Impact of Informatization and Corporate ESG Performance: A Quasi-Natural Experiment Based on Smart City Pilots

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Abstract. In this paper, we first select data from A-share listed companies between 2011 and 2020 as the sample and employ a Difference-in-Differences (DID) model to systematically investigate the relationship between the implementation of smart city policies and corporate ESG performance levels. The study finds that the implementation of smart city policies significantly enhances the level of informatization in the locations of companies, thereby positively influencing their ESG performance levels. It is noteworthy that this effect manifests significant heterogeneity across companies of different natures and various urban locations. Furthermore, to verify the robustness of the research findings, we conduct empirical tests using various methods, including baseline regression, parallel trend analysis, placebo tests, and Propensity Score Matching (PSM). The test results all confirm that the informatization impact generated by smart city policies effectively promotes the elevation of corporate ESG levels, lending strong robustness to this conclusion. In summary, this study reveals that the informatization impact triggered by the implementation of smart city policies plays a constructive role in boosting corporate ESG performance levels. This finding offers robust policy recommendations and empirical support for further refining smart city policy design, propelling companies to reinforce ESG information disclosure, and enhancing their competitiveness and sustainable development capabilities.

Keywords: Informatization Impact; ESG; Smart City; Difference-in-Differences Model; Heterogeneity Analysis.

1. Introduction

The environmental, social, and governance (ESG) performance of companies has been widely recognized as a key indicator for assessing their performance in environmental protection, social responsibility, and corporate governance. It not only serves as an effective means for companies to achieve sustainable development but also enhances their competitiveness in the market [1] (Hou, Y. et al., 2022). Since the United Nations first introduced the concept of ESG in 2004, ESG has gradually become a focus of global academic and industry attention, thanks to active engagement and promotion from various sectors. In 2021, China's State-owned Assets Supervision and Administration Commission incorporated ESG standards into the key areas of promoting corporate social responsibility (Shi, F. et al., 2022), further highlighting the practical need for studying ESG factors in companies[2]. Compared to traditional corporate evaluation systems, the ESG framework not only aligns with China's strategic requirements for sustainable development but also serves as a vital tool for achieving high-quality economic development. Focusing on the dimensions of environment, society, and governance, it aims to provide essential information support for constructing a green, circular, and sustainable economic system. Empirical research also provides ample evidence for the importance of ESG performance. Tong, F. et al. (2022) found that ESG performance significantly and positively affects corporate value among 559 A-share listed companies in China between 2017 and 2020 [3]. Li, J. et al. (2021) revealed that ESG and its individual dimensions notably drive corporate innovation [4]. Notably, despite the relatively short development history of the ESG concept in China, according to the latest data, as of the end of December 2022, a total of 1,472 listed companies had published their 2021 corporate ESG reports. Compared to the previous year, the disclosure rate increased by approximately 31.31%, a clear trend indicating the increasing emphasis Chinese companies place on ESG. This study further explores the potential correlation between the informatization impact triggered by smart city pilot projects and corporate ESG performance. If a

positive relationship exists between the two, it implies that through deeper integration of ESG management and corporate governance, technological innovation and upgrading could more effectively promote eco-friendly resource use, thereby aiding in achieving dual carbon goals and driving high-quality national economic development [5]. In conclusion, refining and optimizing ESG management systems not only serve as crucial safeguards for sustainable corporate operations but also represent active enhancements to corporate governance structures. Therefore, in-depth research into this issue holds significant theoretical and practical implications for guiding the implementation of corporate sustainable development strategies and effectively advancing high-quality economic development in China.

With China's economy entering a stage of high-quality development, digital technology has become a core driving force for promoting digital economic growth. In this context, the construction of smart cities, a new model supported by digital technology that comprehensively applies advanced information technologies such as the Internet of Things and big data to optimize urban planning and management, has gained increasing attention. The informatization impact led by smart city initiatives has become a significant reality. Since the launch of the first batch of smart city pilot projects in China in 2012, over 900 cities had participated in this pioneering endeavor by December 2020. Gu, Q. (2022) believes that smart city construction significantly enhances the level of informatization, thereby boosting the level of corporate innovation and providing valuable policy references for enhancing the overall technological innovation capacity [6]. Furthermore, research by Yu, Y. et al. (2022) indicated that smart city construction effectively optimizes the business environment for enterprises [7]. This raises an intriguing question: if a company is registered in one of China's smart city pilot projects, its environmental, social, and governance (ESG) performance might differ from companies located in non-pilot smart cities. While the field of ESG research has been expanding, the association between smart city construction, informatization development, and corporate ESG performance remains a relatively understudied area. Therefore, this paper aims to delve into the potential relationship and underlying mechanisms between the impact of informatization and corporate ESG performance, hoping to provide valuable supplements and new perspectives for relevant research. Specifically, this study will focus on addressing the following key questions: Can the development of informatization effectively enhance corporate ESG performance? If indeed, what are the specific mechanisms underlying this enhancement? Thoroughly exploring and answering these questions not only hold significant theoretical and practical implications for China to seize the opportunities of informatization development and promote economic structural optimization and transformation but also provide guidance for companies to achieve higher quality and more sustainable development.

On December 5, 2012, China's Ministry of Housing and Urban-Rural Development officially issued the "Smart City" pilot policy. For government agencies, this policy signified a new era: smart city construction allowed government departments to utilize advanced information technology for digital governance and to construct an entirely new e-government system. This transformation not only changed the way cities' industries, public services, and urban environments were managed, but also elevated governmental office operations, regulatory procedures, services, and decision-making processes to a more efficient and precise level of intelligence. From the perspective of enterprises, smart city construction has similarly profound implications. It optimizes the information environment for businesses, accelerates information flow, and enhances the quality of information transmission. Such an environment not only facilitates smoother digital transformation for companies but also improves the quality of internal controls, thereby propelling enterprises towards innovation and transformation under the guidance of information technology and gradually transitioning to new operational models in the new era [8]. Essentially, smart cities represent a highly integrated development strategy of informatization and urbanization, representing a more advanced and sophisticated manifestation in the process of urban informatization. As a crucial national strategy, smart city construction naturally attracts massive investments from both governments and enterprises, encompassing numerous advanced smart projects and substantial funding. These projects and funds rely primarily on cutting-edge information and communication technologies such as big data, the

Internet, and the Internet of Things. Research by Shi, D. et al. (2020) found that this reliance has significantly elevated the level of informatization for smart cities and the enterprises within them, surpassing initial expectations in many cases [9]118. Therefore, smart city construction can be regarded as a natural experimental field for informatization development. This provides a valuable research opportunity for this paper to use the Difference-in-Differences (DID) method to deeply analyze and identify the actual effects of informatization on corporate ESG performance.

Building on the preceding discussion, this study employs the impact of informatization brought about by smart city pilot initiatives as a natural experimental setting and employs the multi-period difference-in-differences (DID) method to investigate how informatization influences corporate ESG performance. This approach effectively uncovers the causal relationship between the informatization impact generated by smart city construction and corporate ESG performance. The main contributions of this paper are as follows: (1) Through the unique natural experimental design of smart city pilot initiatives, this study empirically examines the causal impact of informatization on corporate ESG performance. This innovative research method enriches the existing literature on how informatization affects corporate ESG performance. (2) From a corporate perspective, this study clarifies the specific mechanisms through which informatization impact enhances corporate ESG performance. This provides valuable empirical evidence from the corporate level for the microeconomic effects of smart city pilot policies and, from the standpoint of informatization construction, offers more precise references for policy formulation. (3) This study validates how the effects of informatization impact differ heterogeneously based on various internal and external environmental conditions. This finding is of significant guiding significance for effectively leveraging smart city construction as a policy tool, further promoting corporate engagement in environmental governance, and actively fulfilling social responsibilities.

The remaining part of this paper are arranged as follows: Chapter 2 presents the research design; Chapter 3 presents the empirical results and analysis; Chapter 4 covers heterogeneity analysis; and Chapter 5 concludes with implications.

2. Research Design

2.1 Sample Selection

Considering that the timing of the three waves of smart city pilot policies was in 2012, 2013, and 2015, and taking into account the availability of corporate ESG data, this study selected A-share listed companies from the years 2011 to 2020 as the research sample. Companies in the financial and real estate industries, those that experienced ST events during the sample period, and companies that went public after 2015 were excluded from the sample. To mitigate the impact of extreme values, this study applied a winsorization technique by trimming the upper and lower 1% of the distribution of relevant continuous variables.

2.2 Variable Selection and Descriptive Statistics

The dependent variable in this study is corporate ESG performance. Drawing on existing research and considering data availability, this study utilized Bloomberg's ESG scores to measure corporate ESG performance. These scores are based on publicly available information such as corporate social responsibility reports, annual reports, and websites, comprehensively assessing the environmental, social, and governance dimensions of companies, with scores ranging from 0.1 to 100.

To control for the influence of various features at both the corporate and city levels, this study incorporated a series of corporate characteristic variables following the approach of Shidaqian et al. (2020). These variables include firm size, measured using the natural logarithm of total assets; debt-to-equity ratio, reflecting the company's capital structure; return on assets (ROA), calculated as the ratio of net profit to total assets; equity concentration, represented by the sum of the holdings of the top ten circulating shareholders of the company; and asset growth rate, indicating the company's growth capability [9]122.

This study, based on the definition of corporate information disclosure level, carried out empirical research on the ESG information disclosure level of 3644 enterprises to better assess whether smart city policies had an impact on corporate information disclosure. Specific descriptive statistics are presented in Table 1. As indicated in Table 1, the mean information disclosure level of the 3644 sampled companies is 20.111, with a standard deviation of 6.396. The minimum value is 1.240, the median is 19.421, and the maximum value is 55.372.

Table 1. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
ESG	3644	20.111	6.396	1.240	19.421	55.372
treat	3644	0.487	0.500	0.000	0.000	1.000
roa	3637	0.065	1.819	-14.302	0.034	108.366
invt	3633	0.053	0.052	0.000	0.038	0.642
tang	3581	0.413	0.183	0.000	0.407	0.875
Sale	3569	1.36e+10	2.69e+10	4.17e+06	4.91e+09	4.33e+11
cfin	3635	3.122	1.682	0.732	2.712	13.530
ctech	3636	0.026	0.019	0.001	0.021	0.163

2.3 Empirical Methodology and Model Specification

This study leverages the informational impact brought about by the development of smart cities to validate the relationship between informatization and corporate ESG performance. A key initiative in China's smart city development was the establishment of three batches of smart city pilot cities in 2012, 2013, and 2015. This exogenous event significantly altered the levels of informatization in cities and companies. As individual firms cannot predict whether their city will become a smart city pilot, nor can they intervene in government decisions in the short term, the implementation of smart city pilot policies can be viewed as an exogenous informational shock [9]121 (Shi, D et al., 2020). Due to the gradual implementation and quasi-natural experimental nature of the smart city pilot policy, this study employs a multi-period Difference-in-Differences (DID) method to identify the impact of the informational shock generated by the smart city pilot policy on corporate ESG performance. The different implementation years of the policy provide the time dimension for DID identification, while the status as a pilot city provides the group dimension for DID identification. Since the first batch of pilot cities was established at the end of 2012, the year 2013 is considered the initial year for policy effects. In the process of determining the experimental and control groups, as some smart cities are at the county or district level, defining these cities as the experimental group could overestimate the results. Therefore, in the process of defining the experimental group, this study excludes prefecture-level cities where county-level cities or district-level areas are located. Furthermore, based on the standards mentioned above, this study determines whether a listed company is located in a smart city; if the listed company is located in a county-level city or district-level area, it is excluded. This allows for the estimation of the net effect of city-level informatization on corporate ESG. Building upon the discussions above, the multi-period Difference-in-Differences model is specified as follows:

Among them, represents the dependent variable, which is the ESG performance of the enterprise in the year; represents the dummy variable of whether the city implemented the smart city pilot policy in the year. It takes the value of 1 if the city where the firm is located is identified to have implemented the policy, otherwise it takes the value of 0. represents a series of control variables that influence corporate ESG. represents individual fixed effects, represents city fixed effects, represents year fixed effects, and represents the error term. The regression coefficient of primary interest in this study is , where its sign, magnitude, and absolute value can to some extent characterize the causal impact of informatization shock on corporate ESG performance.

3. Empirical Results and Analysis

3.1 Baseline Regression

Table 2 presents the baseline regression results of the impact of informatization shock induced by smart cities on corporate information disclosure levels. Columns 1 to 3 respectively show the regression results without controlling for any covariates, the results controlling only for firm-level factors, and the results controlling for both firm-level and city-level factors. In these columns, the regression coefficients are 0.591, 0.589, and 0.543. The first two coefficients are significantly positive at the 1% level, and the third coefficient is significantly positive at the 5% level. This suggests that under the influence of smart city policies, the information disclosure level of companies can increase by approximately 5 percentage points. Thus, it can be inferred that the informatization shock triggered by smart cities contributes to the promotion of corporate ESG information disclosure. This conclusion remains positive and robust even after controlling for both firm-level covariates and city-level covariates.

Table 2. Baseline Regression

	(1) ESG	(2) ESG	(3) ESG
treat	.591***	.589***	.543**
	(.197)	(.171)	(.195)
roa		-.139***	-.139***
		(.029)	(.029)
invt		1.236	1.296
		(1.509)	(1.457)
tang		1.998***	2.076***
		(.54)	(.565)
Sale		0	0
		(0)	(0)
cfin			.076
			(.189)
ctech			.069
			(9.092)
_cons	19.83***	18.239***	17.974***
	(.099)	(.634)	(1.033)
Observations	3635	3549	3540
R-squared	.722	.734	.733

Note: The figures in parentheses are standard errors.
*** p<.01, ** p<.05, * p<.1

3.2 Robustness Test

3.2.1 Parallel Trends Test

Since a key assumption of the difference-in-differences method is that the treatment and control groups should exhibit parallel trends, this section starts with a parallel trends test. Given the multi-period nature of the implementation of smart city pilot policies, and following the approach of Xu and Lian, as well as Wang and Wang (2018), the current study constructs the testing model as shown below [10].

Among them, represents a series of dummy variables. When the treatment group is in the year before (after) policy implementation and during the year of policy implementation, is assigned a value of 1; otherwise, it is assigned 0. Specifically, the case where is consolidated into for treatment. The remaining parts of the model are set the same as the baseline model and will not be reiterated. To illustrate the results more intuitively, the horizontal axis represents the time points from the policy trial, while the vertical axis represents the effects of the policy changes.

From Figure 1, it can be observed that when i=-3 to i=-1, the S is not significant. This indicates that before the implementation of the smart city policy, there is no significant difference in the level

of ESG information disclosure between the control group and the treatment group, and the possibility of parallel trends cannot be rejected. Over the six years after the policy implementation, impact of on policy changes on ESG levels is significant from the current period and the first period of policy implementation. This suggests that the informationization impact caused by the implementation of smart city policies has no time lag on the ESG levels of companies and can be sustained for a period of time. Although the impact coefficient in the second and third years after the implementation of the smart city policy is positive, it is not statistically significant. However, the impact coefficients are positive and significant in the subsequent fourth and fifth years but become not significant again in the sixth year. This implies that the impact of the implementation of smart city policies on ESG levels of companies has a certain lag period, and this positive effect also exhibits some intermittency and instability. Looking at the dynamic effects, the effects of the smart city policy in the current period and the first period are more significant, while there are signs of weakening effects in the later periods. Therefore, it is necessary to enhance the stability and sustainability of the policy.

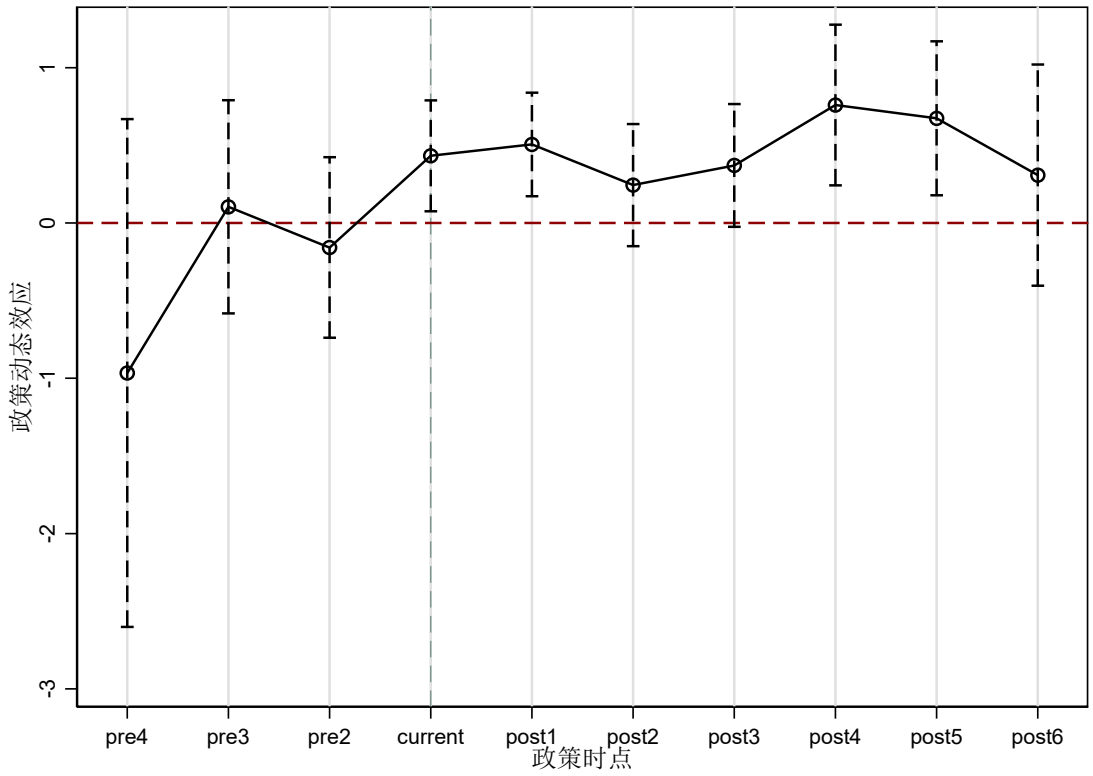

Figure 1. Parallel Trend Test

3.2.2 Placebo Test

We generate a random variable and repeat the estimation to conduct a placebo test. For the random variable, we reset it randomly and perform 1000 rounds of random sampling on the treatment group, extracting the coefficients of the random variable. These coefficients are plotted in Figure 2. The conclusion drawn from this test is that the kernel density plot of the coefficients of the randomized DID term is centered around 0. This suggests that the average value of the estimated coefficients is around 0, which is significantly different from the coefficient of 0.543 in the baseline regression. This indicates that the positive relationship between company ESG levels and the informationization impact generated by the implementation of smart city policies is unlikely to be influenced by other undetected non-random features. Thus, our conclusion remains robust.

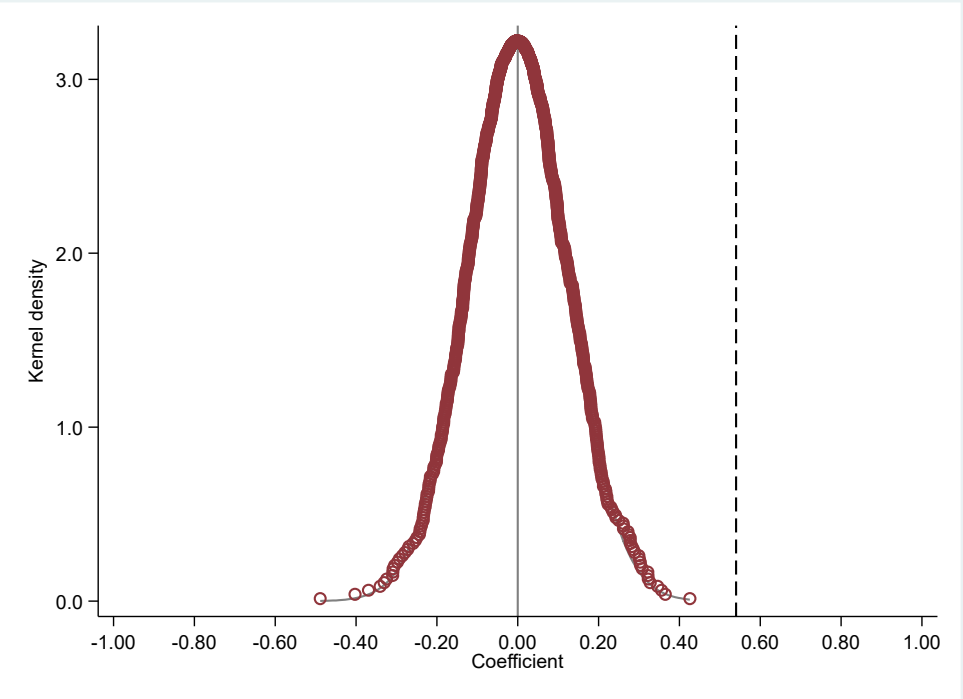

Figure 2. Placebo Test

3.2.3 Propensity Score Matching (PSM)

In order to mitigate potential selection bias, we conducted a one-to-one comparison of ESG performance for the collected sample companies. After removing outliers in the context of the baseline analysis, as evident from the regression results in Table 3 based on PSM, our conclusion remains significant within a 10% confidence interval. The robustness of the baseline regression indicates that the impact of smart city policies continues to exhibit a positive correlation with corporate ESG performance.

Table 3. Propensity Score Matching

	(1) ESG
treat	.383*
	(.185)
roa	.202
	(.589)
invt	1.596
	(1.637)
tang	2.769***
	(.613)
Sale	0
	(0)
cfin	.074
	(.165)
ctech	.975
	(9.896)
_cons	17.73***
	(.909)
Observations	3216
R-squared	.731

Note: The figures in parentheses are standard errors.
**** p<.01, ** p<.05, * p<.1*

4. Heterogeneity Analysis

4.1 Heterogeneity of Company Nature

Following the classification by Rao Yue (2022), we categorize companies into state-owned enterprises and non-state-owned enterprises, which exhibit significant differences in various aspects such as operational practices, tax incentives, bank credit, and responsibility fulfillment [11]38. Therefore, it is necessary to conduct a heterogeneity analysis based on company nature to diagnose whether the nature of companies affects their ESG levels. According to the relevant information provided by the database, we assign a value of 1 to state-owned enterprises and label other types of enterprises, such as private and foreign-owned enterprises, as non-state-owned enterprises with a value of 0. The regression analysis is presented in Table 4 below.

Based on the regression results, the coefficient for state-owned enterprises is 0.212, while the coefficient for non-state-owned enterprises is 0.762. The ESG levels of non-state-owned enterprises are higher than those of state-owned enterprises. The underlying reason for this disparity might be that state-owned enterprises bear greater social responsibilities, have closer ties with the government, and are subject to more administrative intervention. On the other hand, non-state-owned enterprises often prioritize economic benefits over social responsibilities, operate more flexibly, and are more affected by smart city policies [11] 47 (Rao Yue, 2022).

Table 4. Heterogeneity Analysis of Company Nature

	(1) ESG	(2) ESG
treat	.212	.762*
	(.265)	(.385)
roa	.039	-.145***
	(.139)	(.005)
invt	2.912	-1.649
	(2.766)	(4.026)
tang	3.895***	-.089
	(1.287)	(.791)
Sale	0*	0
	(0)	(0)
cfin	.068	.01
	(.235)	(.114)
ctech	15.537**	-19.882
	(7.093)	(23.547)
_cons	17.134***	18.856***
	(1.386)	(.882)
Observations	1467	2075
R-squared	.767	.732

Note: The figures in parentheses are standard errors.
**** p<.01, ** p<.05, * p<.1*

4.2 City Location Heterogeneity Analysis

Due to varying levels of economic development and different policies in different regions, the operational capabilities and strengths of companies also differ. Therefore, in accordance with the classification method for Eastern, Central, and Western regions as published by the National Bureau of Statistics in "Division Method of Eastern, Central, and Northeastern Regions," this study classifies sample companies into three types based on their registered addresses: Eastern, Central, and Western. For the sake of simplicity, we group Eastern and Central regions as non-Western regions and conduct regression analyses accordingly, as shown in Table 5 below.

Based on the regression results, it can be observed that the coefficient for Western regions is 1.13, while the coefficient for non-Western regions is 0.375. This discrepancy is primarily due to factors such as the traditional production layout, resource development, technological level, and regional

environment limitations in Western regions (Yang Dacheng, 1996). As a result, Western regions have relatively fewer smart city initiatives compared to other regions. Enterprises in these areas are more sensitive to smart city policies and experience a more significant impact from the generated informational shock. The reason for this could be attributed to the lower degree of marketization in Western regions, leading to higher incentives and emphasis on ESG levels among enterprises. These enterprises exhibit greater sensitivity to national policies, resulting in improved performance following the influence of smart city policies. These companies might have the capacity to enhance their ESG performance in the long term, given their heightened attention to and incentives for ESG improvement [12].

Table 5. City Location Heterogeneity Analysis

	(1) ESG	(2) ESG
treat	1.13*	.375
	(.611)	(.223)
roa	-.014	-.139***
	(.254)	(.003)
invt	.898	1.471
	(4.928)	(3.732)
tang	3.367**	1.455
	(1.092)	(.9)
Sale	0**	0
	(0)	(0)
cfin	-.25	.262*
	(.156)	(.142)
ctech	-31.484	5.847
	(32.571)	(11.137)
_cons	18.767***	17.599***
	(.681)	(.939)
Observations	796	2746
R-squared	.699	.747

Note: The figures in parentheses are standard errors.
**** p<.01, ** p<.05, * p<.1*

5. Conclusion and Implications

With the high-quality development of China's economy, the construction of smart cities, which utilizes digital technology as its core and leverages technologies such as the Internet of Things and big data to facilitate urban planning and management, has shown significant effectiveness in our country. The resulting impact of digitalization from this development cannot be underestimated. This paper, under the context of the widespread trend of digitalization in the information age, discusses the increasing focus of companies on ESG (Environmental, Social, and Governance) factors. Using data from A-share listed companies between 2011 and 2020, the paper systematically demonstrates the positive relationship between the impact of smart city policies and the ESG performance of enterprises through the use of a double-difference model. Robustness and heterogeneity analyses are conducted, and the findings confirm the positive and robust impact of the digitalization impact resulting from smart city policies on ESG performance.

The study reveals the following key findings: Firstly, if a company is located in a city that is part of the smart city policy trial, its ESG performance is higher compared to companies not influenced by the smart city policy. Secondly, there is heterogeneity in ESG performance based on enterprise nature and city location. In terms of enterprise nature, non-state-owned enterprises exhibit higher ESG performance compared to state-owned enterprises due to their greater flexibility in actions and reduced administrative intervention. In terms of city location, the ESG performance of companies in western cities impacted by the smart city policy is higher than that of companies in the central and eastern regions. This is due to the less developed economic conditions in the western regions,

resulting in a greater sensitivity of enterprises to national policies and stronger incentives for ESG performance improvement. Thirdly, the robustness test indicates that the impact of smart city policy implementation on ESG performance exhibits a certain lag. From a dynamic perspective, the effects of the policy are stronger in the initial periods, while they weaken in the later stages.

In summary, this positive impact also demonstrates certain intermittency and instability. The conclusions of this paper provide relevant departments with empirical evidence for establishing long-term policy mechanisms and offer suggestions for enhancing ESG performance to contribute to the establishment of a green and sustainable economic system, promoting high-quality economic development in China.

In light of the empirical findings, the paper suggests several implications. Firstly, in the era of abundant internet information, relevant government departments need to establish long-term policy mechanisms to ensure that policies are effectively formulated and implemented, benefiting both enterprises and the people, and exerting positive effects. Secondly, companies should actively respond to smart city policies implemented by the government, effectively utilizing them to empower efficient and high-quality development and contribute to the healthy growth of the economy. Lastly, investors should consider the development conditions of the location where a company is situated before making investment decisions, predicting the development prospects and potential for growth, in order to enhance investment value and improve the ESG performance of the company.

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