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Research on Informatization Level, Technological Innovation and Urban Environmental Pollution: A Quasi-Natural Experiment Based on the Next-Generation Internet Demonstration City Policy

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Abstract: This study uses the data of 280 Chinese prefecture-level cities from 2008 to 2019 as the research samples, and the DID (difference-in-difference) model to explore the negative impact of the Next-Generation Internet Demonstration City Policy (NGIDCP) on urban environmental pollution, and further analyzes the transmission mechanisms of informatization level and technological innovation in this influence. The results show that the NGIDCP can effectively reduce urban environmental pollution, and the conclusion still holds after various robustness tests. The informatization level and technological innovation have some mechanism effects on the impact of the NGIDCP on urban environmental pollution. The results of the regional heterogeneity test show that the negative impact of the NGIDCP on urban environmental pollution is significant in the eastern and western regions and has little effect on the central region. At the end of the paper, some recommendations on urban environmental pollution based on the conclusions drawn from the study are proposed.

Keywords: DID (difference-in-difference) model; the Next-Generation Internet Demonstration City Policy (NGIDCP); urban environmental pollution

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1. Introduction

The rapid industrialization and population growth in the world have intensified the conflicts between resource consumption and environment pollution, which pose a serious challenge for many countries. In the past, many countries had a crude economic growth approach, which simply pursued economic growth and increased productivity while ignoring the importance of environmental protection. In recent years, the problem of global environmental pollution has become increasingly serious, which has attracted more and more attention from all walks of life. Global environmental problems have affected all aspects of human well-being and lvelihood. For instance, the emission of pollutants such as SO_2, industrial wastewater, industrial soot and $PM_{2.5}$ have led to the reduction of forest and grasslands, the expansion of desert areas, the water crisis, and air pollution. As an emerging economy, China has achieved remarkable economic growth and national strength since its reform and opening up. However, the accelerated urbanization and industrialization have generated some serious problems such as massive energy consumption and pollutant emissions.

The Chinese government plays much attention to the control of environmental pollution and has issued many environmental protection policies, focusing on strengthening ecological environmental protection. In 2021, it issued the *Opinions on Deepening the Battle against Pollution*, which aims to implement various measures to prevent and control pollution. In particular, with regard to ecological protection, it stresses the need to adhere to integrated ecological protection and systematic management, coordinates areas such as industrial development, pollution controlandecological conservation, collaboratively promotes pollution reduction, expands greening areas, promotes ecological protection, resource conservation and green low-carbon development [1]. Therefore, finding ways to reduce urban environmental pollution while maintaining economic growth is an important topic in the current context.

China's digital economy is showing a booming trend, and the Internet takes modern information and communication technology (ICT) as the core, and its rapid development is affecting people's life. To further push the growth of the Internet in China, the government issued the *Notice on the Construction of National Next-Generation Internet Demonstration City* in 2013, aiming to popularize the application of the Internet in pilot cities, cultivate new services, new markets and new forms of business, and enhance industrial scale and innovation capacity, thus making full use of the network's convergence and leading role of the Internet and advancing the growth of digital industry. In this context, during the implementation process of the Next-Generation Internet Demonstration City Policy (NGIDCP), will it alleviate the urban environmental pollution problem? If the answer is yes, what are its channels of action? Based on this, we will analyze the impact of the NGIDCP on urban environmental pollution.

The subsequent research contents of our study are listed below. The second section is the related literature; this section first analyzes the scholars' study on environmental pollution, and then introduces the related literature of the Internet on environmental pollution, and summarizes the literature. On this basis, it puts forward the core elements of ourstudy and the possible marginal contribution of this paper. The third part is the theoretical analysis and hypothesis, which mainly analyzes the effect of the NGIDCP on urban environmental pollution, introduces the mechanism of the impact, and puts forward a research hypothesis. The fourth part is the study design, including the research samples, variable selection and definition, data sources and model setting. The fifth part is the research findings, which mainly carries out the empirical analysis of the hypothesis proposed in the third part, including baseline regression results, a parallel trend test, robustness test, mediation mechanism analysis and regional heterogeneity test. The last is the conclusion, which summarizes the previous content and makes some suggestions, and then analyzes the research shortcomings.

2. Literature Review

With the rapid growth of the economy, the problem of environmental protection has been paid more and more attention. Scholars in China and abroad have conducted more and more in-depth studies on environmental pollution, but most of which mainly focus on the relationship between economic growth and environmental pollution. In those research on the relationship, one famous basic theory is the Environmental Kuznets Curve (EKC) hypothesis. First, Grossman found that there may be an inverted "U" relationship between income and environmental quality when studying the relationship between environmental conditions and income [2]. Later, this relationship was also referred to as the Environmental Kuznets Curve [3]. Based on the EKC, many scholars have conducted relevant studies since then, and there are different views on the inverted "U" curve between economic development status and environmental pollution.

On the one hand, some scholars believe that there is indeed an inverted "U" curve between economic growth and environmental pollution. Moh'd Hemed et al. investigated the dynamic relationship between economic growth and environmental pollution in Brunei and found that in the long-term dynamic relationship, there was an inverted U-shaped curve between Brunei's GDP and CO_2 [4]. Nizamani et al. also confirmed the EKC hypothesis, and found that there was an inverted U-shape between CO_2 emissions and Pakistan's economy [5]. On the other hand, some scholars believe that there may not be an inverted "U" curve between economic growth and environmental pollution, but a relationship in other forms. Adu and Denkyirah empirically tested that short-term economic growth in West Africa significantly increased the emissions of CO_2 and CoWaste, but in the long run, they do not significantly decrease and there was no EKC [6]. Liu and Yang studied the data of the Hubei Province and found that the relationship between environmental pollution and per capita GDP showed a variety of curve features such as "linear", "U-shaped" and "inverted N-shaped" [7]. Based on the data of the Shanxi Province, Luo and Zhang found that its per capita GDP and environmental pollution did not always conform to the "inverted U-shaped" curve, mainly manifested as "N-shaped". Among the environmental indicators, only SO_2 shows an "inverted U-shaped" curve [8]. In addition, some other scholars have examined some factors that influence environmental pollution from other aspects, including technological progress [9,10], R&D investment [11], urbanization level [12,13] and environmental regulation [14].

The next-generation Internet is a comprehensive service network that can accommodate, transmit and manage various forms of information such as audio, video and data signals, and provide various Internet services. Domestic and foreign researchers have long paid attention to the study of the Internet on energy consumption [15,16], but there are few studies on environmental pollution from the Internet; as far as the current research is concerned, the environmental impact of the Internet is still a matter of conflicting opinions. Some scholars believe that the manufacturing and use of ICT equipment consumes a lot of energy, such as electricity [17]. Electricity consumption has a positive impact on the increase of CO_2 emissions, and in the process of the development of ICT, a large amount of energy is consumed, pollutant emissions are constantly increasing and environmental problems are increasingly serious [18,19]. However, most scholars believe that the development of the Internet can realize intelligent environmental governance and reduce the degree of resource mismatch [20]. The construction of network infrastructures are conducive to the online lifestyle of residents and the intensification of industrial production, thus reducing the level of environmental pollution [21,22]. Through data analysis, Gartner found that the pollutant emissions generated by the information industry are much smaller than the pollutant emissions that can be reduced by usingthe Internet in other industries, which shows that the rise of the Internet is beneficial to the green growth of the economy [23]. This paper argues that the NGIDCP has improved the popularization and application of the Internet and the construction of information infrastructure in the pilot cities, promoted the improvement of information technologies such as big data, blockchain and Internet of Things [24]. Therefore, the proportion of highly polluting and energy-consuming industries will be greatly reduced. It is of great significance to reduce urban environmental pollution.

Based on the above literature review, we find that there is a rich body of research on environmental pollution by scholars at present, but the NGIDCP and its relationship with environmental pollution have not been involved. Therefore, this paper will use the DID (difference-in-difference) model to evaluate the impact of the NGIDCP on urban environmental pollution, and further investigate the mediating mechanism and regional heterogeneity of the policy effect. This will provide decision support for the formulation of relevant policies to decrease pollution emissions.

The marginal contribution of this paper may be in two aspects. First, this paper uses the DID to evaluate the impact of the NGIDCP on urban environmental pollution, and it excludes other policies that may potentially affect urban environmental pollution. This will provide more credible empirical evidence for the role of this policy in reducing the urban environmental pollution. Second, the research explains the theoretical channels of the NGIDCP to reduce urban environmental pollution from the perspectives of informatization level and technological innovation, and proves the channels of the policy's action on urban environmental pollution. The findings not only enrich the literature on environmental policies and urban environmental pollution, but also provide an important basis for the government to design and implement effective pollution reduction policies.

3. Theoretical Analysis and Research Hypothesis

3.1. The NGIDCP and Urban Environmental Pollution

The NGIDCP has strengthened the penetration rate of the Internet in pilot cities, enabling the rapid flow of digital production factors such as massive, timely and ubiquitous information flow and data flow [25]. It has promoted the vigorous development of digital industrialization and industrial digitalization with the Internet as the carrier and data resources as the core. Driven by the NGIDCP, the traditional industries and consumption patterns of pilot cities are changing, and the scale of the digital economy is constantly expanding. Transaction Cost Theory points out that the transaction cost is the cost required to obtain accurate market information [26], and the efficient matching of information brought by the Internet reduces the transaction cost of enterprises, makes enterprises continue to expand and provides the possibility for the development of a sharing economy and platform economy.

First, the combination of the Internet and service industry has given rise to various new business forms such as network education, online medical care and Internet entertainment, which has promoted economic growth [27]. Second, the rapid development of various online platforms relying on Internet technology can realize the instantaneous and accurate matching of supply and demand for traditional services [28], which makes the consumption patterns of online shopping, bike-sharing and takeout delivery constantly change, thus promoting the expansion of the scale of the digital economy [29]. Finally, the integration of the traditional industry and Internet technology has optimized all aspects of industrial R&D and design, production and manufacturing, marketing and services and promoted the industries to transform into digital, intelligent and green, such as smart manufacturing and industrial Internet. The expansion of the digital economy plays a major role in reducing environmental pollution. With its high permeability and strong diffusion, the digital economy breaks the boundaries between industries, promotes the integration of related industries and upstream and downstream industries and while the industry is integrated, it has given birth to more industries in the form of a network economy, which is beneficial to upgradethe industrial structure [30]. The advanced industrial structure means that the share of digital and technology-intensive industries is increasing. Most of these industries are clean industries with high efficiency and low energy consumption, which is beneficial for reducing the emissions of environmental pollution. Therefore, this paper proposes:

Hypothesis 1 (H1). *The NGIDCP can reduce urban environmental pollution.*

3.2. The NGIDCP, Informatization Level and Urban Environmental Pollution

The environmental field is a field that integrates various environmental factors. In order to present environmental problems comprehensively, it is especially necessary to realize the mutual sharing of environmental factors through the Internet, so as to promote the overall solution of environmental pollution problems. The creations of next-generation Internet demonstration cities have improved the level of Internet technology applications in pilot cities, promoted the transmission speed, content richness and interaction convenience of urban information resources, and brought open and innovative resources to enterprises [31]. In this way, urban resources can be effectively integrated, information sharing and information exchange between various systems can be enhanced and the development of the urban informatization level can be promoted [32].

The improvement of the urban informatization level provides a powerful opportunity for the optimization of the environmental supervision mode of the government and various environmental protection departments. On the one hand, applications such as big data, cloud computing, remote sensing technology and intelligent detection equipment can help to establish and improve the online monitoring system for pollutant emissions. The monitoring scope is expanded in terms of pollutant types and distribution regions, and an all-weather, multi-level intelligent multi-source sensing system is formed, which improves the early warning and sensing ability of pollution sources, strengthens the environmental supervision ability of the government, and thus improves the level of ecological environmental governance. On the other hand, the environmental information data sharing mechanism has been established through information technology, which can achieve a cross-industry, cross-region and cross-department information connection and resource sharing, unify the standards of data exchange and promote the disclosure of regional pollutant discharge, air environment quality, water environment quality and other information. It can enhance the business cooperation, resource sharing, information exchange and comprehensive data utilization capabilities of various departments, and form the resultant force of environmental supervision [33]. Therefore, this paper proposes:

Hypothesis 2 (H2). *The NGIDCP can reduce urban environmental pollution by improving the informatization level.*

3.3. The NGIDCP, Technological Innovation and Urban Environmental Pollution

The NGIDCP has promoted the vigorous growth of the Internet in pilot cities, and brought the concept of open technological innovation. From the Theory of Consumer Behavior [34], it can be seen that consumers and producers are closely related; consumers buy products to satisfy their own utility and producers produce products that meet consumer utility to meet consumer preferences. Therefore, urban innovation subjects have gradually attached importance to providing users with personalized high-quality products and services, thus forcing innovation subjects to continue to carry out technological innovation. Enterprises are the subject of technological innovation, and the Internet mainly promotes the technological innovation of enterprises from three aspects.

First, the Internet makes the flow of information elements between enterprises more frequent, promotes the exchange and diffusion of enterprise technical knowledge and encourages enterprises to accumulate a large amount of knowledge [35]. The Theory of Endogenous Growth believes that the main driving force of economic growth is the accumulation of knowledge and the innovation activities supported by the flow of data elements, which provides important production raw materials for technological innovation and greatly promotes the progress of enterprise technological innovation. It further improves the speed of enterprises to obtain new technologies, new processes and new products [36]. Second, the Internet has the characteristics of high-speed and convenient information transmission, which reduces the operating costs of enterprises. On the one hand, enterprises can carry out online trading, negotiation and settlement on the Internet platform, which is conducive to comprehensively obtaining local market information and reducing the fixed information cost of publicity and communication. Grossman also put forwanrd a “technical effect” in explaining EKC’s formation, arguing that technological innovation will decrease the investment of production factors in the production process, thereby reducing the environmental pollution. On the other hand, the Internet can simplify the work of data analysis, improve the accuracy and timeliness of information transmission in intermediate product production and processing and reduce the cost of internal control. Capital availability is a prerequisite for enterprises to increase R&D investment and carry out technological innovation [37]. Cost reduction can save the capital of enterprises and provide sufficient financial support for their technological research and innovation. Third, the Internet and big data can help to broaden the scope of information dissemination and reduce the uncertainty of information in economic operations, promote the efficient allocation of innovation resources in a wider range and improve the technological innovation ability of enterprises.

At present, China is taking two main measures to reduce environmental pollution: one is to optimize production methods to reduce pollutant production and form front-end defenses. The other is to strengthen terminal management, and improve the treatment efficiency of pollutants. Improving the technological innovation capability of enterprises plays a key role in reducing the environmental pollution level. For one, the improvement of production technology can reduce the production energy consumption per unit output and the pollution emission in the production process. For two, it is conducive to the generation of the clean production process, increases the use of clean energy, pollution treatment equipment and other inputs, uses advanced technology to create clean energy and improves pollution control technology to solve the recycling problem of polluted wastes. Therefore, this paper proposes:

Hypothesis 3 (H3). *The NGIDCP can reduce urban environmental pollution by promoting technological innovation.*

The theoretical mechanism of the research hypothesis is shown in Figure 1.

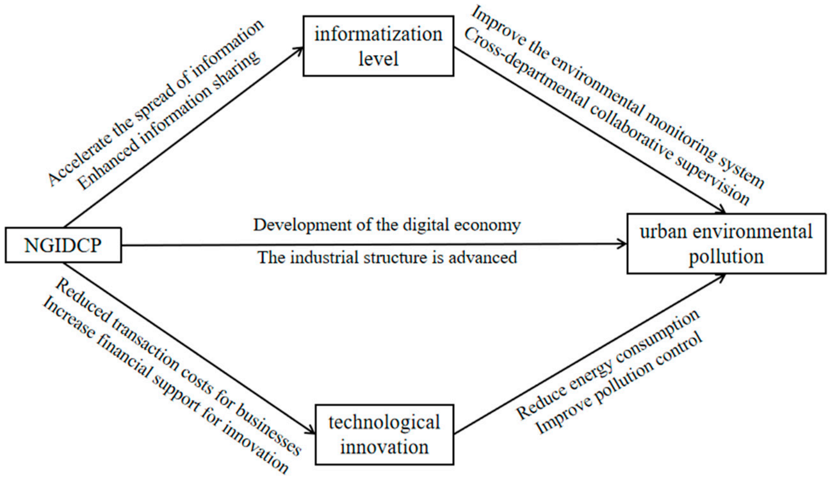

Figure 1. Diagram of the theoretical mechanism.

4. Research Design

4.1. Data Source

This research uses the panel data of 280 Chinese prefecture-level cities from 2008 to 2019 to evaluate the impact of the NGIDCP on reducing urban environmental pollution. Referring to the study of Bao and Zhou [38], the experimental group in this paper is 22 pilot cities that were approved to build next-generation Internet demonstration cities in 2013, and there are 258 cities in the control group. A quasi-natural experiment around the NGIDCP finally yields panel data with a sample observation number of 3360.

Information about the NGIDCP is mainly obtained from the websites of the "Ministry of Industry and Information Technology", and we collected city data from the *China Urban Statistical Yearbook* and *Report on China's Urban and Industrial Innovation in* 2017, and use interpolation methods to supplement missing data.

4.2. Variables Definition and Data Description

4.2.1. Explained Variable

Urban environmental pollution (score) is the core explained variable in this paper. Environmental pollution refers to the behavior of people discharging harmful substances in production, life and other activities, and the emissions exceed the purification capacity of the environment, thereby causing damage to the environment. Regarding the selection of environmental pollution indicators, there is currently no unified index. Some scholars use a single pollutant emission as a measurement index, including industrial sulfur dioxide, industrial soot, industrial wastewater and $PM_{2.5}$ concentration, and some scholars use the entropy method to construct a comprehensive index of environmental pollution to express the environmental pollution. Relatively single indicators cannot fully reflect the level of environmental pollution in China, and the entropy method is a method to assign values according to the difference of each index from an objective perspective. Therefore, drawing on the method of Yu [39] and Li [40], the research uses the entropy method to calculate the weight of emissions of three pollutants (industrial smoke/powder dust, industrial wastewater and industrial sulfur dioxide) in 280 cities in China during 2008–2019, and then obtains the comprehensive environmental pollution index of each city.

4.2.2. Core Explanatory Variable

This study uses the NGIDCP as a policy shock, and the interaction term ($policy_{it}$) of the time dummy variable ($time_{it}$) and the policy dummy variable ($treated_{it}$) as the core explanatory variable. When a city is included in the NGIDCP in 2013, $treated_{it}$ is equal to 1; conversely, $treated_{it}$ is equal to 0. If the city becomes a pilot city in 2013, it has $time_{it} = 1$ in 2013 and later years, conversely, $time_{it}$ is equal to 0. However, if the city is not covered by the NGIDCP, $policy_{it}$ is equal to 0, then it exists in $treated_{it} \times time_{it} = policy_{it}$.

4.2.3. Control Variables

To avoid errors in the results of this paper caused by potential confounding factors, a series of other control variables were also selected. Referring to existing studies, it controls from the perspectives of the economic development level, human capital, government intervention, greening degree and scientific research investment.

In particular, the improvement of the economic development level (pGDP) constantly puts forward new requirements for urban green development, and this paper adopts the regional per capita GDP to characterize the economic development level. Large amounts of human capital (hucap) can effectively improve the technological innovation ability of cities, which may have an impact on urban pollutant emissions and governance, characterized using the number of university students in school as a proportion of the region's year-end population. Infrastructure is a carrier of urban development and has a positive effect on urban ecological protection, which may have an effect on pollution monitoring and management, so the infrastructure level (infra) is expressed by the ratio of the actual road area of each city to the number of year-end population. The fiscal expenditure of local governments may affect the implementation of policy tools, and therefore the pollutant emission of cities, so government intervention (gov) is expressed as a share of GDP using general government expenditure within the budget. The pollution purification capacity of vegetation varies with the greening degree of a city, and the greening level (green) is represented by the green coverage rate of a city. The increase of scientific research investment (tec) can improve the innovation ability of relevant subjects and increase the pollution control level of the city, which is expressed by the proportion of scientific and technological expenditure in the financial expenditure.

4.2.4. Intermediate Variables

The intermediate variables in this study are the level of informatization (infor) and technological innovation (inno). In the analysis of influencing mechanism, this paper analyzes the mediating role of the informatization level and technological innovation on the impact of the NGIDCP on urban environmental pollution. Drawing on the study of Li et al. [41], this study uses the total amount of telecom services per capita to represent the informatization level. Technological innovation is measured by the urban innovation index, which is sourced from the *Report on China's Urban and Industrial Innovation in 2017*. However, as the data in the report only covers up to 2016, the urban innovation index for the years 2017–2019 is estimated using the method of Hu and Liu [42], which involves calculating the five-year geometric growth rate.

The descriptive statistics of the main variables are shown in Table 1.

Table 1. Descriptive statistics of variables.

Variables	Observations	Mean	Std. Dev	Min	Max
score	3360	0.0238	0.0277	0.0000371	0.523
did	3360	0.0458	0.209	0	1
pGDP	3360	3.327	3.018	0.327	23.90
hucap	3360	0.0182	0.0238	0.0000351	0.131
gov	3360	0.189	0.103	0.0437	1.485
infra	3360	4.706	6.124	0.155	73.04
green	3360	39.45	13.65	0.360	386.6
tec	3360	0.0157	0.0156	0.000598	0.207
infor	3360	0.118	0.154	0.00523	2.010
inno	3360	17.86	85.26	0	2171

4.3. Model Setting

To investigate effect of the NGIDCP on urban environmental pollution, the research regards the NGIDCP as a quasi-natural experiment. Following Baltagi [43], the research uses the DID model to conduct the effect assessment, and divides the cities into the experimental group and control group based on whether they were approved to establish next-generation Internet demonstration cities during the study period. The specific model setting is as follows:

$$score_{it} = \alpha_0 + \alpha_1 policy_{it} + \theta X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \tag{1}$$

where the subscript i denotes the city, t denotes time, $score_{it}$ is the explained variable, which indicates the urban environmental pollution level of i city in t year, $policy_{it}$ denotes whether i city is in the NGIDCP in t year; before the policy is set, $policy_{it}$ is equal to 0; in the year of the policy is set and the years after, $policy_{it}$ is equal to 1. X_{it} is the control variables that affect urban environmental pollution with the change of i and t, η_i denotes the urban fixed effect, γ_t is the time fixed effect and ε_{it} is the error term. This paper focuses on the coefficient α_1; it indicates that the NGIDCP can dramatically decrease the urban environmental pollution level in the pilot cities when the coefficient α_1 is negative and significant.

5. Empirical Results

5.1. Baseline Regression Results

This paper first assesses whether the NGIDCP is effective in reducing urban environmental pollution level. Table 2 presents the baseline regression results. Columns (1) and (2) are the results without and with control variables, respectively, and the results in both columns control time and urban individual effects. The regression coefficients in the results reflect that after the addition of control variables, the coefficient of core explanatory variables in this paper remains significantly negative, which means that the establishment of pilot cities has a negative effect on the urban environmental pollution level, and H1 is supported.

5.2. Parallel Trend Test

A basic assumption for using the DID model to assess policy effect is that urban environmental pollution of the experimental group and control group have a common trend when the experimental group is not affected by the NGIDCP. In other words, the two groups need to pass the parallel trend test. In order to verify the parallel trend hypothesis, the paper follows Jacobson et al. [44] to investigate whether the NGIDCP meets the parallel trend hypothesis. It uses the graphical method to test the evolution trend of environmental pollution levels in the experimental group and control group. If the differences between two groups before the policy implementation are not significant, the hypothesis of a parallel trend is passed.

Table 2. Baseline regression results.

Variables	**(1)** **Score**	**(2)** **Score**
did	−0.0099 *** (−4.5701)	−0.0059 ** (−2.4421)
pGDP		−0.0018 *** (−3.4324)
hucap		0.0316 (0.4501)
infra		−0.0001 (−0.5743)
gov		0.0030 (0.4053)
green		0.0000 (1.1153)
tec		−0.0116 (−0.3059)
FE (region)	Yes	Yes
FE (year)	Yes	Yes
_cons	0.0288 *** (28.9857)	0.0310 *** (12.0001)
N	3360	3360

Note: Standard error in brackets in the table; *** and ** denotes significance at the 1% and 5% levels, respectively.

As shown in Figure 2, the horizontal axis represents the years before and after the implementation of the NGIDCP, and the vertical axis shows the coefficient of the difference between two groupsin terms of the impact of the NGIDCP on urban environmental pollution. The results present the coefficients of dummy variables in each year before the implementation of the policy have no marked difference compared with 0, which supports the parallel trend hypothesis. After the creation of the pilot cities, urban environmental pollution level starts to decrease significantly in the fifth year, suggesting that there is a lagged effect of the NGIDCP on urban environmental pollution.

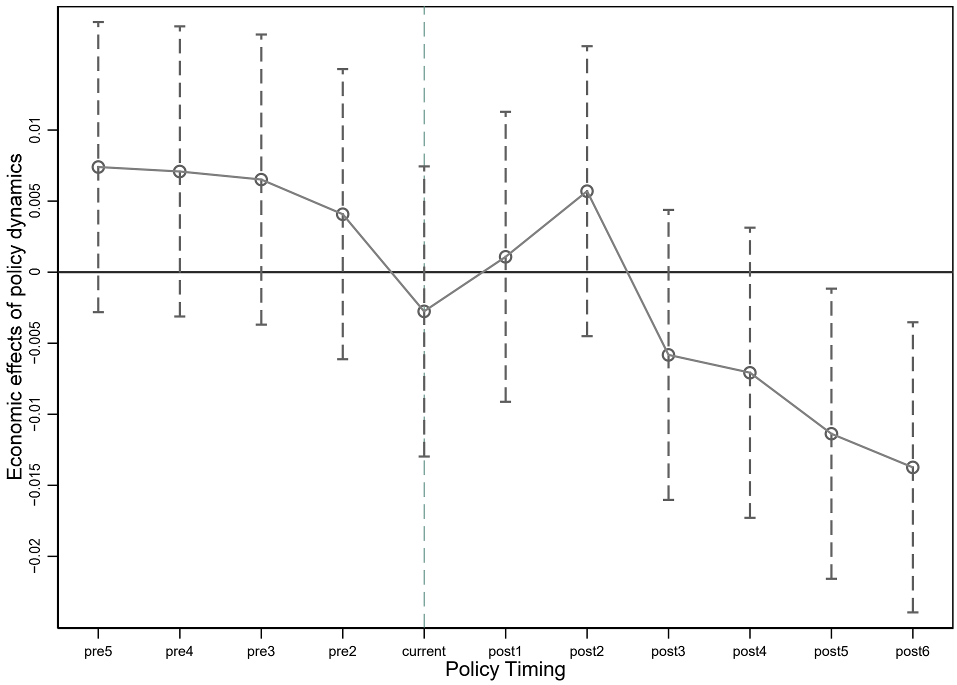

Figure 2. Parallel trend test.

The reason for the lagged effect may be that the implementation of the policy takes a process to attract capital, labor and other factors after the implementation of the policy, and the migration of labor and the construction of infrastructure require a long period. The above results further prove that the NGIDCP can effectively reduce the pollution in the pilot cities.

5.3. Robustness Test

5.3.1. PSM-DID Test

The selection of a city into the NGIDCP may not be random, but may depend on the city's economic status and other factors, which may cause sample selection bias. Therefore, the study follows the study of Heckman et al. [45] and uses the PSM-DID model to confirm the baseline regression results. In particular, the control variables are selected as covariables to estimate the propensity score value, and the samples are matched according to the propensity score value.

This paper mainly adopts the relatively strict caliper nearest neighbor matching method for matching. From the density distribution of propensity score values in Figure 3, we can find that the probability distributions of two groups are closer after matching, which significantly improves the comparability between them, and further indicates that the sample bias is reduced through PSM-DID. According to the matched samples, the regression is combined with the above Equation (1) to obtain the regression results as in Table 3. It can be found that the regression results of columns (1) and (2) are still significant at the 5% level, reflecting the important role of the NGIDCP on urban environmental pollution.

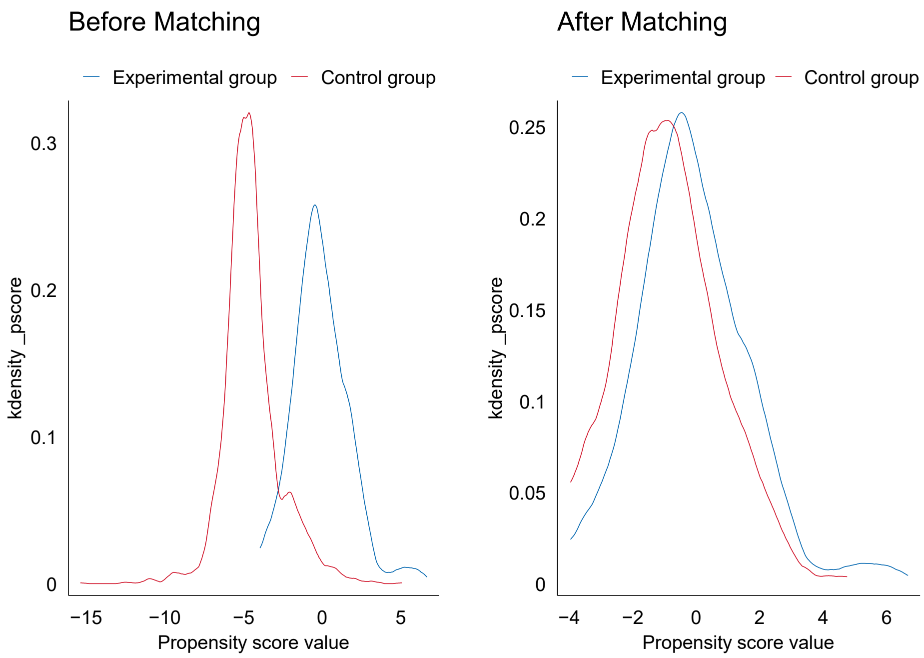

Figure 3. Density distribution of propensity score values.

5.3.2. Substitution of Explained Variable

The explained variable (score) in this paper is calculated by the entropy method based on the data of three types of pollutants in each city. In previous studies, most scholars have adopted industrial SO_2 from three types of pollutants to measure environmental pollution. For robustness testing, the logarithm of industrial sulfur dioxide emissions ($lnSO_2$) is introduced to replace the original explained variable for DID regression. The results are shown in columns (3) and (4) of Table 3. After replacing the explained variable, the coefficient of DID is −0.3986 and passes the significance test, which confirms the robustness of the findings in this paper.

Table 3. PSM-DID and substitution of explained variable tests.

Variables	PSM-DID Test		Substitution of Explained Variable	
	(1)	(2)	(3)	(4)
	Score	Score	$\ln SO_2$	$\ln SO_2$
did	−0.0081 ***	−0.0060 **	−0.5338 ***	−0.3986 ***
	(−3.2877)	(−2.3397)	(−7.1909)	(−4.8279)
control variables	No	Yes	No	Yes
FE (region)	Yes	Yes	Yes	Yes
FE (year)	Yes	Yes	Yes	Yes
_cons	0.0433 ***	0.0442 ***	10.6669 ***	10.7279 ***
	(22.9767)	(6.9583)	(312.6885)	(120.8544)
N	1127	1127	3360	3360

Note: Standard error in brackets in the table; *** and ** denotes significance at the 1% and 5% levels, respectively.

5.3.3. Elimination of Other Policies Interference

The factors influencing urban environmental pollution are relatively complex. According to the existing research and analysis, there may be different policies implemented in the same urban area or at the same time. In other words, the impact of the NGIDCP on reducing the urban environmental pollution level may include the policy effects of other policies. Therefore, to examine the "net effect" of policy impact more accurately, interference from other policies should be excluded. At present, scholars have proved the effect of a low-carbon city policy (lowc) and smart city policy (smart) on air pollution and environmental pollution [46,47]. On this basis, these two policies are controlled in this paper, which may have impacts on urban environmental pollution during the sample period. Additionally, dummy variables of these two policies are added into the regression to reduce the error in the empirical results of this study. The results are shown in Table 4. It can be found that after adding the dummy variables of these two policies, the regression coefficients are still significantly negative, indicating that these two policies have little impact on the research in this paper, which proves that the research findings in this paper are robust.

Table 4. Elimination of other policies interference.

Variables	Lowc		Smart		Lowc and Smart	
	(1)	(2)	(3)	(4)	(5)	(6)
	Score	Score	Score	Score	Score	Score
did	−0.0099 ***	−0.0060 **	−0.0098 ***	−0.0058 **	−0.0098 ***	−0.0059 **
	(−4.5335)	(−2.4850)	(−4.5088)	(−2.4118)	(−4.4722)	(−2.4541)
lowc	0.0001	0.0008			0.0001	0.0007
	(0.0882)	(0.5802)			(0.0838)	(0.5711)
smart			−0.0010	−0.0008	−0.0010	−0.0008
			(−0.8154)	(−0.6664)	(−0.8148)	(−0.6584)
control variables	No	Yes	No	Yes	No	Yes
FE (region)	Yes	Yes	Yes	Yes	Yes	Yes
FE (year)	Yes	Yes	Yes	Yes	Yes	Yes
_cons	0.0288 ***	0.0310 ***	0.0288 ***	0.0310 ***	0.0288 ***	0.0310 ***
	(28.9810)	(12.0069)	(28.9841)	(11.9740)	(28.9794)	(11.9807)
N	3360	3360	3360	3360	3360	3360

Note: Standard error in brackets in the table; *** and ** denotes significance at the 1% and 5% levels, respectively.

5.3.4. Placebo Test

To exclude the effects of other factors on the selection of pilot cities for the NGIDCP, this study refers to the practice of La Ferrara et al. [48] and Cantoni et al. [49] and uses a placebo test by randomly selecting the experimental group. In the study sample, the same number of cities as the pilot cities in the NGIDCP are randomly selected as the experimental group, and the other cities are used as the control group. To ensure the validity of the experimental results, this paper conducts 1000 random sampling. The kernel densities of the t-values of all regression results are shown in Figure 4. It can be found that the t-values of the differential estimation coefficients are within 0.005 and distributed around 0 in most samples, while the corresponding *p*-values are mostly greater than 0.1. The results show that in the experimental group and the control group fabricated by a placebo test, the policy does not have a significant effect on reducing urban environmental pollution, so the findings are robust.

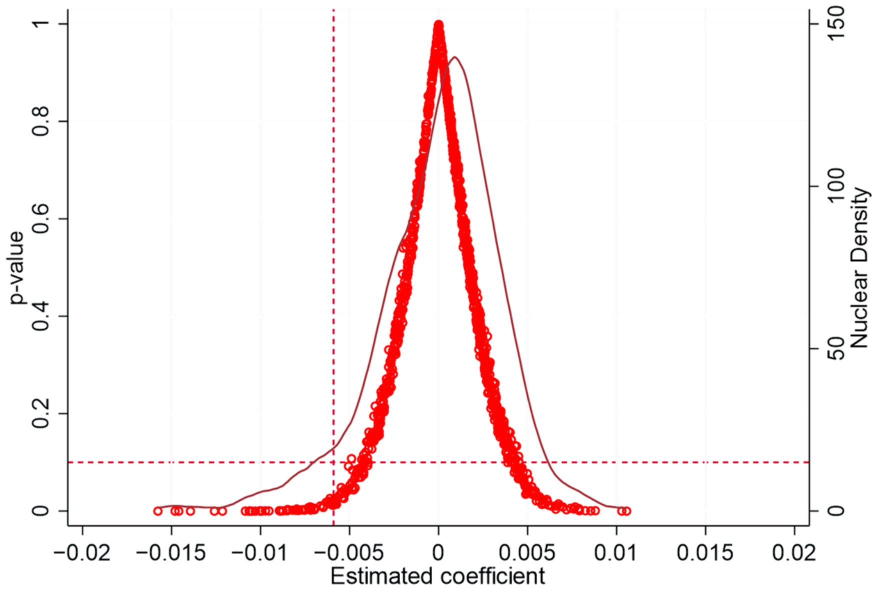

Figure 4. Placebo test.

5.3.5. Counterfactual Test

This paper conducts a counterfactual test by the timing of the change in policy. Specifically, the policy implementation time of the experimental group is returned two years, three years and four years in advance; in other words, the implementation time is fabricated as 2011, 2010 and 2009 for the regression, and the results are shown in Table 5. It can be found that the three columns of regression results are insignificant, showing that the change of urban environmental pollution level matches the actual time of the NGIDCP. The results of the baseline regression are driven by the implementation of this policy, which is evidence that the research findings are robust.

Table 5. Counterfactual test.

Variables	**(1)** **Score**	**(2)** **Score**	**(3)** **Score**
did_2	−0.0061		
	(−1.0908)		
did_3		−0.0050	
		(−0.9714)	
did_4			−0.0040
			(−0.9255)
control variables	Yes	Yes	Yes
FE (region)	Yes	Yes	Yes
FE (year)	Yes	Yes	Yes
_cons	0.0314 ***	0.0318 ***	0.0322 ***
	(12.6049)	(11.9984)	(11.7554)
N	3360	3360	3360

Note: Standard error in brackets in the table; *** denotes significance at the 1% level.

5.4. Mediation Mechanism Analysis

The baseline regression results have proved that the NGIDCP can effectively reduce urban environmental pollution in the pilot cities, so how does this policy affect urban environmental pollution? As described in the previous analysis of H2 and H3, the NGIDCP may act on urban environmental pollution by improving the urban informatization level and technological innovation. Therefore, this paper explores the impact mechanisms one by one with reference to Wen and Ye [50].

$$inn_{it} = \beta_0 + \beta_1 policy_{it} + \theta X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (2)$$

$$score_{it} = \lambda_0 + \lambda_1 policy_{it} + \lambda_2 inn_{it} + \theta X_{it} + \eta_i + \gamma_t + \varepsilon_{it} \quad (3)$$

where inn_{it} is the mediating variable, β_0 and λ_0 are constant terms, β_1, λ_1 and λ_2 are the coefficients of each other variable and the other variables are consistent with Equation (1). A mediation mechanism analysis determines the impact of the NGIDCP on the informatization level and technological innovation based on Equation (2), and then it determines the effect of the mediating variable on urban environmental pollution based on Equation (3). If the coefficients β_1, λ_1 and λ_2 are significant, it means that the reduction impact of the NGIDCP on urban environmental pollution can be transmitted through the informatization level and technological innovation.

The test results are presented in Table 6. Column (1) is the impact of the NGIDCP on the informatization level. It can be found that the impact of this policy on the informatization level is significant, which means that it can effectively improve the informatization level. Column (2) represents the impact of the NGIDCP on urban environmental pollution after adding the informatization level of the intermediary variable, and the regression results are negatively significant at the 5% level, which proves that the NGIDCP can decrease pollution emissions by improving the informatization level. Column (3) is the impact of the NGIDCP on technological innovation; and column (4) is the impact of the NGIDCP on urban environmental pollution after adding the technological innovation of the intermediary variable. It can be found that the regression result is still significantly negative, suggesting that this policy can decrease urban environmental pollution with the help of technological innovation. The above tests confirm H2 and H3.

Table 6. Mediation mechanism analysis.

Variables	**(1) Infor**	**(2) Score**	**(3) Inno**	**(4) Score**
did	0.0082 ***	−0.0056 **	104.6711 ***	−0.0043 *
	(3.2070)	(−2.3285)	(16.3729)	(−1.7077)
infor		−0.0325 *		
		(−1.9100)		
inno				−0.0000 **
				(−2.2401)
control variables	Yes	Yes	Yes	Yes
FE (region)	Yes	Yes	Yes	Yes
FE (year)	Yes	Yes	Yes	Yes
_cons	0.0096 ***	0.0313 ***	−42.0922 ***	0.0304 ***
	(3.5066)	(12.1021)	(−6.1242)	(11.6887)
N	3360	3360	3360	3360

Note: Standard error in brackets in the table; ***, ** and * denotes significance at the 1%, 5% and 10% levels, respectively.

5.5. Regional Heterogeneity Test

The division of Chinese cities into east, central and west has been widely used in previous studies. Therefore, this paper divides the study sample cities into three subsamples according to geographical location: eastern city, central city and western city, to examine the differences in policy effects of the NGIDCP in different regions. The specific regression results are shown in Table 7.

Table 7. Regional heterogeneity test.

Variables	Eastern Region (1) Score	Central Region (2) Score	Western Region (3) Score
did	−0.0067 **	0.0005	−0.0161 ***
	(−2.0539)	(0.0906)	(−3.7860)
control variables	Yes	Yes	Yes
FE (region)	Yes	Yes	Yes
FE (year)	Yes	Yes	Yes
_cons	0.0427 ***	0.0275 ***	0.0101 ***
	(10.1985)	(4.3575)	(2.9468)
N	1344	1308	708

Note: Standard error in brackets in the table; *** and ** denotes significance at the 1% and 5% levels, respectively.

Columns (1), (2) and (3) respectively show the impact of the NGIDCP on urban environmental pollution in the eastern, central and western regions. It can be found that the regression coefficient of column (1) is −0.0067 ($p < 0.05$), showing that the pilot cities, when established in the eastern region, can play an effective role in reducing urban environmental pollution. The regression coefficient in column (2) is not significant for the central region, which means that the policy has no effect on pollution after its implementation in the central region. The regression result in column (3) is significant at the 1% level, meaning that for the western region, the NGIDCP has the greatest impact on urban environmental pollution. This suggests the regional heterogeneity of the impact of the NGIDCP on urban environmental pollution.

The reasons for the above test results may be that the eastern region is economically developed, its cities are close to the coast, and it has certain advantages in human, material, financial and other factors and resources, as well as the perfect infrastructure for the development of the next generation of the Internet digital economy. Therefore, it is very effective to reduce the urban environmental pollution by implementing this policy. The secondary industry occupies a higher percentage of industrial structure in the west cities, and most of them are energy-intensive and highly polluting industries. After the implementation of the policy, the response is more sensitive. Moreover, with the strong support of the "Western Development" and other national strategies, the economic base has been improved and the environment for technological innovation has been enhanced, so the policy is more effective in pollutant reduction. However, the information foundations of cities in the central region are relatively weak, the infrastructures for Internet development are inadequate and the influences of resource endowment and other factors still hinder them from exerting the policy effect.

6. Conclusions and Prospects

6.1. Conclusions and Suggestions

This paper focuses on the NGIDCP and uses the DID model to analyze the data of 280 cities in China from 2008 to 2019. It examines its impact on urban environmental pollution, tests the mediating mechanism and further analyzes the heterogeneity of the impact on urban environmental pollution in different regions. The findings are as follows: first, the NGIDCP can significantly reduce urban environmental pollution. Second, the NGIDCP can improve the informatization level and technological innovation to reduce urban environmental pollution in the pilot cities. Third, the impact of the NGIDCP on urban environmental pollution has regional heterogeneity, and the policy effect is significant in the eastern and western regions, but not in the central region. Therefore, it can be concluded that establishing the next-generation Internet demonstration cities can foster the regional Internet development, enhance the informatization level and technological innovation capacity of urban environmental protection and promote the integration of digitalization and industrialization. At the same time, it optimizes the industrial structure and significantly reduces the energy consumption and urban environmental pollution of pilot cities.

The above conclusions support the previous research conclusions that most scholars believe that the growth of the Internet economy can reduce environmental pollution. However, there are differences in the analysis of regional impact differences, and some studies have found that the effect of digital economy development on the emission reduction of environmental pollution in China is not significant in the western region, and the possible reason for the different findings in ourstudy may be that there are differences in the research time span of this paper, and the implementation time of policies such as the large-scale development of the western region is relatively short when the existing literature is studied, so there are differences in the research findings.

According to the results, the following policy suggestions are put forward. First, it should speed up the construction of Internet infrastructure and the popularization of the next generation Internet as well as the integration with traditional industries. Based on the NGIDCP, it is necessary to accelerate the application of information technology in traditional industries, and drive the transformation of traditional industries to digitalization, intelligence and greening. It should improve the production, transportation and sales efficiency of products, as well as reducing the depletion of resources and the emission of pollutants in the city. Second, it should increase the policy support to foster technological innovation and the development of the digital industries. Technological innovation is an important way to mitigate urban environmental pollution. The government can take the improvement of technological innovation and scaling up the digital economy as the purpose in the future policy formulation. In addition, it should provide support by investing more in innovation, bringing in technical talent and strengthening digital technology infrastructure. Third, the cities in the central region should seize the policy opportunity and enhance the comprehensive competitiveness of regional cities. Central cities should recognize the importance of the Internet, and strengthen the introduction of technical talents and high-quality foreign investment. It is also essential to improve the capacity of technology innovation, develop a digital economy and optimize the industrial structure, reduce urban pollutant discharge and improve the pollution control capacity. Fourth, the government needs to take the lead and fully demonstrate the Internet's role in advancing the green economy. The main way to reduce urban environmental pollution in China is to change the mode of economic development and pursue quality while increasing the speed of economic growth. The government should actively foster the development of high-tech enterprises that use the Internet as a platform, and increase the share of the high-tech industries in the economy. Moreover, it should also inspire contemporary college students to launch their own high-tech ventures and provide a favorable policy environment for their entrepreneurship.

6.2. Shortcomings and Prospects

The shortcomings of the study are mainly listed below:

First, due to the availability of the existing data and the change of data statistical caliber, this paper may not be comprehensive in determining the measurement indicators of environmental pollution, and it is necessary to collect richer data as much as possible in future studies to measure the level of urban environmental pollution more comprehensively.

Second, the impact mechanism of Internet development on environmental pollution is complex and diverse, but is limited by the lack of relevant data and materials; this paper only analyzes from the two mechanisms of the information level and technological innovation, which will make the research of this paper slightly incomplete, so it is necessary to strengthen the collection of relevant data in future research, and also enrich the knowledge reserve of relevant theories.

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