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How Does Digital Transformation of City Governance Affect Environmental Pollution: A Natural Experiment from the Pilot Policy of "National Information City for Public Service" in China

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Abstract: This article investigated the "National Information City for Public Service" policy as the representative policy of China's digital transformation of urban governance to empirically analyze its impact on urban environmental pollution using the DID method. The results indicated that: ① The "National Information City for Public Service" policy has significantly reduced the level of urban environmental pollution by 1.65–2.11% on average. After conducting the robustness test of the PSM-DID method and excluding the effect of exogenous interference of the smart city pilot policy in China, the evaluation showed no significant difference from the conclusion above. ② The mechanism test results showed that the "National Information City for Public Service" policy could reduce urban environmental pollution through the technological innovation effect, industrial structure upgrading effect, resource allocation optimization effect, and urban informatization level improvement effect. ③ The heterogeneity analysis of the city scale presented a positive relationship between the city scale and the level of environmental pollution improvement effect under the "National Information City for Public Service" framework. Meanwhile, the heterogeneity analysis of city characteristics showed that cities with better human capital qualities, stronger local government financial strength, and more advanced financial development levels would obtain greater benefit from the environmental improving effect of this policy. Notably, the environmental improving effect of digital transformation of urban governance would be further amplified in cities with the dual superposition of the Innovative City Pilot Policy and the policy of "National Information City for Public Service". This paper contributed significant referential insights into promoting urban digital transformation and improving urban ecological environment.

Keywords: national information city for public service; digital transformation of city governance; environmental pollution; technological innovation

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1. Introduction

Environment is the foundation of human survival, and a crucial guarantee for the sustainable development of economy and society. However, as an important space for human survival and development, cities are facing serious environmental pollution problems, which is a matter of grave global concern. For China, after nearly 40 years of rapid growth, China's environmental pollution has become increasingly serious, especially in China's cities. In 2014, the ranking of world environmental performance shows that China ranked 118th among 178 countries and regions, which means China's environmental pollution problem is not optimistic. Therefore, how to achieve environmental quality improvement in cities have become the most important issues in green development in China. In recent years, the rapid development and extensive penetration of digital technology have promoted the vigorous development of the digital economy, promoting cities around the world to accelerate the speed of digital transformation. The digital transformation of cities mainly includes digital transformation of economy, life and governance. which provides a new carrier for solving the problems of environmental pollution for Chinese cities. Considering that the traditional urban development model cannot make cities escape the strange circle of pollution curse in China, we cannot help considering whether China can break the chain of city development and environmental pollution by accelerating the application of digital technology to change the urban governance model and promote the innovation and development of urban technology. The analysis of the above issues is of great significance to the improvement of Chinese cities' environmental quality in the digital era. Therefore, these following questions remain to be answered clearly: How does the digital transformation of city governance affect environmental pollution? What are the specific conduction paths that the digital transformation of city governance affects environmental pollution?

Although the scale of digital economy continues to expand, and more and more cities are accelerating the digital transformation, few studies focus on the relationship between digital transformation of city governance and environmental pollution. However, the realization of modernization of the national governance system and governance capacity for the Chinese government needs to investigate the effect of digital transformation of city governance on environmental pollution. Therefore, this paper analyzes the above-mentioned problems from two aspects: theoretical deduction and empirical test. Firstly, this paper analyzed how digital transformation of city governance affects environmental pollution theoretically. Secondly, this paper regards the "National Information City for Public Service" policy as the representative policy of China's digital transformation of urban governance to empirically analyze its impact on urban environmental pollution and the multi-dimensional paths through which the digital transformation of city governance affects environmental pollution using the DID method. Among them, technological innovation effect, industrial structure upgrading effect, resource allocation optimization effect and urban informatization level improvement effect are involved. In this way, this investigation aimed to provide an effective focus for the government to formulate effective environmental policies as well as contribute insights into promoting the green, inclusive and high-quality development of China's economy and society.

The remainder of the paper is organized as follows. Section 2 presents literature reviews. Section 3 is the theoretical analysis about the mechanism of the impact of the "National Information City for Public Service" policy on environmental pollution. Section 4 introduces the model construction and variable selection. Section 5 presents the empirical results and discussions. Section 6 further analyzes the heterogeneity effect for cities with different scales and different characteristics. Section 7 concludes the paper and makes policy recommendations. Section 8 points out the limitations and future research.

2. Literature Review

2.1. The Relationship between Economic Growth and Environmental Pollution

The existing literature has carried out research on the influencing factors of environmental pollution from different angles and has obtained fruitful achievements. The research on the influencing factors of urban environmental pollution was mainly conducted on two aspects. The first one is the relationship between economic growth and various economic activities within the city and environmental pollution. Since the 1990s, scholars have begun to study the relationship between economic growth and environmental pollution. Grossman et al. [1] first made an empirical study based on country panel data and found that there was a significant inverted U-shaped relationship between environmental pollution and per capita income, which was known as the "Environmental Kuznets Curve" (EKC). Subsequently, a lot of literature further worked on the EKC, and most studies believed that the shape of EKC could be quite different due to different countries and different institutional environments. With the increasingly prominent environmental pollution problem in China, studies on China's EKC started begun to emerge. Some scholars used the time series data of a province or city in China to study the relationship between environmental pollution and per capita income [2–4]. Such studies mainly believed that the EKC was applicable to Chinese circumstances. Another scholar conducted empirical research with China's provincial or city-level panel data and found that China's high economic growth did not necessarily lead to high environmental pollution [5]. In addition, some scholars further categorized pollutants and found that the characteristics of EKC between different types of pollutants and economic growth were heterogeneous in China. The characteristics of EKC between sulfur dioxide emissions and economic growth were relatively significant, while there is a significant N-type relationship between industrial waste water emissions and economic growth [6].

2.2. Impact of Various Economic Activities and Governments' City Governance Behaviors on Environmental Pollution

Other scholars put aside the discussion of EKC and analyzed the impact of various economic activities and economic phenomena on environmental pollution, such as investment activities [7,8], international trade [9–11], industrial agglomeration [12,13], industrial structure change [14], etc. As scholars' research went further on economic growth and the relationship between economic activities of various economic entities and environmental pollution, it was found that the improvement of environmental quality was not the endogenous result of economic growth, and the problem of environmental pollution could not be solved automatically in the process of economic growth [6]. Therefore, relevant research began to add government behavior as a variable into the research framework and focused on the impact of governments' various economic and city governance behaviors on environmental pollution, and this approach was arguably another main pathway of the research on environmental pollution influencing factors. Among these factors, the most direct one was the impact of the government's environmental regulation behavior on environmental pollution, which mainly includes the command-controlled environmental regulation policy and the market-incited environmental regulation policy. The command-controlled environmental regulation policy mainly restricted the pollutant discharge behavior of enterprises through strict laws and regulations [15]. Chen et al. [16] found that the increase in the frequency and intensity of environmental punishment could promote the target enterprises to strengthen the level of environmental governance. Moreover, the environmental punishment on the targeted enterprise would also create a deterrent effect on its related upstream and downstream enterprises to promote an increasing investment in their environmental protection funds [17]. However, some studies have found that the separation of environmental administration and environmental justice could easily lead to collusion between local administrative departments and enterprises, resulting in the formalism of environmental pollution governance [18]. Therefore, it was necessary to promote the effective linkage between environmental administration and environmental justice, and the prosecution in terms of the public interest litigation system could be an effective solution to the problems above [19]. The market incentive environmental regulation policy mainly included the emission fee system, tradable licenses, and government subsidies. Compared with the command-control environmental regulation policy, the market incentive environmental regulation policy was more conducive to promoting the enterprise's green technology innovation [20] and internalizing the negative externality characteristics of environmental problems into the enterprise's own cost.

In addition to the research on the most direct government environmental regulation policy, the research on the impact of government governance behavior on environmental pollution was further extended to the impact of competitive behavior among local governments on environmental pollution under the political tournament system in China, such as tax competition [21–23] and fiscal decentralization [24,25]. Furthermore, with the gradual development and evolution of China's urbanization towards urban agglomeration and metropolitan areas, more studies also concentrated on environmental collaborative governance among cities. Based on the data from 30 cities in the Yangtze River Delta, Ma et al. [26] found that there was an urgent need for interprovincial cooperation to fuel the intercity environmental governance. Wu et al. [27] took the cities in the Guangdong–

Hong Kong–Macao Greater Bay Area as the research object and found that the cities in the Guangdong–Hong Kong–Macao Greater Bay Area showed a mutually beneficial cooperative environmental governance model of small circles in the network.

2.3. Impact of Digital Economy on Environmental Pollution

As data are the core production factor of the digital economy, some research focuses on the impact of the application of big data on environmental quality. Etzion et al. [28] proved that the effective allocation of resources brought about by big data is consistent with the direction of sustainable and green development of the environment. Zhang et al. [29] pointed out that the new cleaner production transformation based on big data technology reduced waste water and waste gas that enterprises produced. Ang and Seng [30] summarized the latest developments of big data systems in various representative studies on urban environments, including air pollution monitoring, assistive living, disaster management systems, and intelligent transportation. Zhang et al. [31] constructed a big data driven analytical framework to reduce the energy consumption and emissions for energy-intensive manufacturing industries. Yang et al. [32] proved that big data can affect enterprises' R&D input through "substitution effects" and "complementary effects", which further lead to directed technical change on the impact on the environmental quality.

Then, the research began to turn to the impact of digital economy development on environmental pollution. The development of digital economy promotes the rapid penetration of digital technology in economic, social and other fields, and has a significant impact on the economic operation mode. The development of digital economy can provide strong technical support for environmental governance [33,34]. The development of digital economy can promote the transformation and upgrading of industrial structure [35], stimulate the R&D and innovation vitality of enterprises and promote cleaner production of enterprises [36]. It can also improve the enthusiasm of urban residents to participate in environmental governance by promoting the dissemination of environmental protection information [37]. Although a large amount of research has proven that the development of digital economy can significantly improve environmental quality, the negative impact of the development of digital economy on environmental quality cannot be ignored. Han et al. [38] found that digital economy affects environmental pollution in a nonlinear way. Zhang and Kou [39] proved that the development of digital economy affects the emission of pollution in a U-shaped way.

Based on the research above, the research on the influencing factors of environmental pollution mainly focuses on the relationship between economic growth and environmental pollution, that is, the study on the existence of the environmental Kuznets curve. Secondly, there is some literature that examines the impact of different economic activities and governments' environmental governance behavior on urban environmental pollution. It was arguably true that when studying the impact of government governance behavior on environmental pollution, the aspect of the environmental regulation policy was relatively more focused, and the rest of the research was scattered among various specific governance behaviors of the government. However, there is little research on the effect and mechanism of the overall change of urban governance model and governance concepts on environmental pollution, which left the vacancy for this paper to fill in through in-depth investigation. Thirdly, within the existing literature about the impact of digital economy on environmental pollution, most focus on the positive or negative impact of digital economy development on environmental pollution and its impact mechanism. Less research focus on the impact of digital transformation of urban governance caused by the development of digital economy on urban environmental pollution.

Furthermore, when looking at the environmental pollution caused by the economic behavior of various economic subjects in the city, the government's onefold environmental regulation policy and other scattered governance behaviors did not seem to attain an effective improvement or thorough solution. Hence, the question here is whether it is necessary to fundamentally change the urban governance mode to tackle the long-standing and deeply rooted urban pollution problem?

Urban governance has become an important part of the modernization of the national governance system and governance capacity for the Chinese government, and the wave of digitization has led to all-around changes in the economy and society. As a point for the modernization of the urban governance system and governance capacity, the digital transformation of urban governance has attracted attention nationwide. In 2014, the Chinese government began to implement the national pilot policy of "National Information City for Public Service", which could be regarded as a typical tentative measure for the digital transformation of urban governance in China. On the other hand, it can also be regarded as a natural experiment on the digital transformation of urban governance in China, which provided a valuable opportunity for this paper to investigate the environmental pollution improving effect of the digital transformation of urban governance. Thus, this paper took China's prefecture-level cities as the research object to investigate the impact of the policy of "National Information City for Public Service" on environmental pollution and the impact mechanism between them. The findings would arguably contribute important theoretical significance and practical guiding values for the Chinese government to accelerate the digital transformation of urban governance and the creation of a win–win situation of green and high-quality development under the background of the digital economy era.

The possible contributions of this paper were as follows: ① We used the policy of "National Information City for Public Service" as a representative event of the digital transformation of urban governance to evaluate its impact on environmental pollution, which contributed insights into the literature on the influencing factors of urban environmental pollution; ② this paper systematically discussed the impact mechanism of digital urban governance on environmental pollution, preliminarily constructed the theoretical framework of digital transformation of urban governance on environmental pollution, which enriched the literature on the environmental effects of urban digital governance.

3. Mechanism of the Impact of the "National Information City for Public Service" Policy on Environmental Pollution

Based on the analysis of the background of the policy above, it is arguably true that the construction of "National Information City for Public Service" was the initial attempt of the Chinese government to promote the digital transformation of urban governance. It is the profound reform of urban governance mode based on the application of digital information technology. It also marks the shift of urban development into a digital and intelligent high-level development path. As the representative of the digital transformation of urban governance, the construction of "National Information City for Public Service" will generate the effects on technological innovation, the upgrading of industrial structure, the improvement of resource allocation efficiency, and the improvement of urban informatization level. These four effects are reflected in the impact on urban environmental pollution and the overall reduction of urban environmental pollution levels, which is also the main mechanism for the digital transformation of urban governance to promote the improvement of urban environmental quality. Next, this paper will focus on how to reduce the level of urban environmental pollution through the above four effects.

3.1. The Effect of Technological Innovation

As the primary source of urban environmental pollution, industrial enterprises mainly rely on technological innovation to reduce pollution [40]. As the practice of the "National Information City for Public Service" policy released the need for various digital products and services, the demand can promote the agglomeration of technology-intensive and new materials industries. Hence, the agglomeration of high-tech industries, such as information technology, and new materials will further promote the agglomeration of innovative elements, such as information technology talents and innovative capital in the cities [41]. It can be inferred that the practice of such policy mainly reduces urban environmental pollution through the effect of technological innovation in the following two ways. Firstly, implementing this policy improves the digital and intelligence levels of urban environmental governance through technological innovation and effectively reduces urban environmental pollution. Furthermore, by using the latest digital technology to build a digital public service platform to enhance business sharing and data collaboration among different government departments, the government can massively improve the monitoring of pollutant emissions of high-polluting enterprises. This advantage will enable the government to introduce targeted measures for these enterprises and improve the government's urban environmental pollution control effectiveness. Secondly, the implementation of such a policy will force enterprises to improve resource utilization efficiency and reduce pollutant emissions through technological innovation.

On the one hand, by strengthening the accurate and dynamic monitoring of polluting enterprises, the practice of this policy will form administrational pressure and external constraints on these enterprises, which will increase the intention for enterprises to develop green production technology, seek cleaner production energy, and improve the efficiency of the production in terms of resource utilization efficiency and less pollutant emission levels [42]. On the other hand, the implementation of this policy will further help the agglomeration of various innovative factors, provide a more abundant factor endowment, and create a more friendly environment for enterprises' technological innovation. Such benefits will enable enterprises to promote the popularization and application of green production as well as pollutant discharge technology through technological innovation. In this way, the policy facilitates resource utilization efficiency and reduces pollutant emissions in the production process. Therefore, we can propose the following proposition:

Proposition 1. *The digital transformation of urban governance can reduce the level of urban environmental pollution through the effect of technological innovation.*

3.2. Resource Allocation Optimization Effect

The optimization effect of resource allocation can mainly be reflected in the structural flow, allocation of resources, and the resource utilization efficiency of enterprises. According to the existing research literature, China's high pollution and high energy consumption industries are significantly over-invested [43]. The main reason is that local governments use administrative means to protect enterprises with high pollution, high energy consumption, and low efficiency from being eliminated to ensure local employment and the realization of economic development goals, resulting in difficulties in withdrawing factors from the low efficiency and high pollution market subjects. At the same time, it also prevents the factors from flowing to more efficient industries and market subjects, which reduces the efficiency of resource allocation and becomes a major cause of urban environmental pollution [44]. The construction of the "National Information City for Public Service" policy releases a huge demand for the products and services from information technology manufacturing, service industry, and new material industry. This signal is conducive to stimulating the development of the mentioned technology-intensive industries with low pollution and low energy consumption, which promotes the flow of various factors to these industries. It will ultimately lead to the increase in these emerging technology-intensive industries' proportions in the economy and reduces urban environmental pollution. Secondly, in terms of resource utilization efficiency, the development of emerging technology-intensive industries, such as information technology, new materials, and new energy, is also conducive to encouraging local high-polluting enterprises to further apply digital and intelligent technology in production and marketing. Through the use of digital technology, companies can internally optimize production processes and production plans and keep abreast of the new trends in market demand, which can finally improve resource utilization efficiency, reduce energy consumption per unit output, and reduce the emission levels of various pollutants. Thus, proposition 2 can be introduced:

Proposition 2. *The digital transformation of urban governance can reduce the level of urban environmental pollution through the optimization effect of resource allocation.*

3.3. Industrial Structure Upgrading Effect

On the basis of promoting the structural flow and allocation of factors in "National Information City for Public Service", we can also continue to find an extended conclusion, that is, such optimization effects of resource allocation can promote the flow of factors to the emerging technology-intensive industries, such as information technology, new materials, and new energy, hence expanding the industry scale and the proportion in economy. On the other hand, high pollution and high energy consumption industries will be relatively reduced, eventually promoting the upgrading of industrial structures [45]. In addition, implementing "National Information City for Public Service" will also promote the traditional industries with high pollution and energy consumption to accelerate technological renewal and iteration. By improving their production efficiency through the application of information, digital, and intelligent technologies, these companies will ultimately accelerate the speed of transformation from traditional industries to emerging industries to realize an all-around upgrade. Finally, the implementation of "National Information City for Public Service" will also promote the dynamic replacement efficiency of enterprises [40] so that traditional high-polluting enterprises unable to carry out transformation and upgrading will withdraw from the market. Such an effect will improve the industrial structure [46], show a continuous upgrading trend, and ensure that all kinds of economic entities in the market align with the industry's technical future development. As a result, the effect will lead to high production efficiency, finally reducing energy consumption and pollutant emission levels. Based on this, the analysis can continue to obtain proposition 3:

Proposition 3. *The digital transformation of urban governance can promote the flow of factors to emerging technology-intensive industries and increase the proportion of emerging technology-intensive industries. At the same time, by strengthening the dynamic replacement efficiency of market subjects, the rule of "survival of the fittest" eliminates the subjects of high pollution and high energy consumption industries, which can reduce the level of urban environmental pollution.*

3.4. Promotion Effect of Informatization Level

Zheng et al. [47] believe that the public's environmental concern and participation can effectively encourage the government to pay more attention to local environmental pollution supervision and governance, hence improving local environmental quality by promoting the government and enterprises to increase investment and optimize industrial structure The "National Information City for Public Service" implementation aims to promote the equalization of government public services by means of informatization, digitization, and intelligence. One essential measure is building a unified information platform to achieve full crowd coverage, full-time acceptance, and "one-stop" handling of public services, which will undoubtedly bring greater convenience to public participation in environmental governance. Through the construction of government affairs informatization platforms, the cities can improve the overall informatization level and encourage public participation in environmental governance by means of more efficient and convenient information government acceptance channels to form a practical supervision effect on the government's environmental governance behavior, which can effectively elevate the government's perceptivity to environmental pollution and strengthen environmental governance [48]. In addition, the improvement of the urban informatization level also enables the government to form the dynamic supervision for high-polluting enterprises at a lower cost, which arguably facilitates the efficiency of the government in environmental pollution control [49]. Based on these ideas, this paper puts forward the following proposition:

Proposition 4. *The digital transformation of urban governance can improve the level of urban informatization, strengthen the level of public participation in environmental governance, and* *improve the efficiency and attention of the government in environmental pollution control, which can finally reduce urban environmental pollution.*

4. Model Construction and Variable Selection

4.1. Model Construction

The Chinese National Development and Reform Commission and 12 other departments jointly issued The Notice on Approving 80 Cities Including Shenzhen to Build National Information City for Public Service on 23 June 2014. The primary interest of this attempt was to lay the foundation for the full policy implementation in the future, and the key concerns were the explorations of promoting further administrational and informational integrations within the local governments, digitalizing and optimizing the allocation of public resources, and upgrading the governmental social management and public service mechanism under the framework of this policy. The outcome of these concerns would be applied to expand the coverage of existing public service for people to access any service at any time, particularly linked to the ongoing projects of social insurance, health and medical service, and old-age community supports. It can be inferred that the key measure of this policy is to promote the informatization, digitization, and intelligence level of government public services and urban governance capability through the use of information and digital technology, hence achieving the goal of improving the efficiency of urban governance and the equalization of public services. The establishment of "National Information City for Public Service" can be regarded as the initial attempt of the Chinese government to carry out digital transformation in the field of urban governance. With the continuous deepening of the construction of the "National Information City for Public Service" policy, it is foreseeable that it will have a profound impact on many fields of China's economic and social development.

This investigation took the pilot policy of "National Information City for Public Service" as a natural experiment. It used the difference-in-differences (DID) method to test the effect on environmental governance from the implementation of "National Information City for Public Service", which stood for the digital transformation of urban governance in China. According to the construction idea of the difference-in-differences model, we firstly took pilot cities of the "National Information City for Public Service" policy as the experimental group and the other cities as the control group. If the city was a pilot city, we set the policy dummy variable equal to 1; otherwise, it was equal to 0. Secondly, we set the policy time dummy variable. When the sample was in 2015 and later, the dummy variable of policy time was equal to 1; otherwise, it was equal to 0. Based on the data processing process above, we set the model based on the difference-in-differences method as follows:

$$Pollution_{it} = \alpha_0 + \alpha_1 treat_i * post_t + \gamma X_{it} + \delta_t + \varepsilon_{it} \quad (1)$$

$Pollution_{it}$ represents the urban pollutant emission level of city i in year t. Based on the research of Shi et al. [40], we select urban waste water (ww) emissions and waste gas (wg) emissions to measure the urban environmental pollution level, $treat_i * post_t$ as the multiplication term of the dummy variable of "National Information City for Public Service" and the policy time dummy variable, and its regression coefficient α_1 was the impact of the digital transformation of urban governance on urban environmental pollution. δ_t is the time fixed effect, ε_{it} is the error term.

X_{it} stands for a series of control variables. Referring to the selection methods of control variables in previous research literature, the selected the control variables in this paper mainly include:

Urbanization rate: the urbanization rate is expressed by the proportion of non-agricultural population in the total population. The relationship between urbanization level and urban environmental pollution has been confirmed by much research literature. Martinez-Zarzoso [50] found that there was a significant inverted U-shaped relationship between urbanization level and carbon emissions. Peng et al. [51] found that there was a double threshold effect between urbanization level and air pollution. In addition, the inverted N-type relationship between urbanization and environmental pollution level has also been found in the literature [52].

Financial development level: the financial development level is expressed by the ratio of urban deposit and loan balance to GDP. The level of financial development can significantly impact environmental pollution from multiple channels and mechanisms. On the one hand, financial development reduces environmental pollution by providing financial support for enterprises' technological innovation to achieve energy conservation and emission reduction [53]. However, on the other hand, financial development can also make it easier for polluting enterprises to obtain external financing to expand the production scale, thus aggravating environmental pollution [54].

Infrastructure construction: the level of infrastructure construction is expressed by the mileage of roads per square kilometer of the city. The upgrade of transportation infrastructure has significant economic effects, including the site selection of high-polluting enterprises [55], hence affecting the number and agglomeration level of local high-polluting enterprises to determine local environmental pollution levels. In addition, upgrading transportation infrastructure will intensify the transfer of factors from the secondary industry to the tertiary industry, which enhances the mechanism of eliminating outdated production capacity and promotes the upgrading of industrial structures to reduce environmental pollution [56].

Opening degree: the degree of opening to the outside world, expressed in terms of the proportion of the city's total imports and exports to the city's GDP. The existing literature on the relationship between foreign trade and environmental pollution has not reached a consistent conclusion. Some scholars' research conclusions support the "trade harm theory," [57] and believe that the expansion of foreign trade will aggravate environmental pollution through the "pollution shelter" effect. Other scholars hold the "beneficial trade theory" and their research believes that foreign trade development is beneficial to the introduction of advanced technology, improving resource utilization efficiency, and then achieving energy conservation and emission reduction [58].

Foreign direct investment: foreign direct investment is expressed by the proportion of foreign direct investment in the city's GDP. As for the impact of foreign direct investment on the environmental pollution of the host country, the academic circles mainly have the "Pollution Haven" hypothesis [59,60], which agrees that foreign direct investment will aggravate the environmental pollution of the host country. Another hypothesis is the "Pollution Halo" hypothesis [61], which means foreign direct investment will improve the environmental quality of the host country or support the "N" type nonlinear relationship between foreign direct investment and environmental pollution in the host country [62].

4.2. Data

The data used in this paper are from the *China Urban Statistical Yearbook* from 2004 to 2017, and the data interval is from 2003 to 2016. In view of the lack of data in some years and some prefecture-level cities, we use interpolation [46] to supplement, and finally obtain, the panel data of 277 prefecture level cities in 14 years. The descriptive statistics of variables are shown in Table 1.

According to the statistical results of variables, Table 2 shows the different test results of environmental pollution variables between the experimental group and the control group. It can be seen from Table 2 that the average value of waste water and waste gas emissions of urban samples in the experimental group has decreased significantly after the implementation of the "National Information City for Public Service" policy, which preliminarily shows that the digital transformation of urban governance represented by the construction of "National Information City for Public Service" can significantly reduce the level of urban environmental pollution. The average value of waste water and waste gas emissions of the urban samples in the control group also decreased significantly after the implementation of the "National Information City for Public Service" policy, but the decline range is lower than that of the urban samples in the experimental group, which shows the rationality of using the difference-in-differences model in this paper. Based on this, we mainly use the difference-in-differences method to quantitatively evaluate the policy effect of "National Information City for Public Service". In addition, taking into account the possible problem of sample selection bias caused by non-randomness, we continue to use the difference-in-differences method of propensity score matching to test the robustness of the difference-in-differences method so as to ensure the objectivity and accuracy of the research conclusion in this paper.

Table 1. Descriptive statistics of main variables.

Variable Meaning	Variable Symbol	N	Mean Value	Standard Deviation	Minimum	Maximum
Total factor productivity	*tfp*	3870	2.8214	0.6361	1.1014	4.5532
Industrial structure upgrading	*ind*	3870	0.1885	0.5639	−1.1436	1.6134
Opening degree	*lnopen*	3870	−2.5762	1.5420	−11.6463	2.0398
Infrastructure construction	*inf*	3870	3.1977	0.6114	0.4454	6.3986
Urbanization rate	*lnurb*	3870	3.4855	0.5353	2.5150	4.4872
Financial development	*lnrfe*	3870	0.6049	0.3724	−0.5798	1.9279
Waste gas emission	*wg*	3870	0.0556	0.0483	0.0000	0.4964
Waste water emission	*ww*	3870	0.0711	0.0880	0.0001	0.9126
Innovation performance	*inno*	3870	0.8252	0.9669	0.0000	6.3641
Human capital	*hc*	3870	147.1632	213.6936	0.0000	3282.5720
Financial pressure	*fp*	3870	0.0490	1.1535	−7.1144	2.8564
Foreign direct investment	*lnfdi*	3870	0.8940	0.6112	0.0000	3.6527
Informatization level	*lninf*	3870	1.1025	1.2641	0.0006	15.1815

Table 2. Test results of variable difference.

Variables	Groups	Number of Samples before Policy	Mean Value before Policy	Number of Samples after Policy	Mean Value after Policy	Difference Test
ww	Control group	2518	63.212	665	50.757	12.455 ***
wg	Control group	2518	54.507	665	39.625	14.881 ***
ww	Experimental group	547	123.327	143	104.997	18.331 *
wg	Experimental group	547	80.332	143	52.72	27.611 ***

Notes: t-value in parentheses. * denotes $p < 0.1$, and *** $p < 0.01$.

5. Empirical Results

5.1. The Impact of the Construction of "National Information City for Public Service" on Environmental Pollution

As a major step in the transformation of digital city governance and pushing forward the implementation of "National Information City for Public Service", we will explore new mechanisms and models to optimize the allocation of public resources and make innovations in social management and public services by accelerating the improvement of the level of public services and equality and universality. Improving the level of urban informatization, the efficiency of urban resource allocation, and stimulating the vitality of urban technological innovation, thus provides material and technical guarantees for the control of urban environmental pollution by accelerating the digital transformation of urban governance. Therefore, the development of "National Information City for Public Service" provides a natural experiment for this paper to study the environmental governance effect of the digital transformation of urban governance. We will use the difference-in-differences (DID) method to evaluate the impact of "National Information City for Public Service" on environmental pollution.

In Table 3, columns 1 and 2 are the empirical models without control variables, and columns 3 and 4 are the empirical models with control variables to investigate the impact of the construction of "National Information City for Public Service" on urban waste water and waste gas emissions. The estimation results in Table 3 show that no matter whether the control variable is included or not, the implementation of "National Information City for Public Service" negatively impacts urban waste gas and water emissions. The estimation coefficients are significant, at least at the significance level of 10%, indicating that the construction of "National Information City for Public Service" does reduce urban environmental pollution and has a significant environmental improving effect. Moreover, "National Information City for Public Service" has significantly reduced the waste water emissions by an average of 1.65% and the waste gas emissions by an average of 2.11%.

Table 3. The impact of the construction of "National Information City for Public Service" on environmental pollution.

Explained Variable	*ww*	*wg*	*ww*	*wg*
Method	DID	DID	DID	DID
Treat × Post	−0.0072 * (−1.89)	−0.0137 *** (−6.49)	−0.0165 *** (−4.53)	−0.0211 *** (−10.14)
Controlled variable	NO	NO	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.0740	0.1989	0.0211	0.1095
N	3873	3873	3870	3870

Notes: *t*-value in parentheses. * denotes $p < 0.1$, and *** $p < 0.01$.

5.2. Robustness Test Based on PSM-DID Method

In order to effectively solve the selection bias of the "National Information City for Public Service" policy and effectively avoid the systematic difference in the trend of environmental pollution variables between cities of the experimental group and cities of the control group, we continue to use the PSM-DID method to reselect the samples of the control group so that the samples of the control group and the experimental group can be directly compared and analyzed. In this paper, the probit model is mainly used to estimate the propensity score of experimental group variables and control group variables, and finally identify the samples of cities in the control group similar to cities in the experimental group. Therefore, probit model is set as follows:

$$XXHM_{i,t} = \alpha_0 + \gamma X_{i,t} + Year + \varepsilon_{i,t} \quad (2)$$

$XXHM_{i,t}$ refers to the dummy variable of "National Information City for Public Service". If it is "National Information City for Public Service", then $XXHM_{i,t}$ = 1; if it is not "National Information City for Public Service", then $XXHM_{i,t}$ = 0. $X_{i,t}$ is a series of control variables. This paper mainly selects the opening degree (*lnopen*), infrastructure construction (*lninf*), financial development (lnrfe), urbanization rate (*lnurb*) and foreign direct investment (*lnfdi*) variables for probit regression and propensity matching score.

Before propensity score matching, the sample data need to meet the "overlapping assumption", that is, the propensity scores of the samples of the control group and the experimental group have values in common. As seen from Figure 1, the common value of the experimental group and the control group's sample propensity scores is significant, and most sample propensity scores are within the common value range. After propensity score matching, Figure 2 showed that the standardization deviation of most variables has been significantly reduced. It is arguably true that the propensity score matching method adopted in this paper has well eliminated the problem of sample selection bias. The density curves of the two groups of urban samples before and after propensity score matching can be seen in Figure 3. Before propensity score matching, there is a large bias in the propensity score density curves between the experimental group and the control group samples. After propensity score matching, the propensity score probability density curves of the two groups are very similar, indicating that propensity score matching eliminates most of the selection bias.

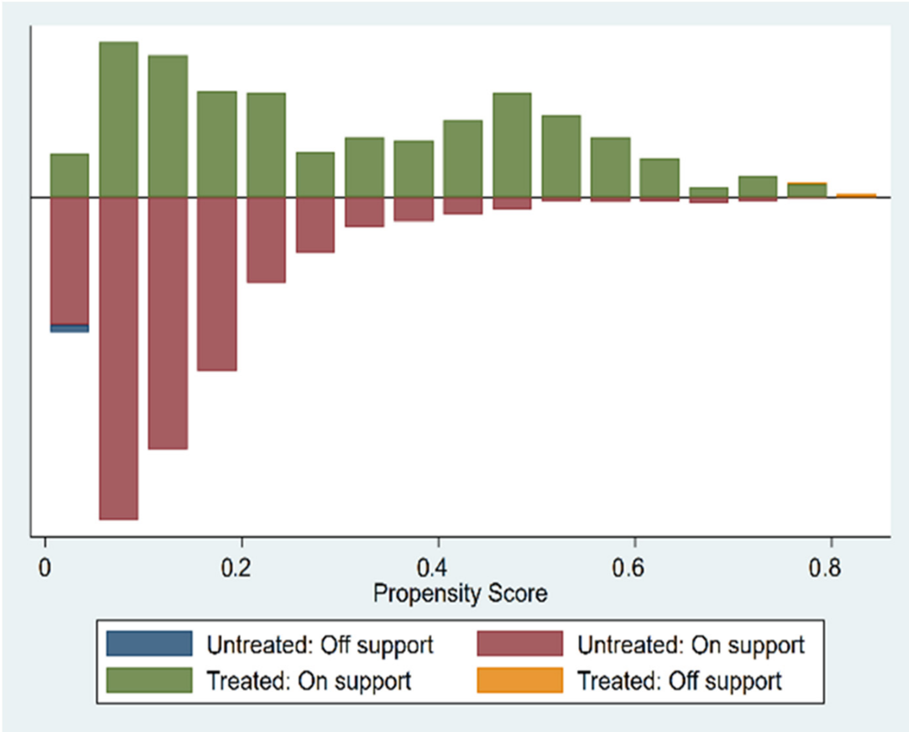

Figure 1. Common value range of propensity score.

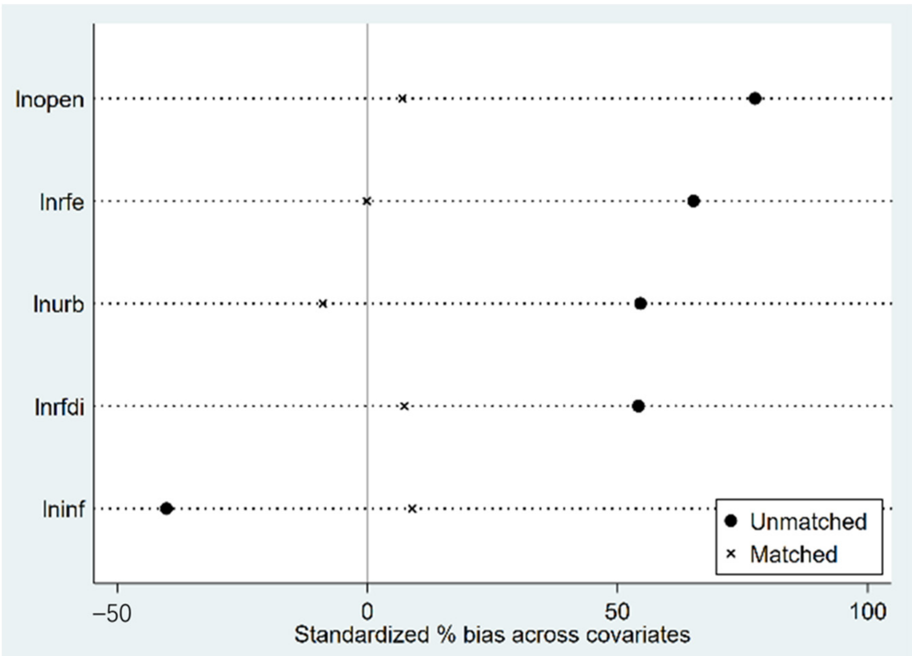

Figure 2. Diagram of standardized bias of each variable.

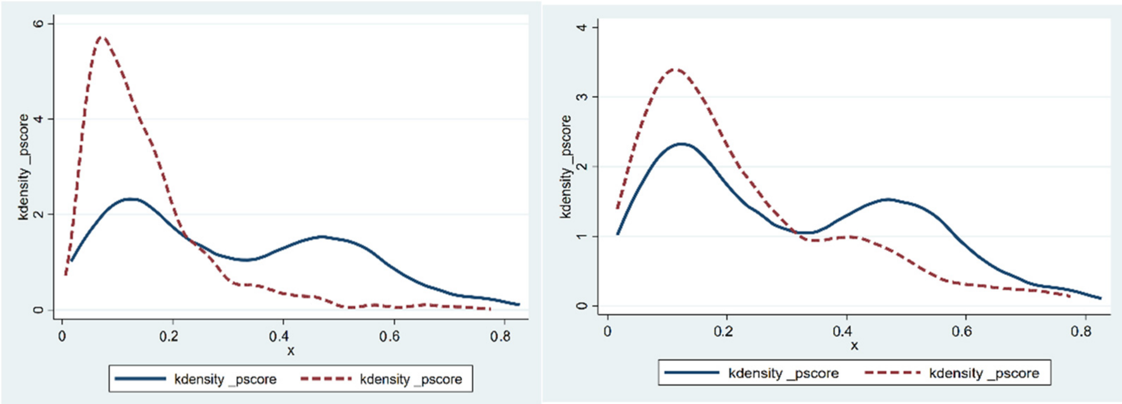

Figure 3. Density before and after propensity score matching.

The results in Table 4 show that by using the PSM-DID method, the "National Information City for Public Service" policy can still significantly reduce urban environmental pollution. The implementation of "National Information City for Public Service" has reduced the urban waste water emissions by 0.71% and the waste gas emissions by 1.35%. There is no significant difference between the empirical results under the PSM-DID method and the empirical results of the above DID method. This further effectively supports the research conclusion that the "National Information City for Public Service" policy is conducive to reducing urban environmental pollution.

Table 4. The impact of the policy of "National Information City for Public Service" on environmental pollution: robustness test by using PSM-DID method.

Explained Variable	*ww*	*wg*	*ww*	*wg*
Method	PSM-DID	PSM-DID	PSM-DID	PSM-DID
Treat × Post	−0.0076 ** (−1.99)	−0.0136 *** (−6.43)	−0.0071 * (−1.86)	−0.0135 *** (−6.39)
Controlled variable	NO	NO	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.0651	0.1958	0.1115	0.2055
N	3870	3870	3870	3870

Notes: *t*-value in parentheses. * denotes $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$.

5.3. Robustness Test by Excluding Smart City Samples

China officially issued the *Notice on Carrying Out the National Smart City Pilot Work* in 2012 to start the construction of China's smart city. The concepts of smart city and "National Information City for Public Service" both emphasize the use of digital and information technology to change the traditional urban development mode and improve the quality of urban operation and development. Among them, the definition of a smart city is to embed all kinds of smart sensors into buildings, power grids, roads, bridges, water supply systems, dams and other facilities to dynamically sense the key information in the operations of core city systems, such as business, transportation, communication, water and energy. Then, the cloud computing and supercomputer are used to analyze and integrate the big data resources generated in urban operations for the dynamic and optimal allocation of urban resources [40]. Referring to the concept of a smart city, it also includes the informatization and digital transformation of urban infrastructure, urban economic activities, and the urban government services. Notably, the implementation of "National Information City for Public Service" focuses more on the digital transformation of urban governance, which mainly emphasizes the need to realize administration collaboration and information sharing among different departments in the government based on unified public service information platforms. The gradual realization of the full population coverage of public and social information services will enable the government to improve the public service and social management ability. Therefore, the practice of "National Information City for Public Service" can better represent the digital transformation of urban governance. However, considering the overlap between the smart city pilot policy and the "National Information City for Public Service" policy in the domains of implementation time and policy content, the smart city policy may become a confounding variable to the conclusions of the investigation. Therefore, this paper chooses to delete the smart city samples and reconducts DID regression to verify the robustness of the research conclusions of this paper.

Table 5 shows the impact of the implementation of the "National Information City for Public Service" policy on urban environmental pollution after deleting the smart city samples. As demonstrated in Table 5, after excluding the exogenous interference of the smart city construction pilot policy, the implementation of the policy still has a significant negative impact on urban waste water emissions and waste gas emissions. Such policy implementation can reduce 0.85% of waste water emissions and 1.59% of waste gas emissions, which further supports the research conclusion.

Table 5. The impact of the construction of "National Information City for Public Service" on environmental pollution: robustness test by excluding smart city samples.

Explained Variable	*ww*	*wg*	*ww*	*wg*
Method	DID	DID	DID	DID
Treat × Post	−0.0084 ** (−1.99)	−0.0157 *** (−6.90)	−0.0085 ** (−1.98)	−0.0159 *** (−6.97)
Controlled variable	NO	NO	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.0802	0.1836	0.0778	0.1931
N	3406	3406	3406	3406

Notes: *t*-value in parentheses. * denotes ** $p < 0.05$, and *** $p < 0.01$.

5.4. Mechanism Test of the Construction of "National Information City for Public Service" Affecting Urban Environmental Pollution

From the above empirical results, it can be seen that the construction of the "National Information City for Public Service" policy can significantly reduce urban environmental pollution. Hence, it is reasonable to look at the impact mechanisms of the "National Information City for Public Service" policy on reducing urban environmental pollution. As mentioned in the second part of this paper, the construction of the "National Information City for Public Service" policy mainly reduces urban environmental pollution through the technological innovation effect, industrial structure upgrading effect, resource allocation optimization effect, and urban informatization level upgrading effect. In order to verify the above impact mechanism, we use the stepwise regression method to empirically test the intermediary effect and impact mechanism of such policy implementation on environmental pollution. The mediating model is set as follows:

$$pollu_{it} = \alpha + \beta treat_i * post_t + \gamma X_{it} + u_i + v_t + \varepsilon_{it} \tag{3}$$

$$pollu_{it} = \alpha + \beta treat_i * post_t + \delta innov_{it}(ind \,\&\, tfp \,\&\, infor) + \gamma X_{it} + u_i + v_t + \varepsilon_{it} \tag{4}$$

$$innov_{it}(ind \,\&\, tfp \,\&\, infor) = \alpha + \beta treat_i * post_t + \gamma X_{it} + u_i + v_t + \varepsilon_{it} \tag{5}$$

The explained variable is the environmental pollution variable (*pollu*), the core explanatory variable is the pilot policy variable of "National Information City for Public Service" ($treat_i * post_t$), and the intermediary variables are the resource allocation efficiency variable (*tfp*), the industrial structure variable (*ind*), the information level variable (*infor*), and the technological innovation variable (*innov*). Among them, the resource allocation efficiency variable is expressed by the urban total factor productivity. The higher the urban total factor productivity, the higher the efficiency of resource allocation in this city. The industrial structure variable is expressed by the ratio of the output of the tertiary industry to the output of the secondary industry. The higher the variable value, the higher the level of industrial structure upgrading. The informatization level variable is expressed by the number of internet users per 10,000 people. The technological innovation variable is expressed by the number of patents per capita. In model (5), the coefficient of $treat_i * post_t$ is expected to be positive, indicating that the policy implementation does have the above four effects. The coefficient of the above intermediary variables in model (4) is expected to be negative, indicating that the policy implementation can reduce the urban environmental pollution by promoting technological innovation, industrial structure upgrading, resource allocation efficiency improvement, and urban informatization level. If the impact of the pilot policy of "National Information City for Public Service" on environmental pollution is mainly produced through the above intermediary mechanism, it should meet the following requirements: firstly, the pilot policy variable of "National Information City for Public Service" has a negative and significant impact on the environmental pollution variables in model (3); secondly, the pilot policy variables of "National Information City for Public Service" have a positive and significant impact on the intermediary variables in model (5); finally, in model (4), the intermediary variable has a negative significant impact on the environmental pollution variable. Moreover, after the introduction of the intermediary variable, the coefficient of pilot policy variable should change from negative and significant in Equation (3) into non-significant in Equation (4), or the coefficient of pilot policy variable is still negative and significant, but its absolute value decreases.

Table 6 shows that the regression coefficients of the pilot policy variable on the above four effects are significantly positive, indicating that the implementation of the "National Information City for Public Service" policy has a positive impact on the above four effects. This empirical result is consistent with the previous theoretical analysis results. When regressing the above four intermediary effect variables and pilot policy variables with the urban waste gas emissions and waste water emissions, the regression results show that the four intermediary effect variables have significantly reduced the urban waste water emissions and waste gas emissions. When the pilot policy variable regresses with the industrial structure upgrading variable, resource allocation efficiency improvement variable, and informatization level improvement variable, the effect of the pilot policy variable on reducing urban environmental pollution is still significant, but the absolute value of its coefficient decreases. When we take the pilot policy variable to regress with the technological innovation variable, the coefficient of the pilot policy variable on urban waste water emissions is no longer significant. The inhibitory effect on urban exhaust emissions is still significant, but the absolute value of the coefficient decreases. This empirical result confirms that the construction of the "National Information City for Public Service" policy can reduce urban environmental pollution through the above four mechanisms.

Table 6. Empirical regression results of the above 4 intermediary effects.

	Model	**(3)**	**(4)**	**(5)**	**(3)**	**(4)**
	Explained variable	*ww*	*ww*	*Innov*	*wg*	*wg*
Technological Innovation Effect	Treat × Post	−0.0165 *** (−4.53)	−0.0049 (−1.27)	0.9656 *** (23.50)	−0.0211 *** (−10.14)	−0.0119 *** (−5.41)
	Innov		−0.0120 *** (−8.18)			−0.0095 *** (−11.49)
	Controlled variable	YES	YES	YES	YES	YES
	Time fixed effect	YES	YES	YES	YES	YES
	Adjusted R^2	0.0211	0.2534	0.5162	0.1095	0.1412
	N	3870	3870	3870	3870	3870

Table 6. *Cont.*

	Model	(3)	(4)	(5)	(3)	(4)
Upgrading Effect of Industrial Structure	Explained variable	*ww*	*ww*	*Ind*	*wg*	*wg*
	Treat × Post	−0.0165 *** (−4.53)	−0.0159 *** (−4.39)	0.0567 *** (2.88)	−0.0211 *** (−10.14)	−0.0205 *** (−9.89)
	Ind		−0.0093 *** (−3.00)			−0.0104 *** (−5.93)
	Controlled variable	YES	YES	YES	YES	YES
	Time fixed effect	YES	YES	YES	YES	YES
	Adjusted R^2	0.0211	0.0236	0.1870	0.1095	0.1182
	N	3870	3870	3870	3870	3870
Improvement Effect of Resource Allocation Efficiency	**Model**	**(3)**	**(4)**	**(5)**	**(3)**	**(4)**
	Explained variable	*ww*	*ww*	*Tfp*	*wg*	*wg*
	Treat × Post	−0.0165 *** (−4.53)	−0.0125 *** (−3.35)	0.0111 *** (3.64)	−0.0211 *** (−10.14)	−0.0183 *** (−8.58)
	tfp		−0.6258 *** (−4.46)			−0.4404 *** (−5.49)
	Controlled variable	YES	YES	YES	YES	YES
	Time fixed effect	YES	YES	YES	YES	YES
	Adjusted R^2	0.0211	0.3565	0.5818	0.1095	0.2146
	N	3870	3870	3870	3870	3870
Promotion Effect of City's Informatization Level	**Model**	**(3)**	**(4)**	**(5)**	**(3)**	**(4)**
	Explained variable	*ww*	*ww*	*Infor*	*wg*	*wg*
	Treat × Post	−0.0165 *** (−4.53)	−0.0070 * (−1.80)	0.3453 *** (5.53)	−0.0125 *** (−5.86)	−0.0183 *** (−8.58)
	Infor		−0.0034 *** (−3.31)		−0.0030 *** (−5.32)	−0.4404 *** (−5.49)
	Controlled variable	YES	YES	YES	YES	YES
	Time fixed effect	YES	YES	YES	YES	YES
	Adjusted R^2	0.0211	0.0565	0.5098	0.2149	0.2146
	N	3870	3870	3870	3870	3870

Notes: *t*-value in parentheses. * denotes $p < 0.1$, and *** $p < 0.01$.

6. Heterogeneity Analysis

6.1. Heterogeneity Analysis of Different Urban Scales

Apart from the above conclusion, it is also reasonable to examine whether the city scale serves as a variable that impacts the conclusion. Large cities always have a higher level of economic agglomeration, more effective resource allocation, and better utilization efficiency, which make it easier to have a salient economic agglomeration effect. At the same time, in the process of continuous expansion of urban scale, it is also easy to have a series of urban problems that lead to an urban congestion effect. The entire process of urban development is likely to experience the above two effects, and the strength of the two effects depends on the effectiveness of the governance mechanism and governance pattern in urban development. By building an efficient public service information system, innovating the urban governance model, and improving the efficiency of urban governance, the practice of "National Information City for Public Service" can eliminate these problems. Therefore, it not only weakens the crowding effect in the process of urban scale expansion but also strengthens its economic agglomeration effect. According to the above analysis, the environmental governance effect of such policy implementation is likely to be different with respect to the city scale. Thus, we divide the urban samples into large, medium-sized, and small cities based on the urban population scale. The regression results are shown in Table 6.

Table 7 shows that the implementation of the "National Information City for Public Service" policy has a significant inhibitory effect on the waste water emissions of large and medium-sized cities, and the regression coefficient to waste water emissions of small cities is positive but not significant. In terms of the absolute value of the regression coefficient, the impact of such policy on waste water emissions increases with the expansion of the urban scale. From the perspective of waste gas emissions, the practice of such policy has a significant inhibitory effect on the waste gas emissions of large, medium, and small cities. The inhibitory effect of the waste gas emissions of medium-sized cities is slightly bigger than that of large cities, and that of small cities is the weakest. This conclusion, to a great extent, confirms the conclusion that the there is a positive relationship between the city scale and the environmental pollution improving effect of the construction of "National Information City for Public Service".

Table 7. Heterogeneity analysis based on different city scales.

Explained Variable		*ww*			*wg*	
City types	Large cities	Medium-sized cities	Small cities	Large cities	Medium-sized cities	Small cities
Treat × Post	−0.0298 *** (−5.43)	−0.0167 ** (−2.15)	0.0008 (0.12)	−0.0206 *** (−5.89)	−0.0214 *** (−4.69)	−0.0163 *** (−4.91)
Controlled variable	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.0947	0.0667	0.0931	0.1647	0.0844	0.0934
N	1255	1116	1494	1255	1116	1494

Notes: *t*-value in parentheses. * denotes ** $p < 0.05$, and *** $p < 0.01$.

6.2. Heterogeneity Analysis of City Characteristics

The construction of "National Information City for Public Service" requires the local government to build a public information service platform to promote the sharing and equalization of public service information. At the same time, it also needs to launch inclusive information-based public service products for different public service scenarios, which requires the local government to invest a lot of human capital, material, financial, and technical resources to provide systematic support. Therefore, the abundance of various urban factor endowments has an important impact on the outcome of the "National Information City for Public Service" policy and the improving effect of urban environmental pollution. Thus, this paper will continue to examine the heterogeneity of environmental pollution improving effects of cities with different characteristics in the process of building "National Information City for Public Service" from the perspective of urban human capital level, government financial pressure level, financial development level, and whether they are innovative cities. In the empirical test process, we select the number of college students per 10,000 people to represent the level of urban human capital, the proportion of government fiscal deficit in GDP to measure the level of local government financial pressure, and the proportion of deposit and loan balance of financial institutions in GDP to measure the level of urban financial development. In addition, this paper also divides the urban samples into innovative and non-innovative cities based on whether they are selected as pilot innovative cities to measure the technological innovation ability of cities. We bisect the other characteristic variables mentioned above based on their sample median and divide the urban samples into cities with high and low human capital, cities with high and low financial pressure, and cities with high-level and low-level financial development.

In Table 8, the empirical results show that the "National Information City for Public Service" policy has a significant inhibitory effect on the waste water and waste gas emissions of cities with a high level of human capital. For cities with low human capital, the practice of such policy has no significant impact on their waste water emissions. The impact coefficient on the waste gas emissions is lower than that of cities with a high level of human capital in terms of the coefficient's absolute value and significance level. This result shows that human capital plays an important supporting role in the digital transformation of urban governance. While effectively supporting the work of the construction of "National Information City for Public Service", human capital can significantly improve its improving effect on urban environmental pollution. This is because the more abundant the labor with higher education level, the more knowledge and technologies they master, therefore the more effective they are in supporting the design and construction of different information infrastructures in cities. In addition, since the "National Information City for Public Service" policy focuses on improving the quality and equalization of public services, the government needs to take the lead in investing resources in building various public service information platforms and purchasing various digital products and services from society. Notably, those measures mentioned above must be supported by the financial strength of the local government. The empirical results show that the environmental pollution improving effect of such policy in low financial pressure cities is higher than that in high financial pressure cities. On the one hand, this is because cities with high financial pressure will focus more on local economic growth, and they find it easy to take an inclusive and cautious attitude towards local environmental pollution. On the other hand, due to the lack of financial resources in cities with high financial pressure, the effect of such policy is likely to be greatly reduced.

Table 8. Heterogeneity analysis based on the characteristics of urban human capital and financial pressure.

Explained Variable	*ww*		*ww*	
City types	Cities with high human capital	Cities with low human capital	Cities with greater financial pressure	Cities with less financial pressure
Treat × Post	−0.0193 *** (−3.97)	−0.0015 (−0.17)	−0.0022 (−0.39)	−0.0239 *** (−4.54)
Controlled variable	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.0419	0.0591	0.0875	0.0266
N	1935	1935	1935	1935
Explained variable	*wg*		*wg*	
City types	Cities with high human capital	Cities with low human capital	Cities with greater financial pressure	Cities with less financial pressure
Treat × Post	−0.0218 *** (−9.23)	−0.0132 ** (−2.19)	−0.0147 *** (−4.03)	−0.0229 *** (−8.38)
Controlled variable	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.1787	0.0604	0.1170	0.2337
N	1935	1935	1935	1935

Notes: *t*-value in parentheses. * denotes ** $p < 0.05$, and *** $p < 0.01$.

In addition to the financial situation of the government, the development of the local financial system also directly affects the financial support level this policy can obtain. In Table 9, the empirical results show that when implementing this policy, cities with low financial development levels show no significant impact on waste water emissions, and the inhibitory effect on waste gas emissions is significantly weaker than in those with high financial development levels. Finally, this paper examines the heterogeneity of environmental improving effects in promoting the implementation of this policy between innovative and non-innovative cities. The empirical results show that the environmental improving effect of innovative cities in promoting the construction of "National Information City for Public Service" is significantly stronger than that of non-innovative cities. This result may have the following explanations. Implementing the pilot policy of innovative cities is conducive to promoting the agglomeration of various innovative elements into cities. Hence, it promotes improving urban industrial productivity and upgrading industrial structure through technological innovation and technological transformation of industries with high pollution, high energy consumption, and low efficiency. It also expects the scale and proportion of technology-intensive and capital-intensive industries, such as the modern information technology industry, to further increase. Therefore, it directly reduces urban environmental pollution and lays a solid technical and industrial foundation for further practicing such policy.

Table 9. Heterogeneity analysis based on urban financial development level and different innovation attributes.

Explained Variable	*ww*		*ww*	
City types	Innovative cities	Non-innovative cities	Cities with low financial development	Cities with high financial development
Treat × Post	−0.0249 *** (−2.78)	−0.0111 *** (−2.67)	−0.0036 (−0.50)	−0.0235 *** (−5.05)
Controlled variable	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.0619	0.0645	0.0840	0.0353
N	578	3292	1934	1936
Explained variable	*wg*		*wg*	
City types	Innovative cities	Non-innovative cities	Cities with low financial development	Cities with high financial development
Treat × Post	−0.0262 *** (−5.78)	−0.0142 *** (−5.72)	−0.0136 *** (−3.21)	−0.0222 *** (−8.92)
Controlled variable	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Adjusted R^2	0.2418	0.0758	0.0705	0.1571
N	578	3292	1934	1936

Notes: *t*-value in parentheses. * denotes *** $p < 0.01$.

7. Conclusions and Policy Implications

This article investigated the "National Information City for Public Service" policy as the representative policy of China's digital transformation of urban governance to empirically analyze its impact on urban environmental pollution using the difference-in-differences method. This paper has important referential significance for clarifying the internal logical relationship between the digital transformation of urban governance and the improvement of urban environmental quality, and it also contributed to promoting the efficient integration of urban digitization and green development. The key findings of the research are as follows:

Firstly, the digital transformation of urban governance has significantly reduced the level of urban environmental pollution by around 1.65–2.11% on average. After the robustness test of the PSM-DID method and excluding the exogenous interference of the smart city pilot policy, the empirical estimation results were the same as the above conclusions. Compared with previous studies, this study gives a quantitative analysis of the digital transformation impact on environmental pollution. This quantitative study can have a more precise application for policy makers. Compared with the existing research, this study conducted a quantitative analysis of the impact of digital transformation on environmental pollution. Quantitative research will help policy makers formulate more accurate policies.

Secondly, the mechanism test results showed that the digital transformation of urban governance can reduce urban environmental pollution through the technological innovation effect, industrial structure upgrading effect, resource allocation optimization effect, and urban informatization level improvement effect. This study has investigated the mechanism of the impact of digital transformation of urban governance on environmental pollution from many aspects. There is no such research in the existing literature. The research will help policy makers to observe the implementation effect of digital transformation of urban governance more directly. It is helpful to find alternative, revisable and improved paths when aiming at strengthening its environmental governance effect. This research is conducive to formulating more focused policy.

Thirdly, the heterogeneity analysis of different city scales showed that the environmental pollution control effect of the digital transformation of urban governance increases with the expansion of a city's scale. The heterogeneity analysis of different city characteristics showed that cities with higher human capital levels, stronger local government financial strength, and more advanced financial development levels have stronger environmental improving effects of the digital transformation of urban governance. The environmental improving effect of digital transformation of urban governance is stronger in cities with the dual superposition of "Innovative City Pilot Policy" and the policy of "National Information City for Public Service". The heterogeneity analysis of different city scales has significance. In particular, the digital transformation of urban governance affects the difference of environmental improvement under different conditions of human capital levels and financial development levels. This finding was not mentioned in previous studies. This is of significance for formulating more focused digital transformation and environmental governance strategies for cities of different sizes and characteristics in the future.

The policy and practical implications of this paper mainly include the following points:

Firstly, the government should accelerate the digital transformation of urban governance and improve the quality of the urban environment. The digital transformation of urban governance is an important part of urban digital transformation. The empirical results shows that the digital transformation of urban governance marked by the policy of "National Information City for Public Service" has an important impact on reducing urban environmental pollution. Therefore, the Chinese government should accelerate the digital governance transformation of cities in the future and further integrate the urban digital development and green development into considerations.

Secondly, the digital transformation of urban governance needs the support of abundant financial resources and high technical accumulations to ensure the significance of its environmental improving effect. It is suggested that cities with a certain development foundation should have good preparation when ensuring the budget of financial investment for the digital transformation of urban governance. They also should actively guide the technical strength and enthusiasm of different market players to enhance their participation in the process of digital transformation of urban governance to ensure coherence.

Thirdly, the digital transformation of urban governance would be best if started from large and medium-sized cities. When the digital transformation of large and medium-sized cities is successful or has reached a certain level, then the government can continue to implement the digital transformation of governance in small cities. Thus, it will finally achieve the binding development pattern of digital transformation of urban governance for different scales of cities. According to the research conclusion of this paper, the improving effect of digital transformation of urban governance on urban environmental pollution has city scale heterogeneity. Due to the abundant elements of technical talents and high levels of economic agglomeration, large cities have more advantageous basic conditions for digital transformation of urban governance compared to small cities. The urban environmental improving effect brought by digital transformation of urban governance is also more salient. Therefore, in the process of comprehensively promoting the digital transformation of urban governance, the government should take large cities' digital transformation of urban governance as the starting point. By making use of the resource advantages of large cities, the government can accumulate beneficial experience and explore feasible modes of digital transformation of urban governance. The government can also make full use of the advantageous human capital and technology elements in large cities to strengthen the coordination and cooperation with the surrounding small cities to accelerate small cities' digital transformation of governance.

Finally, in terms of financial support, the digital transformation of urban governance at different levels of financial pressure has significantly reduced environmental pollution, but the pollution reduction effect of the low financial pressure group is greater than that of the high financial pressure group. The financial pressure expressed by the financial deficit rate indicator also represents the government's administrative intervention level in the construction of digital transformation of urban governance. When local governments compete for GDP growth, they will give up long-term environmental protection and industrial upgrading so that when government intervention is strong, the effect of digital transformation of urban governance in reducing environmental pollution is weaker. Therefore, the government should clarify its role and positioning in the process of promoting the digital transformation of urban governance to avoid offside. While giving play to the decisive role of the market in the process of digital transformation of urban governance, it is also necessary to prevent the absence of the role of the government. In areas requiring government support, the government should give corresponding support on the premise of not violating the market rules to ensure the smooth implementation of projects related to the digital transformation of urban governance. The government should make efforts to play the role of "night watchman", create a stable, harmonious and orderly market environment for the digital transformation of urban governance, and protect and promote orderly market competition. In the process of digital project development and construction, supporting enterprises to play a leading role, and the focus of government departments is to ensure that the market mechanism of free competition operates well.

8. Limitations and Future Research

This paper takes the pilot policy of "National Information City for Public Service" implemented in China as the representative policy of the digital transformation of urban governance, constructs a natural experiment, and analyzes its impact on environmental pollution by the theoretical and empirical test. As a global digital economy power, China has solid digital economy foundations. However, there are still many countries in the world with backward digital economy development and low levels of digital infrastructure construction. Whether such countries can improve environmental pollution by promoting the digital transformation of urban governance is not covered in this study. Therefore, whether the conclusions drawn from China can be applied to other countries and regions needs further comparative analysis, which is the limitation of this paper. When studying the impact of digital transformation on the environment in the future, we should pay more attention to the comparative analysis among countries, so as to form digital transformation and environmental governance advice for countries of different levels of economic development.

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