8], thereby strengthening external pressure on firms to improve ESG performance. From the perspective of organizational information processing theory [9], firms facing complex external environments and diverse stakeholder demands need stronger capabilities to acquire, transmit, and integrate information. The higher-quality information environment created by smart city development helps firms obtain policy, market, technological, and governance-related information in a more timely manner, improves internal control, digital management, and cross-departmental coordination [4], and thereby enhances firms' internal governance capacity for ESG practices.

Although recent studies have begun to examine the microeconomic effects of smart city pilots and show that they can affect green innovation, digital transformation, and green total factor productivity [3,10,11], these studies mainly interpret the firm-level effects of smart city development from the perspectives of innovation output, technological transformation, or production efficiency. They have not fully explained how multiple stakeholders, under a regional informatization shock, influence corporate ESG behavior through external monitoring, nor have they sufficiently examined how firms respond differently to changes in the internal and external information governance environment. ESG performance covers environmental responsibility, social responsibility, and corporate governance, and therefore

provides a more comprehensive measure of how firms respond to the demands of multiple stakeholders. This study therefore takes corporate ESG performance as the entry point and further investigates whether smart city pilots improve corporate sustainability behavior by enhancing the external information environment and strengthening the internal governance foundation.

Based on the above analysis, this study uses China's smart city pilot program as a quasi-natural experiment and employs data on Chinese A-share non-financial listed firms from 2009 to 2020 to examine the causal effect of informatization shocks on corporate ESG performance using a staggered difference-in-differences approach. We find that smart city pilots significantly improve corporate ESG performance, and this conclusion remains valid after a series of endogeneity checks and robustness tests. Mechanism analyses show that informatization strengthens external monitoring by capital market participants through an investor attention mechanism, and improves internal governance efficiency by enhancing firms' ability to acquire, transmit, and integrate information, consistent with organizational information processing theory. Heterogeneity tests show that the ESG-enhancing effect of smart city pilots is more pronounced among firms whose executives have environmental backgrounds, firms in heavily polluting industries, and firms located in regions with stronger environmental regulation. Tests of economic consequences further show that ESG improvements driven by informatization increase both short-term profitability and long-term market value.

This study makes three main contributions. First, it extends research on informatization and corporate ESG from firms' internal digital capabilities to external information environment shocks. Existing studies typically explain improvements in corporate ESG performance from the perspectives of corporate digital transformation [3] and the application of digital technologies [4], with the underlying logic mainly centered on internal data use and digital management. In contrast, this study treats smart city pilots as a quasi-natural experiment and conceptualizes urban informatization as a policy shock that improves public digital infrastructure and the external information environment. It identifies the causal effect of this shock on corporate ESG performance. In doing so, this study not only complements the literature on the determinants of corporate ESG performance, but also places ESG issues within a broader framework of information frictions, public digital infrastructure, and firm behavioral responses.

Second, this study deepens the mechanism-related explanation of how urban informatization is associated with corporate ESG performance from the dual perspectives of external monitoring and internal governance. Although prior studies have examined external information environment factors such as media coverage [7], investor attention [8], and public data openness [12], less is known about whether city-level informatization shocks are accompanied by changes in monitoring by capital market participants and firms' internal information processing capabilities. Drawing on investor attention theory and organizational information processing theory, this study provides evidence consistent with the proposed external monitoring and internal governance channels. Specifically, smart city pilots are associated with stronger external monitoring, reflected in greater market visibility of firms' ESG behavior and stronger capital market attention, and with improved internal governance conditions, reflected in firms' enhanced ability to acquire, transmit, and integrate information. These findings enrich the explanation of how improvements in the urban information environment are related to improvements in corporate ESG performance.

Third, this study reveals the boundary conditions and economic consequences of the joint role of informatization and green development in promoting corporate ESG performance. We find that the ESG-enhancing effect of smart city pilots is stronger for firms whose executives have environmental backgrounds, firms in heavily polluting industries,

and firms located in regions with stronger environmental regulation. This suggests that after urban informatization improves the external information environment and firms' information processing capabilities, its effect on ESG performance is more fully released when it is combined with firms' green awareness, industry-level pressure for green transformation, and regional environmental governance constraints. Further analysis shows that ESG improvements induced by informatization increase both short-term profitability and long-term market value. This indicates that ESG improvement is not merely a responsibility-related cost, but a governance practice that can align social value with economic value. While Zhang et al. [13] document the productivity-enhancing effect of ESG improvement, our analysis provides complementary evidence from the perspective of firm value.

The remainder of this paper is organized as follows. Section 2 introduces the policy background and develops the research hypotheses. Section 3 describes the research design. Section 4 reports the empirical results, including the baseline estimates and a series of robustness tests. Section 5 presents the mechanism tests, heterogeneity analyses, and tests of economic consequences. The final section concludes and discusses policy implications.

2. Policy Background and Hypothesis Development

2.1. Policy Background

The concept of the “smart city” can be traced back to International Business Machines Corporation's 2008 “Smart Earth” vision, which proposed embedding and applying next-generation information technologies, such as the Internet of Things and cloud computing, across different sectors of society to facilitate interaction among diverse stakeholders and enable more precise, efficient, and transparent management of production and daily life. As an important vehicle for deploying these technologies and advancing the digital economy at the urban level, the smart city has, to some extent, superseded the earlier notion of the “digital city.” More specifically, smart cities improve the efficiency and convenience of interactions among governments, the public, the media, and enterprises [1], thereby helping to overcome the long-standing fragmentation among economic actors and promoting coordinated development across public administration, industry, environmental protection, and public welfare [5]. With the deepening integration of next-generation information technologies into urban modernization, the Chinese government has attached increasing importance to smart city development and has gradually launched a series of related initiatives. In early 2013, the Ministry of Housing and Urban-Rural Development announced the first batch of national smart city pilots. The second and third batches were subsequently announced in August 2013 and April 2015, respectively, ultimately covering 290 counties and cities.

As an advanced form of urban informatization, smart city construction inherently involves the innovative application of information technology and can thus substantially improve the level of informatization in both cities and the enterprises located within them. In the context of China's smart city pilot program, the National Smart City (District, Town) Pilot Indicator System (Trial) issued by the Ministry of Housing and Urban-Rural Development identifies support systems and infrastructure as one of the four primary criteria for pilot selection, covering wireless network coverage, urban public basic databases, and information security. The policy also requires the establishment of a unified urban public information platform with centralized management and data exchange functions to meet the needs of public information sharing and service provision across different urban services and industrial sectors. In August 2013, following the announcement of the second batch of smart city pilots, the Ministry issued specific implementation guidelines requiring local governments to “prioritize information integration, sharing, and collaboration” and to

focus on the development of urban public information platforms and public basic databases. The guidelines also emphasized the development of urban application systems and the achievement of demonstrable economic and social benefits. These requirements indicate that the smart city pilot program was accompanied by continued investment in information infrastructure, thereby enabling informatization to support economic development and social governance. In March 2014, the State Council issued the National New-type Urbanization Plan (2014–2020), which set out a new strategic direction for smart city development by calling for the coordinated use of material, informational, and intellectual resources in urban development, the innovative application of next-generation information technologies such as the Internet of Things, cloud computing, and big data, and their deep integration with urban economic and social development. In August of the same year, the Guiding Opinions on Promoting the Healthy Development of Smart Cities, jointly issued by eight ministries and commissions, set out five major goals for smart city construction: accessible public services, refined urban management, livable environments, intelligent infrastructure, and long-term cybersecurity. Subsequently, the 13th Five-Year Plan for National Economic and Social Development, released in March 2016, introduced for the first time the concept of “developing a number of new-model smart cities,” which emphasized a people-centered approach. In essence, the new-model smart city seeks to improve urban governance by breaking down information silos and enabling the smooth flow of data as a factor of production, thereby fostering a new pattern of sustainable socio-economic development. This urban-level objective is broadly consistent with the firm-level pursuit of ESG development, with informatization serving as an important link between the two.

The foregoing discussion provides the institutional background for this study’s research design, which treats the smart city pilot program as an exogenous shock to informatization development. According to the Worldwide Smart Cities Spending Guide published by International Data Corporation (IDC), China’s total IT investment in smart cities reached USD 25.9 billion in 2021, representing year-on-year growth of 15% and ranking second only to the United States worldwide. In the Chinese market, the three largest investment areas are sustainable infrastructure, data-driven governance, and digital management, which were projected to account for more than half of total smart city investment during the 2020–2024 forecast period. At the project level, smart city initiatives, including smart government systems, environmental monitoring platforms, smart finance systems, and urban big data platforms, are built on information infrastructure such as the Internet of Things, 5G networks, and data centers, and they directly affect the economic activities of firms. An illustrative example is Wuhan. In September 2021, “Wuhan Cloud,” the country’s first city-named cloud platform, was officially launched as a flagship project in the city’s new-type smart city development. By integrating data from multiple government departments and other entities into a unified urban big data platform, Wuhan Cloud not only promotes the modernization of urban governance and the digital economy, but also facilitates firms’ adoption of cloud-based technologies. In turn, this process supports corporate digital transformation, improves the digital business environment, and reshapes firms’ core competitiveness and value creation.

2.2. Hypothesis Development

Corporate ESG performance is typically shaped within the external information environment in which firms and multiple stakeholders are jointly embedded. Because ESG activities involve multiple objectives, including environmental responsibility, social responsibility, and corporate governance, their outcomes have strong externalities. Firms’ internal governance willingness alone may therefore be insufficient to generate sustained incentives for ESG improvement. For stakeholders such as investors, analysts, institutional investors,

governments, and the general public, the ability to identify, evaluate, and respond to corporate ESG behavior depends on the availability, transmission efficiency, and verifiability of information in the external environment [14]. When urban information infrastructure is underdeveloped and public information flows are inefficient, stakeholders face higher costs in identifying and monitoring firm behavior, which may weaken both the external pressure and the internal incentives for firms to improve ESG performance. By promoting digital infrastructure, government data systems, and urban information platforms, smart city pilots improve the information environment shared by firms and stakeholders, thereby creating the conditions under which informatization may affect corporate ESG performance.

From the perspective of external monitoring, investor attention theory suggests that attention among capital market participants is scarce, and that information visibility and information acquisition costs shape both the direction of attention and the intensity of monitoring [6]. As urban informatization improves, information related to firms' operations, environmental governance, and social responsibility becomes easier for external actors to obtain and process. Stakeholders such as the media, analysts, and institutional investors can therefore pay attention to, evaluate, and monitor corporate ESG behavior at lower cost. As the market visibility of corporate ESG behavior increases, firms face stronger reputational constraints, valuation pressure, and external governance pressure [15], which gives them greater incentives to improve ESG decisions. Accordingly, smart city pilots may enhance corporate ESG performance by strengthening external monitoring by capital market stakeholders.

From the perspective of internal governance, organizational information processing theory suggests that firms facing complex external environments and diverse stakeholder demands need stronger capabilities to acquire, transmit, and integrate information [9]. The high-quality information environment created by smart city development not only improves the ability of external actors to monitor firms, but also provides firms with better conditions for absorbing policy, market, technological, and governance-related information [16]. Firms can identify changes in the external environment and stakeholder demands more promptly, and transform external information into concrete governance decisions through internal control, digital management, and cross-departmental coordination [17]. As information delays and organizational frictions decline [18], the internal governance foundation for ESG practices improves, making it easier for ESG activities to become stable internal governance arrangements rather than merely external requirements.

In sum, the informatization shock induced by smart city pilots can promote corporate ESG performance by improving the external information environment and strengthening the monitoring of corporate ESG behavior by capital market stakeholders. It can also improve internal governance efficiency by enhancing firms' ability to acquire, transmit, and integrate information. Based on this reasoning, this study proposes the following hypothesis, with the corresponding conceptual framework shown in Figure 1.

H1. *The informatization shock induced by smart city pilots significantly improves corporate ESG performance.*

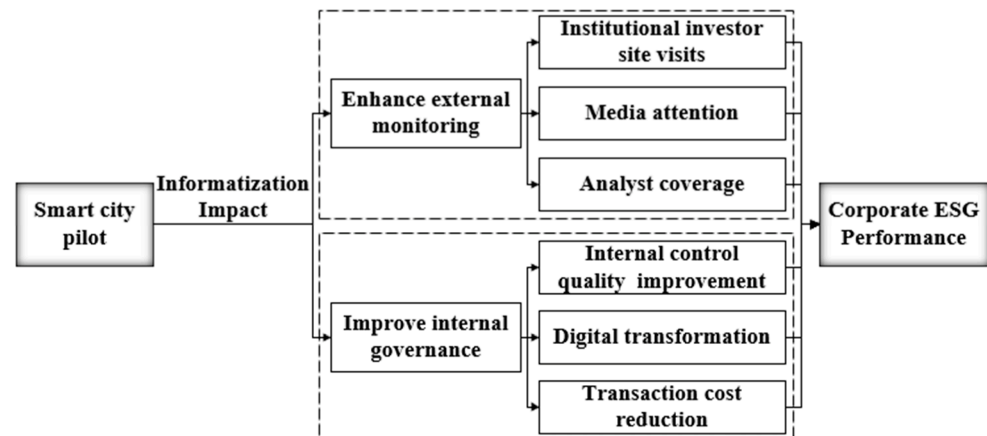


Figure 1. Framework Diagram.

3. Research Design

3.1. Sample Selection

Our sample consists of A-share listed firms on the Shanghai and Shenzhen stock exchanges from 2009 to 2020. The sample is cleaned by excluding financial and real estate firms, firms designated as ST or *ST during the sample period, firms with negative equity, and observations with substantial missing financial data. To mitigate the influence of outliers, all continuous variables are winsorized at the 1st and 99th percentiles. The final sample includes 3327 firms and 28,574 firm-year observations. Firm-level financial data are obtained from the CSMAR database, and city-level data are collected from the National Bureau of Statistics of China and the Wind database.

3.2. Empirical Model

To examine the effect of smart city pilots on corporate ESG performance, we estimate the model (1):

$$ESG_{i,c,t} = \alpha_0 + \alpha_1 Smartcity_{c,t} + \alpha_2 X1_{i,t} + \alpha_3 X2_{c,t} + \mu_i + v_c + \delta_t + \varepsilon_{i,c,t} \quad (1)$$

where i , c and t index firms, cities and years, respectively, and ε is the error term. The dependent variable $ESG_{i,c,t}$ is firm i 's ESG performance located in city c in year t . The key explanatory variable $Smartcity_{c,t}$ indicates whether city c implemented the smart city pilot policy in year t . $X1_{i,t}$ and $X2_{i,t}$ denote firm-level and city-level control variables, respectively. μ_i , v_c and δ_t are firm, city and year fixed effects, respectively. Our coefficient of interest is α_1 , which captures the direction and magnitude of the effect of smart city pilot policy on firms' ESG performance. To address potential heteroskedasticity and serial correlation, we cluster standard errors at the city level.

3.3. Variable Definitions

3.3.1. Dependent Variable

Corporate ESG performance (ESG). Prior studies commonly use third-party ESG ratings or ESG scores to measure corporate ESG performance [12,19,20]. Since this study focuses on Chinese A-share listed firms, we use the Huazheng ESG rating as the baseline measure of corporate ESG performance. The Huazheng ESG rating draws on international ESG evaluation principles and is designed with reference to China's institutional context, capital market environment, and the disclosure practices of listed firms, which gives it strong applicability to the Chinese market. The Huazheng ESG rating does not rely solely on firms' voluntary disclosures. Instead, it integrates public information from annual

reports, ESG reports, corporate announcements, regulatory disclosures, and business registration data, and combines traditional and alternative data to systematically assess the ESG performance and risk profiles of listed firms. It has therefore been widely used in recent studies on Chinese corporate ESG performance [12].

Specifically, the Huazheng ESG rating consists of nine categories, ranked from highest to lowest as AAA, AA, A, BBB, BB, B, CCC, CC, and C. We assign scores from 1 to 9 in ascending order. In addition, because a single ESG rating may be affected by short-term disclosure fluctuations, rating update frequency, and measurement noise, we use Huazheng's quarterly ratings and calculate the average of the four quarterly rating scores for each firm-year as the annual measure of ESG performance. This treatment improves the stability of the measure and helps mitigate potential measurement bias between ESG ratings and firms' actual ESG performance.

3.3.2. Independent Variable

Smart city pilot (*Smartcity*). We define the policy shock variable, *Smartcity*, as equal to 1 if a sample firm is registered in a city covered by the smart city pilot program after the city becomes a pilot city, and 0 otherwise. Specifically, the three batches of smart city pilots were announced in January 2013, August 2013, and April 2015, respectively. Accordingly, *Smartcity* is set to 1 for firms registered in cities included in the first or second batch of pilots from 2013 onward, and 0 otherwise. For firms registered in cities included in the third batch of pilots, *Smartcity* is set to 1 from 2015 onward, and 0 otherwise.

3.3.3. Control Variables

Control variables are selected from both firm-level and regional characteristics. Firm-level controls include firm size (*size*), firm age (*age*), financial leverage (*lev*), profitability (*roe*), growth opportunities (*growth*), state ownership (*nature*), labor intensity (*eidensity*), CEO duality (*dual*), and operating cash flow (*ocf*). Regional controls include GDP growth rate (*gdpgrowth*), fiscal deficit ratio (*fisdeficit*), fixed asset investment growth rate (*capex-growth*), and local credit conditions (*bankcredit*). The definitions of all variables are reported in Table 1.

Table 1. Variable Definitions.

Variable	Code	Variable Description
Dependent variables		
Corporate ESG performance	<i>ESG</i>	Measured as the annual average of quarterly Huazheng ESG ratings.
Independent variables		
Smart city pilot	<i>Smartcity</i>	Dummy variable equal to 1 if the city where the firm is located implemented the smart city pilot policy in that year, and 0 otherwise.
Control variables		
firm size	<i>size</i>	The natural logarithm of total assets at the end of the year in a firm.
firm age	<i>age</i>	The natural logarithm of the establishment time of the firm.
financial leverage	<i>lev</i>	Total liabilities/total assets.
profitability	<i>roe</i>	Net profit/average shareholders' equity.
growth opportunities	<i>growth</i>	Market value/asset replacement cost of the firm.
state ownership	<i>nature</i>	Dummy variable equal to 1 for state-owned firms, and 0 otherwise.
employee intensity	<i>eidensity</i>	Number of employees/main business income.

Table 1. Cont.

Variable	Code	Variable Description
CEO duality	<i>dual</i>	Dummy variable equal to 1 if the chairperson and the general manager are the same person, and 0 otherwise.
operating cash flow	<i>ocf</i>	Net cash flows from operating activities/total assets.
GDP growth rate	<i>gdp_grow</i>	Annual GDP growth rate of each city.
fiscal deficit ratio	<i>fisdeficit</i>	Annual fiscal deficit/GDP of each city.
fixed asset investment growth rate	<i>capexgrowth</i>	Annual fixed asset investment growth rate of each city.
credit conditions	<i>bankcredit</i>	Annual outstanding loans/GDP of each city.

4. Empirical Results

4.1. Descriptive Statistics

Table 2 reports the descriptive statistics for the main variables. As shown in Panel A, the mean value of corporate ESG performance is 4.1207, and the median is 4.0000. The distributions of the other control variables fall within reasonable ranges and are not discussed in detail for brevity. Panel B reports two univariate comparisons of corporate ESG performance, measured by the annual mean and annual median of quarterly ESG ratings, respectively. The results show that firms' ESG performance increases significantly after the implementation of the pilot policy, providing preliminary evidence in support of H1. The absolute values of both the Pearson and Spearman correlation coefficients among the main variables are below 0.5. The VIF test shows that the maximum variance inflation factor is 1.76 and the mean value is 1.27, both well below 10, indicating that severe multicollinearity is not a concern. These results are available upon request.

Table 2. Descriptive Statistics.

Panel A: Descriptive statistics.							
Variable	N	Mean	Sd	Min	P50	Max	
ESG	28,574	4.1207	0.8779	1.0000	4.0000	7.7500	
Smartcity	28,574	0.2401	0.4271	0.0000	0.0000	1.0000	
size	28,574	22.1284	1.2824	19.5910	21.9356	26.4299	
age	28,574	2.8506	0.3529	0.0000	2.8904	4.2047	
lev	28,574	0.4147	0.2029	0.0274	0.4091	0.8747	
roe	28,574	0.0609	0.1277	−1.3044	0.0702	0.3240	
growth	28,574	0.1624	0.3759	−0.6570	0.1065	3.5959	
nature	28,574	0.3708	0.4830	0.0000	0.0000	1.0000	
eidensity	28,574	1.4217	1.1381	0.0338	1.1397	8.7061	
dual	28,574	0.2712	0.4446	0.0000	0.0000	1.0000	
ocf	28,574	0.0479	0.0692	−0.2017	0.0470	0.2729	
gdpgrowth	28,574	0.0683	0.0309	0.0080	0.0730	0.1500	
fisdeficit	28,574	0.0793	0.0593	0.0130	0.0484	0.2444	
capexgrowth	28,574	0.0244	0.0271	−0.0390	0.0260	0.0760	
bankcredit	28,574	1.4657	0.3932	0.7020	1.3918	2.2071	
Panel B: Descriptive statistics grouped by whether the pilot policy was implemented.							
	Mean after policy implementation (1)	Mean before policy implementation (2)	(2) − (1)	T-test			
Annual mean of quarterly ratings	4.1304	4.0874	0.0430	3.5755 ***			
Annual median of quarterly ratings	4.1293	4.0912	0.0381	3.0253 ***			

Notes: *** indicates statistical significance at the 1% level.

4.2. Baseline Results

Based on model (1), Table 3 reports the estimated effect of smart city pilots on corporate ESG performance. With firm and year fixed effects included, Columns (1)–(3) of Table 3 report results from specifications that (1) exclude control variables, (2) include firm-level controls, and (3) further include city-level controls. Across all specifications, the coefficient on the smart city pilot indicator remains positive and statistically significant, suggesting that the informatization improvement induced by smart city pilots increases corporate ESG performance, which supports Hypothesis H1.

Table 3. Baseline Results.

	(1) ESG	(2) ESG	(3) ESG
<i>Smartcity</i>	0.0624 ** (2.1544)	0.0568 ** (2.0409)	0.0708 *** (2.6957)
<i>size</i>		0.1386 *** (8.9611)	0.1385 *** (8.9524)
<i>age</i>		−0.2655 (−1.5952)	−0.2869 * (−1.8013)
<i>lev</i>		−0.5419 *** (−9.5142)	−0.5502 *** (−9.5758)
<i>roe</i>		0.2492 *** (5.9996)	0.2499 *** (6.0592)
<i>growth</i>		−0.0461 *** (−4.2091)	−0.0455 *** (−4.2616)
<i>nature</i>		0.0913 ** (2.3815)	0.0881 ** (2.3053)
<i>eidensity</i>		0.0228 *** (2.7784)	0.0222 *** (2.6702)
<i>dual</i>		−0.0049 (−0.2676)	−0.0053 (−0.2877)
<i>ocf</i>		−0.2662 *** (−3.4566)	−0.2711 *** (−3.5203)
<i>gdpgrowth</i>			0.6175 (1.0037)
<i>fisdeficit</i>			−0.3024 (−0.5302)
<i>capexgrowth</i>			−0.2540 (−1.0020)
<i>bankcredit</i>			−0.0987 (−1.0847)
<i>cons</i>	4.1549 *** (597.2575)	2.0115 *** (3.7363)	2.2098 *** (4.1159)
<i>Firm FE</i>	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes
<i>within R²</i>	0.0005	0.0186	0.0194
<i>N</i>	28574	28574	28574

Notes: ***, **, and * respectively indicate statistical significance at the 1%, 5%, and 10% levels. The t-values in parentheses have been adjusted for robust standard errors (clustered to the city level). The rest of the text is the same.

4.3. Robustness Tests

4.3.1. Parallel-Trend Test

To ensure that the staggered difference-in-differences model used in this study satisfies the parallel trend assumption and to illustrate the dynamic effect of smart city pilots on

corporate ESG performance before and after policy implementation, we conduct an event-study analysis using the following model:

$$ESG_{i,p,t} = \alpha_0 + \sum_{n=-5}^6 \alpha_n Smartcity_{c,t}^n + \alpha_2 X1_{i,t} + \alpha_3 X2_{i,t} + \mu_i + v_c + \delta_t + \varepsilon_{i,c,t} \quad (2)$$

Here, $Smartcity^n$ denotes the policy-shock variable defined by relative year, with the year of pilot implementation as the reference point. The year before policy implementation is used as the base period. Observations six or more years after implementation and five or more years before implementation are grouped into the endpoints. α_n is the estimated coefficient relative to the base year. The results in Figure 2 show that the coefficients on the time dummies before policy implementation are statistically insignificant, indicating that the parallel trend assumption holds before treatment. Following Roth [21], the p-value from the F-test of the joint significance of the pre-treatment coefficients is 0.6654, suggesting that the pre-treatment estimates are not jointly significant and further supporting the validity of the parallel trend assumption.

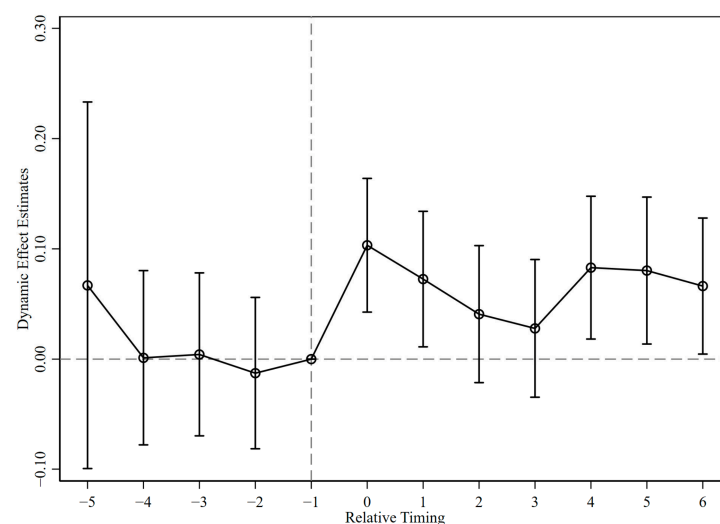


Figure 2. Parallel Trend Test (95% CI).

To address potential bias in TWFE estimates arising from heterogeneous treatment effects, we employ four alternative estimators. First, we use never-treated units as the control group [22]. Second, we estimate group-time average treatment effects, which avoids using already-treated units as controls [23]. Third, we estimate the average treatment effect by comparing changes between groups that have just been treated and groups that have not yet been treated in the same period, and then aggregating these comparisons using appropriate weights [24]. Fourth, we use the stacked estimator, which reconstructs relative event time and obtains a weighted average of treatment effects after excluding “bad” control groups [25]. Figure 3 shows that the parallel trend assumption continues to hold under these alternative estimation strategies, supporting the robustness of the main findings.

Recent studies point out that event-study tests of parallel trends may have low statistical power and may generate distorted or biased estimates [26]. Therefore, we further adopt the Honestdid approach proposed by Rambachan and Roth [27] to conduct inference and sensitivity analysis when the parallel trend assumption may be violated. Specifically, we construct the maximum deviation from parallel trends (Mbar), and then obtain confidence intervals for the post-treatment point estimates corresponding to different degrees of deviation. Figures 4 and 5 report the sensitivity analysis of the treatment effect in the

implementation year under the relative magnitude restriction (one times the deviation) and the smoothness restriction (two standard deviations), respectively. The results indicate that even when the parallel trend assumption is allowed to deviate to some extent, the policy effect remains statistically significant.

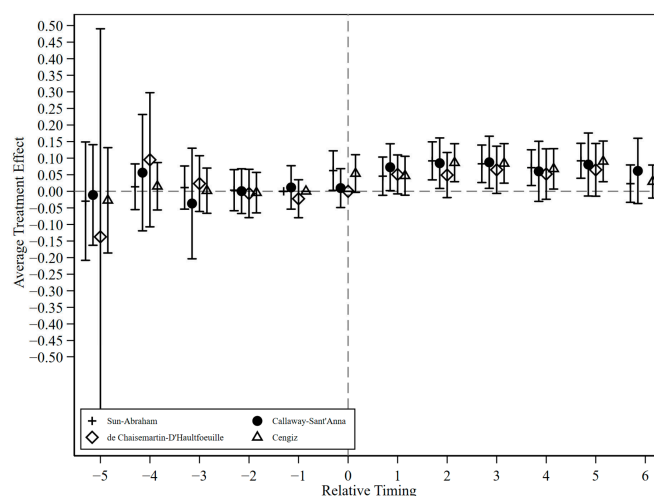


Figure 3. Parallel Trend Tests Accounting for Heterogeneous Treatment Effects (95% CI).

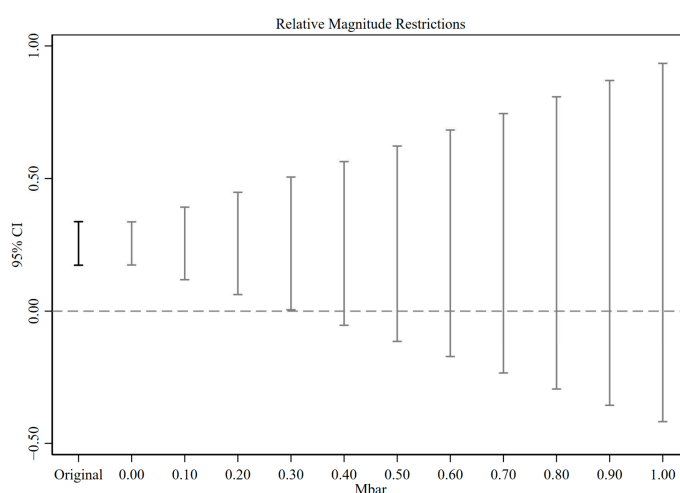


Figure 4. Relative Magnitude Restriction.

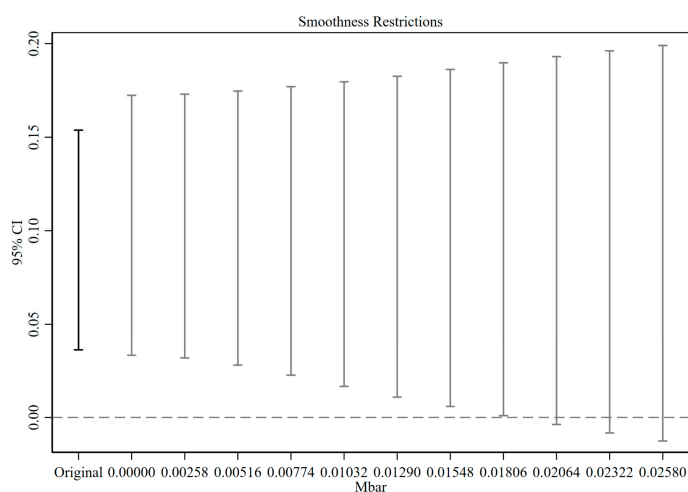


Figure 5. Smoothness Restriction.

4.3.2. Excluding the Influence of Unobservable Factors

First, we address the possibility that unobservable time-varying confounders may bias the estimated policy effect. Following the counterfactual framework for causal effect estimation proposed by Liu et al. [28], we use the matrix completion estimator (MC) for imputation. As shown in Figure 6, the results continue to support the parallel trend assumption.

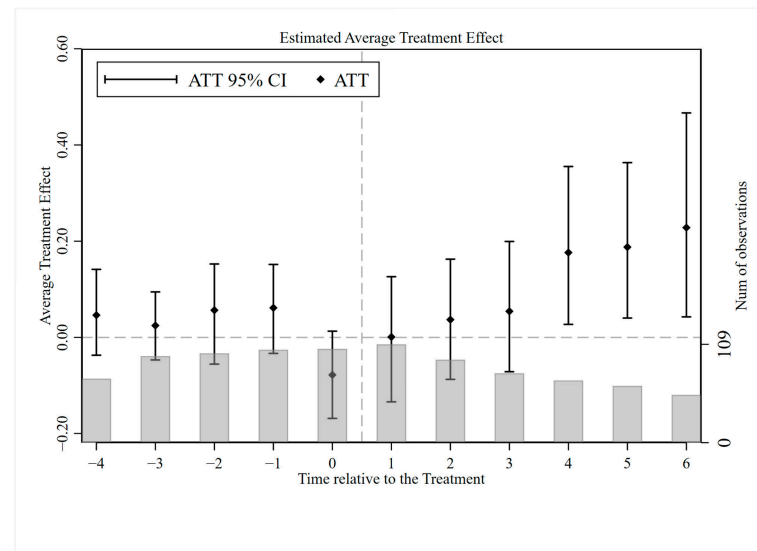


Figure 6. Counterfactual Estimation.

Second, we conduct a placebo test to rule out the influence of omitted variables. Specifically, we extract the policy shock variable for all sample observations, randomly reassign it to each observation, and repeat the regression 1000 times. If a placebo effect exists, the reassigned policy shock variable should remain significantly associated with corporate ESG performance because of unobserved factors not accounted for in the model. Figure 7 shows that the estimated placebo coefficients are distributed around zero, with both the mean and the median close to zero. This evidence rules out the presence of a placebo effect.

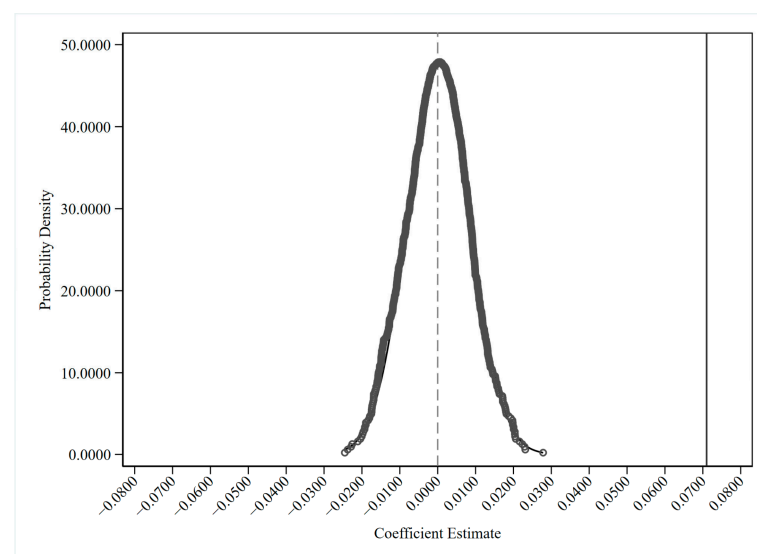


Figure 7. Placebo Test.

4.3.3. Excluding the Influence of Concurrent Policies

To avoid potential interference from other relevant policies implemented during the same period, we further control for the effects of government public data openness, low-carbon city pilots, and the National Civilized City program.

First, government public data openness may improve corporate ESG performance by establishing city-level public data platforms and increasing data availability and information transparency [12]. Accordingly, we construct a dummy variable based on the year in which each city launched its government public data platform. The variable equals 1 for the year in which the firm's city launched the platform and all subsequent years, and 0 otherwise. Second, the low-carbon city pilot policy may affect corporate ESG practices by strengthening low-carbon development constraints, promoting green technology applications, and improving urban environmental governance [29]. We therefore construct a dummy variable based on the year in which the firm's city was included in the low-carbon city pilot program. The variable equals 1 from the pilot year onward, and 0 otherwise. Third, the National Civilized City program may influence corporate environmental performance and ESG behavior by improving urban governance, strengthening environmental regulation, and reinforcing social responsibility norms [30]. Accordingly, we construct a dummy variable based on the year in which the firm's city was designated as a National Civilized City. The variable equals 1 for the designation year and all subsequent years, and 0 otherwise. As shown in Table 4, after adding these concurrent policy variables separately and jointly, the baseline conclusion remains robust.

Table 4. Excluding the Influence of Concurrent Policies.

	(1) ESG	(2) ESG	(3) ESG	(4) ESG
<i>Smartcity</i>	0.0720 *** (2.7366)	0.0710 *** (2.7321)	0.0704 *** (2.6956)	0.0713 *** (2.7476)
<i>Public data openness</i>	0.0196 (0.9766)			0.0164 (0.7968)
<i>Low-carbon city</i>		0.0263 (1.0121)		0.0241 (0.9385)
<i>Civilization city</i>			0.0092 (0.2879)	0.0125 (0.4042)
<i>cons</i>	2.1958 *** (4.0943)	2.1904 *** (4.0960)	2.2076 *** (4.0963)	2.1772 *** (4.0555)
<i>Controls</i>	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes
<i>within R²</i>	0.0194	0.0195	0.0194	0.0195
<i>N</i>	28,574	28,574	28,574	28,574

Notes: *** indicates statistical significance at the 1% level.

4.3.4. Additional Robustness Tests

First, we address potential measurement error. We begin by replacing the core explanatory variable. Specifically, we re-identify the treatment group based on firms' office locations and construct a new policy shock variable. We then replace the dependent variable in several ways. First, we use the median of Huazheng's quarterly ESG ratings to construct the annual ESG measure. Second, we use Bloomberg's ESG disclosure score to remeasure corporate ESG performance. Bloomberg's ESG coverage includes only

a subset of Chinese listed firms and years, and its evaluation is based only on firms' voluntary disclosures.

In addition, given that corporate ESG ratings may be affected by strategic disclosure and heterogeneity across rating agencies, we conduct three further tests. First, following Grewal et al. [31], we identify sentences in firms' MD&A sections that contain substantive ESG-related information, including specific emission reduction targets, quantitative data, timetables, and action plans. We then use the share of such sentences to measure substantive ESG discourse as an alternative proxy for ESG performance. Second, we control for firms' potential ESG greenwashing. Following Yu et al. [32] and Long et al. [33], we measure ESG-washing suspicion using the relative gap between firms' ESG disclosure scores from Bloomberg and ESG performance scores from Huazheng. Specifically, we standardize the disclosure score and the performance score within each industry, and define the ESG-washing measure as the standardized disclosure score minus the standardized performance score. Third, we control for ESG rating disagreement. Following Hu et al. [34], we use ESG ratings from six rating agencies, namely CNRDS, Wind, Huazheng, FTSE Russell, SynTao Green Finance, and Bloomberg. After converting ratings from different agencies into a comparable scale, we calculate the standard deviation of ESG scores assigned to the same firm in the same year by different agencies, requiring coverage by at least two agencies. This standard deviation is used as the measure of ESG rating disagreement. The corresponding results are reported in Columns (1)–(5) of Table 5; the baseline conclusion remains robust.

Table 5. Other Robustness Tests.

	(1) Replace the independent variable	(2) Replace the dependent variable 1	(3) Replace the dependent variable 2	(4) Controlling for ESG-washing	(5) Controlling for ESG rating disagreement	(6) Adding province-level pre-treatment covariates
<i>Smartcity</i>		0.0626 ** (2.3794)	0.9314 *** (3.1474)	0.0753 *** (2.9142)	0.0778 *** (3.0204)	0.0628 ** (2.3303)
<i>Smartcity2</i>	0.1096 ** (2.1590)					
<i>ESG-washing</i>				0.0863 (0.9470)		
<i>ESG rating disagreement</i>					−0.6069 *** (−7.3212)	
<i>cons</i>	2.1712 *** (7.6000)	2.0477 *** (3.8975)	−3.3758 (−0.4707)	2.1302 *** (3.9174)	2.2304 *** (3.9491)	2.9510 *** (3.0567)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Predetermined covariates × Year FE</i>	No	No	No	No	No	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>within R²</i>	0.0189	0.0234	0.0224	0.0192	0.0325	0.0232
<i>N</i>	28,574	28,574	10,215	9778	27,963	21,295

Table 5. Cont.

	(7)	(8)	(9)	(10)	(11)	(12)
	PSM	Entropy balancing	Adding Industry FE	Province-by- Year FE	City-Industry double cluster	Balance panel
<i>Smartcity</i>	0.0569 * (1.9606)	0.0705 *** (2.6580)	0.0719 *** (2.7531)	0.0705 *** (2.7985)	0.0708 *** (3.5034)	0.0770 ** (2.4877)
<i>cons</i>	3.0106 *** (5.1907)	2.7348 *** (4.7875)	2.1390 *** (4.0328)	2.1319 *** (4.3442)	2.2098 *** (3.3342)	0.3864 (0.4432)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	No	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	No	Yes	Yes
<i>Industry FE</i>	No	No	Yes	No	No	No
<i>Province-by-Year FE</i>	No	No	No	Yes	No	No
<i>within R²</i>	0.0167	0.0144	0.0195	0.0195	0.0194	0.0162
<i>N</i>	20,628	28,574	28,574	28,582	28,574	13,247

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

Second, to mitigate potential endogeneity arising from nonrandom policy assignment, we first examine whether treated and control cities differ systematically in pre-treatment characteristics. We select urban internet penetration, industrial wastewater discharge, annual average PM2.5 concentration, GDP growth, fiscal deficit ratio, fixed asset investment growth, and local credit conditions to capture city-level characteristics related to information infrastructure, pollution emissions, and economic development. As shown in Table 6, the univariate tests indicate that these characteristics are generally not significantly different between the treatment and control groups. Next, we use city characteristics in the year before policy implementation as pre-treatment covariates and re-estimate the baseline model after controlling for the interactions between these pre-treatment covariates and year fixed effects. In addition, we use both firm-level and city-level characteristics as matching variables and re-estimate the model based on propensity score matching, using 1:4 nearest-neighbor matching, and entropy balancing, with the balancing target set to 2. The corresponding results are reported in Columns (6)–(8) of Table 5. The baseline conclusion remains robust.

Table 6. Predictability Test of Pilot Assignment and Univariate Analysis.

	(1)	(2)	(3)	(4)
	<i>Smartcity</i>	Treatment Group Mean	Control Group Mean	T Test
<i>Internet penetration rate</i>	−0.0001 (−0.1783)	29.57195	28.2309	−0.4605
<i>Municipal industrial wastewater discharge</i>	−0.0000 (−1.6430)	8219.1430	7134.5712	−1.0517
<i>Annual average PM2.5 concentration</i>	−0.0005 (−0.4790)	44.2573	42.0622	−1.1602
<i>gdp_grow_rate</i>	−1.4243 * (−2.0365)	0.1141	0.1033	−3.4768 ***
<i>fisdeficit1</i>	−0.3407 (−1.1066)	0.0945	0.0889	−0.7593
<i>capexgrowth</i>	−0.0048 (−0.0050)	0.0650	0.0605	3.2764 ***
<i>bankcredit2</i>	0.0033 (0.0593)	1.0860	1.1382	1.4300
<i>cons</i>	0.5283 *** (4.2417)			

Table 6. Cont.

	(1)	(2)	(3)	(4)
	<i>Smartcity</i>	Treatment Group Mean	Control Group Mean	T Test
<i>City FE</i>	Yes			
<i>Year FE</i>	Yes			
<i>within R²</i>	0.0106			
<i>N</i>	3946			

Notes: *** and * respectively indicate statistical significance levels at the 1% and 10% levels.

Third, we further control for omitted variables along multiple dimensions. We add industry fixed effects and re-estimate the model after controlling for province-by-year fixed effects. Fourth, to mitigate the influence of heteroskedasticity and other potential factors, we adjust the standard errors using two-way clustering at the city and industry levels. Fifth, we conduct a subsample test by retaining only the balanced panel. As reported in Columns (9)–(12) of Table 5, the baseline results remain highly robust.

5. Further Analysis

5.1. Mechanism Tests

The preceding results show that smart city pilots significantly improve corporate ESG performance. To further examine the underlying mechanisms, this study follows the theoretical logic developed above and analyzes two channels: external monitoring and internal governance. Specifically, informatization may promote corporate ESG performance by strengthening monitoring by external stakeholders and improving the efficiency of firms' internal governance. Based on this reasoning, we construct the following mediation models to test these mechanisms.

$$Path_{i,c,t} = \beta_0 + \beta_1 Smartcity_{c,t} + \beta_2 X1_{i,t} + \beta_3 X2_{c,t} + \mu_i + v_c + \delta_t + \varepsilon_{i,c,t} \quad (3)$$

$$ESG_{i,c,t} = \gamma_0 + \gamma_1 Smartcity_{c,t} + \gamma_2 Path_{i,t} + \gamma_3 X1_{i,t} + \gamma_4 X2_{c,t} + \mu_i + v_c + \delta_t + \varepsilon_{i,c,t} \quad (4)$$

Here, *Path* denotes the mechanism variable, corresponding to the external monitoring mechanism and the internal governance mechanism, respectively. Specifically, following Jiang and Yuan [35], we measure external monitoring using three indicators: institutional investor attention, measured as the natural logarithm of one plus the number of on-site visits by institutional investors to a firm in a given year; media attention, measured as the natural logarithm of one plus the total number of newspaper and online media reports on a firm in a given year; and analyst attention, measured as the natural logarithm of one plus the number of analyst or analyst-team coverage instances for a firm in a given year. Following Huang et al. [36], we measure internal governance using three indicators: internal control quality, measured by the internal control index from the DIB database; the degree of corporate digital transformation, measured by the share of digital-related keywords in the MD&A section; and transaction costs, measured by the administrative expense ratio. All other settings are the same as those in the baseline model.

5.1.1. External Monitoring Mechanism

Table 7 reports the results for the external monitoring mechanism. Columns (1), (3), and (5) show that smart city pilots significantly increase institutional investor site visits, media attention, and analyst attention, respectively. This indicates that informatization shocks are associated with greater market visibility of firm behavior and stronger attention to corporate ESG behavior from capital market stakeholders. After these mechanism variables are included, Columns (2), (4), and (6) show that institutional investor site visits,

media attention, and analyst attention are all positively and significantly associated with corporate ESG performance, and the corresponding Sobel tests are significant. These results are consistent with the external monitoring mechanism proposed above. Specifically, as smart city pilots improve the urban information environment, capital market stakeholders are better able to obtain, process, and evaluate information related to firms' ESG behavior. The resulting increase in institutional investor site visits, media coverage, and analyst coverage provides empirical support for the view that stronger external monitoring is an important channel associated with the ESG-enhancing effect of smart city pilots.

Table 7. External Monitoring Mechanism Tests.

	(1)	(2)	(3)	(4)	(5)	(6)
	<i>Institutional Investor</i>	<i>ESG</i>	<i>Media</i>	<i>ESG</i>	<i>Analyst</i>	<i>ESG</i>
<i>Smartcity</i>	0.1224 * (1.7489)	0.0807 * (1.8688)	0.1413 *** (3.5497)	0.0719 *** (2.7359)	0.1008 *** (3.0252)	0.0703 ** (2.5814)
<i>Path</i>		0.0451 *** (5.8666)		0.0166 ** (2.0662)		0.0507 *** (5.2059)
<i>cons</i>	−3.6938 *** (−2.8595)	1.4122 *** (3.2161)	−10.8521 *** (−7.2910)	2.2230 *** (4.2270)	3.1141 *** (3.3874)	2.5022 *** (4.5372)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>within R²</i>	0.0409	0.0747	0.0648	0.0196	0.0672	0.0223
<i>N</i>	13,114	13,307	28,518	28,518	27,438	27,437
<i>Sobel Z</i>	5.657 ***		3.811 ***		7.057 ***	

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

5.1.2. Internal Governance Mechanism

Table 8 reports the results for the internal governance mechanism. Columns (1), (3), and (5) show that smart city pilots significantly improve firms' internal control quality and digital transformation, and significantly reduce the administrative expense ratio. These results indicate that informatization shocks are associated with better internal governance conditions, stronger information-processing capacity, and higher organizational operating efficiency. After these mechanism variables are included, Columns (2), (4), and (6) show that internal control quality and digital transformation are positively and significantly associated with corporate ESG performance, whereas the administrative expense ratio is negatively and significantly associated with corporate ESG performance. The corresponding Sobel tests are also significant. These results are consistent with the internal governance mechanism proposed above. Specifically, as smart city pilots improve the urban information environment, firms are better positioned to acquire, transmit, and integrate external information, and to translate such information into internal governance arrangements. The observed improvements in internal control quality and digital transformation, together with the reduction in administrative expense ratio, provide empirical support for the view that improved internal governance is an important channel associated with the ESG-enhancing effect of smart city pilots.

5.2. Heterogeneity Analysis

5.2.1. Executive Environmental Background

Whether informatization shocks translate into improvements in corporate ESG performance depends first on whether firms have the organizational capacity to identify and respond to green governance requirements. According to upper echelons theory [37], managers' knowledge structures and career backgrounds shape how firms interpret changes in the external environment and formulate strategic responses. Executives with environ-

mental backgrounds are more likely to pay attention to environmental governance, social responsibility, and sustainable development issues, and are also better able to translate the monitoring pressure and governance requirements brought about by improvements in the external information environment into internal corporate decisions [38]. Therefore, when smart city pilots improve the urban information environment, firms with executives who have environmental backgrounds are more likely to respond proactively to external stakeholder demands and improve ESG performance.

Table 8. Internal Governance Mechanism Tests.

	(1)	(2)	(3)	(4)	(5)	(6)
	<i>IC Index</i>	<i>ESG</i>	<i>Digitalization</i>	<i>ESG</i>	<i>Transaction Costs</i>	<i>ESG</i>
<i>Smartcity</i>	0.0031 * (1.6857)	0.0707 *** (2.6903)	0.3132 *** (9.7125)	0.0775 *** (2.8823)	−0.0049 ** (−2.4698)	0.0711 *** (2.7218)
<i>Path</i>		0.4735 *** (8.9903)		0.0279 *** (5.0954)		−0.9595 *** (−7.8502)
<i>cons</i>	6.1178 *** (212.4953)	−1.3392 * (−1.9590)	−20.1682 *** (−10.7467)	2.5514 *** (4.9415)	0.1940 *** (10.5807)	2.4575 *** (4.6692)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>within R²</i>	0.2597	0.0234	0.2367	0.0206	0.3034	0.0229
<i>N</i>	25,711	25,581	27,754	27,280	28,574	28,574
<i>Sobel Z</i>	1.817 *		4.097 ***		4.744 ***	

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

Based on this reasoning, we divide the sample according to whether a firm's executives had environmental backgrounds in the year before policy implementation. Columns (1) and (2) of Table 9 show that the positive effect of smart city pilots on corporate ESG performance is mainly concentrated among firms whose executives have environmental backgrounds, and the test of differences in coefficients across groups is significant. This finding indicates that informatization shocks do not automatically translate into ESG improvements. Their effect depends on whether corporate managers can recognize the value of green governance and convert external information pressure into internal action. Executive environmental background strengthens firms' ability to respond to the joint advancement of informatization and green development, thereby amplifying the ESG-enhancing effect of smart city pilots.

Table 9. Heterogeneity Analysis results.

	(1)	(2)	(3)	(4)	(5)	(6)
	<i>ESG</i> <i>Executive Environmental Background</i>	<i>ESG</i> <i>Environmental Background</i>	<i>ESG</i> <i>Polluting Industry Status</i>	<i>ESG</i> <i>Industry Status</i>	<i>ESG</i> <i>Environmental Regulation Intensity</i>	<i>ESG</i> <i>Regulation Intensity</i>
	<i>With</i>	<i>Without</i>	<i>Heavily Polluting</i>	<i>Non-Heavily Polluting</i>	<i>Stronger</i>	<i>Weaker</i>
<i>Smartcity</i>	0.1426 ** (2.0866)	0.0581 ** (2.4234)	0.1082 * (1.8575)	0.0689 ** (2.3313)	0.1115 *** (2.8221)	0.0488 (1.2663)
<i>cons</i>	1.2038 (0.8075)	1.8364 *** (3.4661)	1.0571 (1.3550)	1.4131 ** (2.1942)	1.2715 * (1.9276)	1.8318 ** (2.3994)
<i>Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>within R²</i>	0.0418	0.0218	0.0266	0.0238	0.0285	0.0235
<i>N</i>	3120	20,105	7678	12,995	11,189	9402
<i>p Value</i>		0.040		0.010		0.060

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

5.2.2. Polluting Industry Status

The effect of smart city pilots on corporate ESG performance may also vary with the environmental responsibility pressure faced by different industries. Firms in heavily polluting industries generate stronger environmental externalities, and their production and operating activities are more likely to be subject to government regulation, investor evaluation, and public scrutiny [39]. When the information environment is relatively weak, external stakeholders face higher costs in identifying and monitoring firms' environmental behavior, which may weaken the pressure on firms to improve ESG performance. After smart city pilots improve the external information environment, the environmental behavior of heavily polluting firms becomes easier to identify, evaluate, and respond to, thereby strengthening external monitoring constraints. At the same time, heavily polluting industries face greater pressure for green transformation and have more room for ESG improvement, making them more likely to exhibit stronger ESG-enhancing effects under informatization shocks.

Accordingly, we divide the sample according to whether a firm belonged to a heavily polluting industry in the year before policy implementation. Columns (3) and (4) of Table 9 show that the positive effect of smart city pilots on corporate ESG performance is more pronounced among firms in heavily polluting industries, and the test of differences in coefficients across groups is significant. This result suggests a complementary relationship between urban informatization and industry-level green transformation pressure. For heavily polluting firms with stronger environmental externalities and greater demand for external monitoring, improvements in the information environment can more effectively strengthen stakeholder oversight and accelerate ESG practices and green transformation.

5.2.3. Regional Environmental Regulation Intensity

Regional environmental regulation intensity is an important institutional condition shaping the effect of informatization on corporate ESG performance. Regions with stronger environmental regulation usually have clearer green development requirements and stronger environmental governance constraints, which expose firms to greater pressure for green transformation [40]. In this context, the improvement in the information environment brought about by smart city pilots can further increase the transparency and monitorability of environmental regulation enforcement, making it easier for external stakeholders to assess whether firms effectively respond to green governance requirements. At the same time, stronger environmental regulation provides clearer policy expectations for firms' ESG practices, making it easier for firms to translate changes in the external information environment into internal governance improvements and green actions.

Based on this reasoning, we divide the sample according to the intensity of environmental regulation in the region where the firm is located in the year before policy implementation. Columns (5) and (6) of Table 9 show that the positive effect of smart city pilots on corporate ESG performance is more pronounced in regions with stronger environmental regulation, and the test of differences in coefficients across groups is significant. This finding indicates that the effect of informatization shocks on corporate ESG performance does not operate in isolation, but works jointly with regional green governance constraints. Urban informatization improves the external information environment and firms' information-processing conditions, while environmental regulation strengthens the institutional pressure for green transformation. Together, they promote improvements in corporate ESG performance.

5.3. Economic Consequences

An improvement in corporate ESG performance induced by a regional informatization shock does not necessarily imply an improvement in firms' overall operating performance. It is therefore necessary to further examine whether smart city pilots generate observable effects on other key economic outcomes by improving corporate ESG performance. To this end, this study examines firms' short-term and long-term performance. Following the logic of Li et al. [41], we employ a two-stage least-squares estimation approach to capture the transmission path through which the shock affects firm performance by influencing ESG performance, thereby providing a more systematic assessment of its economic consequences. In the first stage, we estimate Model (1) and obtain the fitted value (*ESG_hat*), which represents the change in corporate ESG performance driven by the pilot policy. In the second stage, we regress firm performance in period $t + 1$ on *ESG_hat* to examine whether this policy-induced change in ESG performance leads to subsequent changes in firm performance. Short-term performance is measured by ROA, while long-term performance is measured by Tobin's Q.

Table 10 reports the two-stage least-squares estimation results. As shown in Columns (1) and (3), the coefficients on the smart city pilot variable are significantly positive, indicating that the informatization shock induced by smart city pilots is positively associated with corporate ESG performance, consistent with the baseline results reported above. We implement the two-stage least-squares estimation using the “ivreghdfe” command in Stata 17.0, which allows us to obtain standard errors clustered at the city level consistently within the full 2SLS estimation procedure. In addition, the Kleibergen–Paap rk Wald F statistic exceeds 16.38, indicating that the instrument passes the weak-IV diagnostic. Columns (2) and (4) show that the coefficients on predicted corporate ESG performance are also significantly positive. This suggests that the improvement in corporate ESG performance induced by smart city pilots is further associated with higher short-term profitability and greater long-term market valuation. Overall, these results provide evidence consistent with the view that informatization-induced ESG improvement is accompanied by favorable economic consequences for firms.

Table 10. Economic Consequences results.

	(1)	(2)	(3)	(4)
	<i>ESG</i> <i>Stage I</i>	<i>ROA</i> <i>Stage II</i>	<i>ESG</i> <i>Stage I</i>	<i>TobinQ</i> <i>Stage II</i>
<i>Smartcity</i>	0.0585 ** (2.5148)		0.0580 ** (2.4958)	
<i>ESG_hat</i>		0.0624 * (1.7489)		3.5529 ** (2.2859)
<i>Controls</i>	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes
<i>City FE</i>	Yes	Yes	Yes	Yes
<i>Year FE</i>	Yes	Yes	Yes	Yes
<i>Kleibergen–Paap rk LM statistic</i>		6.805 ***		6.702 ***
<i>Kleibergen–Paap rk Wald F statistic</i>		17.952		18.762
<i>N</i>	24,911	24,911	24,911	24,911

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

6. Conclusions and Implications

6.1. Conclusions

The key issue in digital infrastructure development is not only whether urban informatization can be improved, but also whether improvements in the external information environment can be translated into substantive improvements in firms' sustainable behavior. Using the smart city pilot policy as a quasi-natural experiment, this study examines

the effect of informatization shocks on corporate ESG performance based on data from Chinese A-share listed non-financial firms from 2009 to 2020 and a staggered difference-in-differences approach. The results show that smart city pilots significantly improve corporate ESG performance, and this conclusion remains valid after a series of endogeneity checks and robustness tests. Mechanism tests provide evidence consistent with the proposed external monitoring and internal governance channels. Specifically, smart city pilots are associated with stronger monitoring by capital market stakeholders, in line with investor attention theory. They are also associated with improvements in firms' ability to acquire, transmit, and integrate information, consistent with organizational information processing theory and the internal governance channel. Heterogeneity analyses show that the ESG-enhancing effect of smart city pilots is more pronounced among firms whose executives have environmental backgrounds, firms in heavily polluting industries, and firms located in regions with stronger environmental regulation. These findings indicate that the coordination between informatization and green development can more effectively promote improvements in corporate ESG performance. Further tests of economic consequences show that ESG improvements driven by informatization enhance firms' short-term profitability and long-term market value. This evidence suggests that corporate ESG improvement is not merely a responsibility-related cost, but a governance practice that can align social value with economic value.

6.2. Implications

First, urban informatization should move beyond the expansion of digital infrastructure toward the optimization of the information environment, so as to strengthen external stakeholders' ability to identify, evaluate, and monitor firm behavior. This study shows that smart city pilots promote corporate ESG performance primarily because they improve the external information environment in which firms operate, making firm behavior more visible and more easily evaluated by capital market stakeholders. Future smart city development should therefore not rely solely on network coverage, the number of platforms, or the scale of data as evaluation criteria. Greater attention should be paid to the efficiency of information flows, information availability, and information verifiability. In key areas such as corporate environmental governance, public services, market regulation, and credit system development, cities should further promote the integration of urban data resources, coordination among government information systems, and optimization of public information services, thereby reducing the costs for investors, analysts, institutional investors, and other stakeholders to obtain and process firm-related information. Urban informatization can impose stable constraints on firms' sustainable behavior only when information infrastructure is effectively transformed into external monitoring capacity.

Second, firms should actively improve their internal information processing capacity and governance efficiency, so that improvements in the external information environment can be transformed into the capacity to implement ESG practices. This study provides evidence that the ESG-enhancing effect of smart city pilots is accompanied by stronger external monitoring and improvements in firms' internal governance efficiency. This means that improvements in external information infrastructure do not automatically lead to better corporate ESG performance. Firms also need the organizational capacity to absorb, integrate, and use external information. Firms should embed ESG governance into internal control, digital management, and cross-departmental coordination processes, and improve their ability to identify changes in policy, markets, technology, and stakeholder demands. In particular, managers should strengthen their awareness of green development and long-term value creation. Rather than treating ESG as a short-term compliance burden, they should regard it as an important governance tool for improving risk management, enhancing

access to resources, and strengthening long-term competitiveness. Informatization-driven ESG improvement can be further translated into better operating performance and firm value only when firms' internal governance capacity can effectively absorb changes in the external information environment.

Third, smart city development should be coordinated with the green governance system, so that informatization can better support firms' green transformation. This study finds that the positive effect of smart city pilots on corporate ESG performance is more pronounced among firms whose executives have environmental backgrounds, firms in heavily polluting industries, and firms located in regions with stronger environmental regulation. This indicates that informatization shocks need to be combined with firms' green awareness, industry-level pressure for green transformation, and regional environmental governance constraints in order to fully release their policy effects. Accordingly, local governments should avoid separating informatization from green governance when promoting smart city development. Instead, digital infrastructure, environmental regulation, industrial upgrading, and corporate ESG governance should be incorporated into an integrated policy framework. For heavily polluting firms and firms facing greater pressure for green transformation, local governments should improve firms' ability to identify green transformation directions and respond to external monitoring requirements through digital regulation, environmental governance information sharing, green technology services, and better matching of transition policies. In regions with stronger environmental regulation, the complementarity between institutional constraints and improvements in the information environment should be further strengthened, so that green development goals can be translated into corporate ESG practices through a higher-quality information environment.

6.3. Limitations

Admittedly, this study still has some limitations. Due to data availability and the need to maintain consistency in the research design, the sample period ends in 2020 and does not cover the post-COVID period, during which digital transformation accelerated, ESG regulation became stronger, and emerging digital technologies such as artificial intelligence developed rapidly. Therefore, the findings of this study mainly reflect the effect of China's smart city pilot policy on corporate ESG performance under a relatively stable institutional and economic environment before the pandemic. After 2020, firms' digital transformation, capital-market ESG evaluation systems, regulatory environments, and macroeconomic conditions have all changed substantially. These factors may interact with urban informatization and further alter the way and intensity through which informatization affects corporate ESG behavior. Future research may extend the sample to the post-pandemic period as data become more complete, and further examine the long-term effects of informatization on firms' sustainable behavior in the context of smart city development, artificial intelligence adoption, and strengthened ESG regulation.

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