Energy Proceedings
Vol 31, 2023
ISSN 2004-2965

Has Smart City Construction Reduced Corporate Pollution Emissions? New Evidence from Chinese Corporate Pollution Data

Juan Li*, Zixuan Li, Huiping You
School of International Business, Southwestern University of Finance and Economics (*Corresponding Author)

ABSTRACT

Using China's smart city construction as a quasi-natural experiment, by matching the data of the Chinese Industrial Enterprises Database, Chinese Enterprises Pollution Emission Database and prefecture-level city data from 2008-2014, this paper evaluates the impact of smart city construction on enterprise pollution emissions using the difference-in-difference method (DID) and propensity score matching DID method (PSM-DID). The empirical results show that smart cities construction effectively promotes the pollution reduction of enterprises, and the estimation results based on the PSM-DID method show robust. The mechanism investigation shows that smart city construction can achieve effective suppression of enterprise pollution emissions through the output effect, technology effect and scale effect.

Keywords: smart city, enterprise pollution emission, technological innovation, quasi-natural experiment, DID, China Enterprise Pollution Database

NONMENCLATURE

Abbreviations	
DID	difference-in-difference
PSM	Propensity score matching
TFP	total factor productivity
Symbols	
t	Year
i	Enterprise
j	Industry
ε	Random error term

1. INTRODUCTION

The shift from pursuing economic growth to reducing corporate pollution while pursuing development and the shift from the traditional city development model to the smart city development model are not only China's development plans but also important measures for China to improve its economic development. Therefore, the goal of identifying the influencing factors of corporate pollution emissions and seeking measures for reducing corporate pollution emissions can be a powerful help for the government to formulate environmental policies and improve the quality of economic development.

The application of advanced technologies to make cities smarter, more efficient and more effective to safeguard the lives of their residents as well as the operation of their cities is the original purpose of the smart cities construction. Modern smart cities pay special attention to efficient and sustainable solutions in energy management and environmental management to meet the extreme demands of urbanization. So in addition to administrative measures, is it possible to reduce pollution emissions from companies by other means, such as changing the model of governing cities and improving the continuous innovation of technology? Most of the existing studies related to smart cities are qualitative analyses, and the few empirical studies on whether environmental pollution is related to smart cities are only city level data.

This paper uses the 2008-2014 Chinese industrial enterprise database, the Chinese enterprise pollution database, and prefecture-level city data. The overall study investigates the level of change in total enterprise pollution emissions in the context of increasingly improved smart city construction and assesses whether enterprises suppress the scale of their pollution emissions due to the construction of smart cities. With the PSM-DID method, an accurate assessment of whether the construction of smart cities can suppress the effect of enterprise pollution emissions to a certain extent is achieved.

The possible contributions of this paper are as follows. First, since a quantitative assessment of the evaluation of smart city policies is currently lacking, this paper expands and improves this field by quantitatively analyzing the relationship between pollution emissions and smart city construction policies. Second, this paper explores possible new directions in the factors affecting pollution emissions through an in-depth analysis of the logical processes and mechanisms between smart city policies and corporate pollution emissions. Third, the sample data of this paper were selected from 2008-2014 using the Chinese Enterprises Pollution Emission Database, which was used for the first time to study the impact of smart city construction on reducing enterprise pollution emissions. Finally, the PSM-DID approach to study the extent to which the implementation of smart city construction inhibits corporate pollution emissions can help increase research on the PSM-DID dimension.

The remainder of this paper is organized as follows. Section 2 provides a brief literature review. Section 3 analyzes the theoretical framework of smart city construction affecting corporate pollution emissions. Section 4 explains the model, the variables and the data used in this study. Section 5 presents the empirical results and analysis. Section 6 provides conclusions and related policy implications.

2. LITERATURE REVIEW

The research mainly focuses on the connotation and effect of smart cities and the factors influencing corporate pollution emissions. There are many studies on the connotation of smart cities. The word "smart" means an automated mechanism that can perform the required activities in a given domain [1]. Initially, smart cities were considered to be an advanced stage of urban development, that is, a new model of informational development of cities. China's pilot smart cities have improved the efficiency of urban economic and ecological operations and have had a positive impact on the economy, resource consumption, and pollution emissions [2]. Several studies have focused on the effects generated by smart cities. Many scholars believe that the functions of smart cities are not simply limited to social and economic development but should also include sustainable consumption and production and resource management. Paying more attention to sustainable governance in the process of building smart cities is an important direction [3–5].

Many factors can influence the firm level pollution emissions. The relationship between different environmental constraints is investigated. In studies related to environmental regulations, most scholars focus on the "Porter hypothesis" to see whether the coordination of economic development and environmental protection is influenced by technological innovation under environmental regulations [6]. The Porter hypothesis has been used to examine whether the coordination of economic development and environmental protection are affected by technological innovation under environmental regulations. In fact, in addition to technological innovation, the adoption of end-of-pipe governance policies has been an important way for enterprises to reduce pollution emissions. Most of the existing studies on end-of-pipe policies for enterprise pollution emissions have been conducted on the "Two Control Zones" (the SO_2 control zones and the acid rain control zones).

There are still some limitations in this field of research. First, from the perspective of research, the current research is rarely concerned with the construction of smart cities. Second, in terms of research methods, most of the literature analyzing the relationship between smart city construction and enterprise pollution emissions consists of purely theoretical modeling arguments. Finally, in terms of research data, most domestic scholars base their studies on data from the China Urban Statistical Yearbook, while few use the China Enterprise Pollution Database.

3. A THEORETICAL FRAMEWORK FOR SMART CITY CONSTRUCTION AFFECTING CORPORATE POLLUTION EMISSIONS

The actions of smart cities to influence enterprise pollution reduction are divided into three mechanisms: output effect, technology effect and scale effect. First, reducing output by firms has been called a way for firms to reduce emissions. Under the influence of smart city construction, all industries may be upgraded so that industries and organizations that cannot adapt to the new changes will gradually shrink, while enterprises will gradually form new production models and industrial organization models to achieve new economic growth points [7]. Second, smart cities have inherently innovative advantages in construction, with high technology levels and resource allocation efficiency, so the formation of technology and distribution effects can reduce pollution emissions and improve the environment [8]. Expanding from another perspective, the study found that the construction of smart cities can mitigate the extent of environmental degradation due to rapid urbanization through an innovation-driven strategy [9,10]. Third, in the context of smart city construction, there is the phenomenon that enterprises with large volumes, high energy consumption, and high pollution will continue to upgrade and move out.

4. MODELS, VARIABLES, AND DATA

4.1 Models

The time-varying DID method examines the effect of smart city construction to reduce the enterprises' pollution emissions in 2012, 2013, and 2014. The baseline regression equation is as follows.

$$Y_{ict} = \alpha_0 + \alpha_1 DID_{it} + \gamma X_{ict} + \theta Z_{ct} + \lambda_i + \mu_t + \varepsilon_{it} \quad (1)$$

where i, t and c represents enterprise, year and city, respectively; Y_{ict} is industrial wastewater emissions as a proxy for the level of enterprise pollution emissions; DID_{it} is a policy dummy variable to identify the cities selected for the smart city pilot policy. In the dummy variable, the value of 1 shows the year of implementing smart city construction onwards (2012, 2013, and 2014) for the pilot cities; otherwise, it is 0. The coefficient α_1 measures the impact of smart city construction represented by the effect of green technological innovation on reducing enterprise pollution emissions. X_{ict} represents the firm-level control variables, including firm total assets, profits, age, leverage ratio, fixed assets share and ownership. Z_{ct} indicates such city-level controlling variables as economic development, the share of secondary industry, and population density. ε_{it} is the random error term.

4.2 Variables

In this paper, the explanatory variable is the smart city dummy variable *DID*, and the policy of smart city construction exists according to the form of dummy variables. Hence, the dummy variable is 1 for those pilot cities selected for smart city construction in 2012, 2013, and 2014 and the remaining years are 0. The explanatory variable is the corporate wastewater emissions, InWater_emit.

4.3 Data sources

In this study, the data sources include the China Industrial Enterprise Database, the China Enterprise Pollution Database, and the prefecture-level city database. This study combines both databases. This paper uses a sample of prefecture-level city-level data from the China City Statistical Yearbook.

Fig.1 compares the pollution emissions of enterprises in the two groups of smart and non-smart cities, implying that industrial wastewater emissions in smart cities are significantly lower than in non-smart cities.

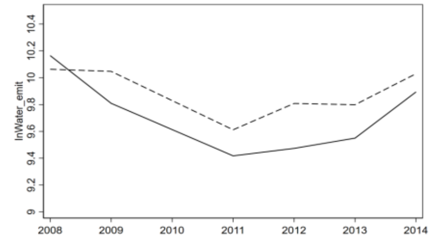

Fig.1. Trends of emissions of smart and non-smart cities

5. EMPIRICAL RESULTS AND ANALYSIS

5.1 Parallel trend test

Fig.2 verifies the parallel trend test, which shows that treatment and control groups have the same emission trend before implementing the smart city policy, the parallel trend test can be successfully passed.

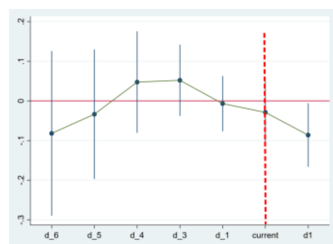

Fig.2. Parallel trend test results

5.2 Baseline regression results

Column (1) of Table 1 shows that the estimated coefficient of *DID* is negative and statistically significant at 10% level, implying that implementing a smart city construction policy reduces enterprises' pollution emissions. According to columns (2) and (3), the estimated coefficients of our interest are negative and statistically significant at 1% level, indicating a significant reduction in the industrial wastewater emissions after implementing the smart city construction. After controlling all kinds of fixed effects, the results are still robust which is shown in Column (4) of Table 1.

Table 1 Basic results

	(1)	(2)	(3)	(4)
	In*Water_emit*	In*Water_emit*	In*Water_emit*	In*Water_emit*
did	-0.029*	-0.052***	-0.050***	-0.042**
	(0.016)	(0.018)	(0.018)	(0.018)
City-level control variables	No	Yes	Yes	Yes

Firm-level control variables	No	Yes	Yes	Yes
Firm fixed effect	No	Yes	Yes	Yes
Year fixed effect	No	No	Yes	Yes
Industry-year fixed effect	No	No	No	Yes
Constant	9.991***	9.993***	8.575***	9.080***
	(0.003)	(0.004)	(0.149)	(0.210)
observations	214875	182171	181721	159339
Adjusted R^2	0.809	0.812	0.812	0.815

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

5.3 Robustness tests

This study uses the PSM-DID method to reexamine the impact of smart cities on enterprise emissions as a robustness check. Theoretically, the treatment group of pilot smart cities should be randomly selected, or the policy shock is exogenous. In order to improve the contrast between cities, we firstly apply a Logit model to predict the likelihood of cities to carry out smart city policy, then the results are referred to as the propensity to match the score value and its closest city accordingly are specified as the control group. The matching results can be referred as Fig.3, Table 2 and Fig.4.

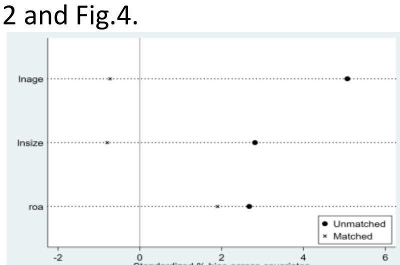

Fig.3.Comparison of standard deviations before and after matching

Table 2 PSM pairwise balance analysis

variables	Sample matching	Mean: Treated group	Mean: Control group	SE	% of SE changes	T-test: t-value	T-test: P-value
ln*size*	Unmatched	11.374	11.328	2.8	71.7	4.89	0.000
	Matched	11.374	11.387	-0.8		-1.16	0.245
Roa	Unmatched	.14033	.13042	2.7	29.0	4.33	0.000
	Matched	.14033	.13329	1.9		3.51	0.000
ln*age*	Unmatched	2.3333	2.3055	5.1	85.6	8.84	0.000
	Matched	2.3333	2.3380	-0.7		-1.05	0.292

Table 3 shows that after conducting the PSM-DID test, the enterprises' emissions reduce significantly due to the implementation of the smart city policy, and the reduction rate of wastewater emissions is more than 5%. It indicates that our conclusions are valid and implementing smart cities lessens the harmful effects of enterprise emissions on the environment.

Table 3 PSM-DID robustness tests

	(1) ln*Water_emit*	(2) ln*Water_emit*
DID	-0.030*	-0.052***
	(0.016)	(0.018)
City-level control variables	No	Yes
Firm-level control variables	No	Yes
Firm fixed effect	No	Yes
Year fixed effect	No	Yes
Industry-year fixed effect	No	Yes
Constant	9.991***	8.466***
	(0.003)	(0.146)
observations	214875	181893
R^2	0.864	0.872
Adjusted R^2	0.809	0.811

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

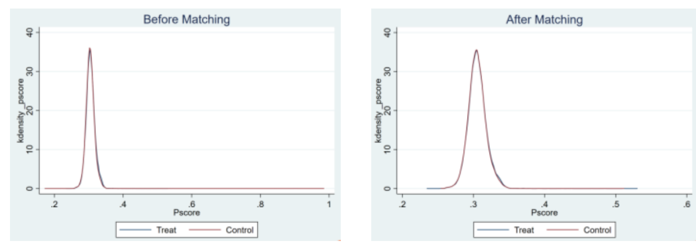

Fig.4. Density function of propensity score

5.4 Heterogeneity analysis

5.4.1 City-level heterogeneity

The results in columns (1) and (2) of Table 4 show that smart city construction has an insignificant effect on reducing corporate pollution emissions in cities with low population density, but this effect is significant in cities with high population density. Cities with a high population are more capable of mitigating the problem of corporate pollution emissions compared with cities with a low population. According to columns (3) and (4), the level of human capital positively correlates with the reduction of wastewater emissions of enterprises from the perspective of wastewater emissions. Thus, human capital has a facilitating effect on developing smart cities, and cities with a high level of human resources can have more human resources, which can significantly reduce the enterprises' pollution. The results in columns (5) and (6) show that the cities with a higher economic development have a higher suppression effect on corporate emissions than those with less economic development if corporate wastewater emissions are the main variable.

Table 4 Results of heterogeneity of urban population size

	（1）	（2）	（3）	（4）	（5）	（6）
	low population density	high population density	low human capital	high human capital	low development	high development
DID	-0.011	-0.062**	0.070***	-0.201***	-0.012	-0.041*
	(0.026)	(0.026)	(0.024)	(0.029)	(0.032)	(0.022)
City-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	8.451***	8.393***	8.714***	8.352***	8.362***	8.341***
	(0.232)	(0.186)	(0.224)	(0.206)	(0.221)	(0.208)
observations	79394	101922	73744	98793	78256	95572
Adjusted R^2	0.811	0.813	0.852	0.788	0.802	0.835

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

5.4.2 Firm-level heterogeneity

Table 5 shows the companies that conducted the study in this paper, partly state-controlled and partly private, shown in columns (1) and (2). Analyzing the feasibility of smart cities centered on state-owned enterprises shows that the estimated coefficients are significant at 1% level. However, studying the private enterprises shows that the estimated coefficients are insignificant, implying the vital role of state-controlled enterprises in reducing production emissions under the influence of policies. The estimated results in columns (3) and (4) of Table 5 show that the pollution emissions of high-polluting enterprises reduce significantly in the continuous development of smart cities, while the reduction of emissions is insignificant in low-polluting enterprises. According to Table 5, columns (5) and (6), and the division criterion is the median of the enterprises' total assets. Analyzing large-scale enterprises shows that the estimated coefficient of smart cities has a negative correlation at 10% significance level. This result implies that the development of smart cities promotes such enterprises to reduce their emissions significantly.

Table 5 Results of the test for firm-level heterogeneity

	（1）	（2）	（3）	（4）	（5）	（6）
	SOEs	Non-SOEs	high-polluting firms	low-polluting firms	large-scale firms	small-scale firms
DID	-0.049***	-0.083	-0.049*	-0.047*	-0.049*	-0.037
	(0.019)	(0.066)	(0.026)	(0.026)	(0.025)	(0.026)
City-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	8.502***	7.885***	8.510***	8.538***	7.792***	8.506***
	(0.148)	(0.763)	(0.204)	(0.218)	(0.299)	(0.196)
observations	164067	17027	97740	76243	89959	84542
Adjusted R^2	0.811	0.808	0.811	0.797	0.810	0.813

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

5.5 *Mechanism testing and analysis*

5.5.1 Output effect

The regression coefficient of *DID* in Table 6 is less than 0 and significant at 1% level. This result implies that enterprises adjust their current production methods and apply effective measures at their production end to reduce pollution emissions to achieve the emission reduction target under the influence of smart city construction. In this way, smart city construction makes enterprises reduce their own emissions.

Table 6 Impact of smart city construction on the amount of wastewater generated

	output effect
	In*Water_production*
DID	-0.054***
	(0.019)
City-level control variables	Yes
Firm-level control variables	Yes
Firm fixed effect	Yes
Year fixed effect	Yes
Industry-year fixed effect	Yes
Constant	8.460***
	(0.152)
observations	181905
Adjusted R^2	0.808

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

5.5.2 Technology effect and scale effect

Referring to Levinson (2009) and Chen et al. (2021), this paper decomposes enterprise wastewater discharge ($Water\_emit_{it}$) into enterprise wastewater discharge intensity ($inten_{it}$) and enterprise output value ($output_{it}$).

$$Water\_emit_{it} = \frac{Water_{emit_{it}}}{output_{it}} \times output_{it} = inten_{it} \times output_{it} \quad (2)$$

Table 7 Impact of smart city construction on the intensity of wastewater discharge

	（1）technology effect	（2）scale effect
	Ininten	ln(output +1)
DID	-0.041**	-0.012
	(0.019)	(0.007)
City-level control variables	Yes	Yes
Firm-level control variables	Yes	Yes

Firm fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
Industry-year fixed effect	Yes	Yes
Constant	1.993***	6.545***
	(0.151)	(0.059)
observations	180981	224604
Adjusted R^2	0.805	0.861

Notes: The values in parentheses are robust standard errors. *, ** and *** represent the statistical significance level of 10%, 5% and 1% respectively.

According to Table 7, smart city construction encourages enterprises to innovate their green and clean technologies and thus achieve emission reduction. Also, it reasonably controls the scale of pollution-intensive enterprises to achieve emission reduction. In the actual operation of smart city construction, the former should be the main focus, actively promoting enterprise clean technology innovation.

6. CONCLUSION AND POLICY IMPLICATION

This paper investigates smart city impact on enterprise pollution emissions using China's smart city construction as a quasi-natural experiment. The empirical results show that smart cities construction effectively promotes the pollution reduction of enterprises. In addition, results based on heterogeneity reveals that cities with higher population density, higher levels of human capital, and larger economies, as well as state-owned enterprises, highly polluting enterprises, and large-scale enterprises, have more significant pollution reduction effects formed under the influence of smart city construction. The mechanism results show that smart city construction can achieve effective suppression of enterprise pollution emissions through the output effect, technology effect and scale effect.

Combining the results of the empirical study, this paper proposes the following three specific policy recommendations. First, by providing a supportive platform for innovation and scientific research, the government can help enterprises to combine and cooperate to cultivate more quality talents and pave the way for constructing smart cities in terms of public service, human capital, and environmental policies. Second, due to the differences in city scales, larger cities are able to implement and use emerging smart technologies more vigorously, covering different aspects of the enterprise througha large number of applications and enhancing the ability to allocate resources in a comprehensive manner. Third, non-polluting and small- and medium-sized enterprises should transform the production process to use clean energy more actively to achieve the purpose of optimizing environmental pollution.

ACKNOWLEDGEMENT

We thank the editor and the reviewers. The authors acknowledge MOE (Ministry of Education of China) Humanities and Social Sciences Project (Grant Number: 19YJC790062).

REFERENCES

[1] Ahad MA, Paiva S, Tripathi G, Feroz N. Enabling technologies and sustainable smart cities. Sustainable Cities and Society 2020;61(2):102301.

[2] Song M, Tan KH, Wang J, Shen Z. Modeling and evaluating economic and ecological operation efficiency of smart city pilots. Cities 2022;124(3):103575.

[3] AlZubi AA, Alarifi A, Al-Maitah M, Alheyasat O. Multi-sensor information fusion for Internet of Things assisted automated guided vehicles in smart city. Sustainable Cities and Society 2021;64(1):102539.

[4] Munawar HS, Qayyum S, Ullah F, Sepasgozar S. Big Data and Its Applications in Smart Real Estate and the Disaster Management Life Cycle: A Systematic Analysis. BDCC 2020;4(2):4.

[5] Westraadt L, Calitz A. A modelling framework for integrated smart city planning and management. Sustainable Cities and Society 2020;63(3):102444.

[6] Dechezleprêtre A, Koźluk T, Kruse T, Nachtigall D, Serres A de. Do Environmental and Economic Performance Go Together?: A Review of Micro-level Empirical Evidence from the Past Decade or So. IRERE 2019;13(1-2):1–118.

[7] Figueiredo R, Matos Ferreira JJ de. Spinner Model: Prediction of Propensity to Innovate Based on Knowledge-Intensive Business Services. J Knowl Econ 2020;11(4):1316–35.

[8] Chu Z, Cheng M, Yu NN. A smart city is a less polluted city. Technological Forecasting and Social Change 2021;172:121037.

[9] Cao W, Zhang Y, Qian P. Corrrection: The Effect of Innovation-Driven Strategy on Green Economic Development in China-An Empirical Study of Smart Cities. Int. J. Environ. Res. Public Health 2019, 16(9), 1520. International journal of environmental research and public health 2020;17(10).

[10] Contreras G, Platania F. Economic and policy uncertainty in climate change mitigation: The London Smart City case scenario. Technological Forecasting and Social Change 2019;142(1):384–93.