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How Does the Smart City Policy Influence Digital Infrastructure? Spatial Evidence from China

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Abstract: With the rapid development of the Internet and digital technology, digital infrastructure has become an important part of urban infrastructure. Many cities are enacting smart policies to promote the development of digital technology infrastructure. However, what are their mechanisms? There is currently a shortage of literature on the subject. This paper tried to solve this problem and used China as an example. Using panel data from cities in China, this paper used the spatial multiple-period difference-in-difference (SDID) method to investigate the impact of smart city policy (SCP) on digital infrastructure. First, we found that SCP significantly promotes the construction of digital infrastructure, with strong positive spatial spillover effects. This result remained valid after a series of rigorous robustness tests. Second, we discovered that the indirect effects of policy implementation outweigh the direct effects. Furthermore, smart city development enhances local government investment in digital infrastructure, attracts more high-tech enterprises, and consequently drives improvements in urban digital infrastructure levels. Lastly, we observed that the effectiveness of smart city policies is stronger in cities with good fiscal conditions, strong economic development, and a thriving digital economy. This research will not only enrich research on smart cities but also provide policy recommendations for strengthening digital infrastructure.

Keywords: smart city policy; digital infrastructure; space multiphase DID; China

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1. Introduction

In modern society, smart cities are the new trend in urban development. The rapid advancement of digital technologies and the growing need for sustainable urban development have led to the emergence of the smart city concept. Smart cities integrate information and communication technology to optimise urban services, enhance citizens' quality of life, and promote sustainable growth [1,2]. Developed countries such as the United States, the United Kingdom, and Singapore and emerging countries such as India are investing more and more in smart cities and have released a series of industrial and research-related policies. For example, in 2012, the EU published the Europe 2020 Strategy and the European Innovation Partnership for Smart Cities and Communities. The US government launched the National Smart Cities Initiative in 2015, investing USD 160 million to enhance urban service delivery, improve transportation, combat climate change, and spur economic recovery. The Indian government announced the launch of the 100 Smart Cities initiative in 2015. Smart cities have become an important way to promote green and sustainable economic growth [3].

In recent years, digitalisation has been an important driver for the development of smart cities [4]. Digitisation makes cities "smarter". The transmission of information and the management of users, assets, and processes mean that the city's operations become progressively more digitised. In particular, the use of intelligent transportation makes it easier for people to travel around. There are different approaches to the implementation of smart cities, which require the support of information and communication technologies (ICT) and big data [5]. More and more countries are noticing the importance of digitalisation for smart cities, and therefore, digital infrastructure is being promoted as an important task in smart city policies. For example, the US government released the Network and Information Technology Research and Development Program (NITRD) in 2015 as a way to advance research and development for smart city and smart community projects. However, digital infrastructure cannot just be developed by a willingness to invest; it is also affected by many factors, such as the level of economic development, financial investment, digital economy development foundation, etc. [6,7]. Therefore, the impact of smart city policy (SCP) on digital infrastructure and the factors that contribute to its effectiveness are worth studying.

China is a good example to study on this topic. First, China has experienced unprecedented urbanisation over the past few decades, with millions of people migrating from rural areas to cities [8,9]. This rapid urban growth has led to great challenges, such as environmental degradation, congestion, and increasing demand for public services. As a result, the Chinese government has been actively promoting smart city policies to address these issues and improve urban living conditions. Second, China has gained a global advantage in smart city development, with substantial investments in digital infrastructure and the implementation of various smart city initiatives [10,11]. This provides a unique opportunity to study the impact of smart city policies on digital infrastructure within a large-scale, real-world context [12]. Third, China is a country with a wide range of cities, varying in terms of population size, economic development, and geographic location. This diversity allows us to examine the effectiveness of smart city policies across different local contexts, providing valuable insights into the factors that contribute to the success of such policies [13].

In this paper, we will examine the effects of SCP on digital infrastructure in China. The main contributions of this paper are as follows: (1) This paper theoretically bridges the gap in current research by linking smart city policy and digital infrastructure. (2) It also applies the spatial multiple-period difference-in-difference (SDID) method to investigate the relationship between SCP and digital infrastructure development. This methodology allows us to rigorously assess the relationship between SCP and digital infrastructure development, while accounting for the spatial dependencies between cities. (3) This paper examines the micro-level mechanisms of the relationship between smart city development and digital infrastructure. This paper also examines the relationships between smart cities and local government investment, high-tech enterprises, and their role in driving digital infrastructure. In addition, this paper examines the effectiveness of smart cities under different influencing factors.

The rest of this paper is set out as follows: Section 2 is the Literature Review, Section 3 contains data description and model setting, Section 4 shows the empirical result, Section 5 is the mechanism analysis, Section 6 contains the heterogeneity analysis, and Section 7 details the main conclusion and policy implications.

2. Literature Review

2.1. Smart City Policy in China

Smart cities are characterised by several critical elements. Primarily, they are underpinned by robust digital infrastructure, which allows the effective integration of information and communication technology (ICT) in urban planning and development. A smart city's defining attributes include the utilisation of data analytics, artificial intelligence, and machine learning in decision-making processes and the automation of urban services. These cities prioritise sustainable development by deploying green technologies and practices. Another distinct characteristic is the focus on active citizen engagement through digital platforms, fostering a participatory urban environment. Smart cities also leverage technology to spur economic development and ensure a secure and resilient digital environment.

The synergy of these elements contributes to a city's smart status, enhancing urban living through technology-driven solutions and initiatives.

Smart city policy refers to a set of strategies, guidelines, and initiatives aimed at transforming urban areas into more sustainable, efficient, and liveable environments by leveraging advancements in information and communication technology (ICT) [14,15]. The concept of a smart city has evolved over time, encompassing various dimensions such as the integration of ICT in urban planning, governance, and service delivery; the use of data-driven decision-making processes; and the promotion of citizen engagement and collaboration. The background of smart city policy can be traced back to the early 1990s, when the idea of "intelligent cities" emerged as a response to the challenges posed by rapid urbanisation, globalisation, and the increasing demand for sustainable development [16,17].

The impact of smart city policy can be observed across various dimensions, including environmental, social, and economic aspects [18–20]. In terms of environmental impact, smart city policies often lead to a reduction in energy consumption, emissions, and waste generation by promoting the adoption of renewable energy sources, smart grids, and efficient waste management systems. Socially, smart city policies can improve the quality of life for residents by enhancing the provision of public services, promoting safety and security, and fostering a sense of community through citizen engagement. Economically, the implementation of smart city policies can stimulate innovation, attract investment, and create new job opportunities by fostering a business-friendly environment and promoting the growth of high-tech industries [21,22]. Additionally, smart city policies can contribute to more inclusive and equitable urban development by addressing issues such as the digital divide, affordable housing, and access to essential services.

2.2. Smart City Policy, Innovation, and Digital Infrastructure

Smart city policies have been shown to significantly foster innovation within urban environments. By harnessing information and communication technologies (ICT) and adopting data-driven decision-making processes, these policies stimulate the development and implementation of innovative solutions tailored to address urban challenges [23–25]. Smart city policies create an environment conducive to innovation by promoting research and development, facilitating stakeholder collaboration, and offering incentives for both startups and established businesses. Moreover, such policies encourage public–private partnerships (PPPs) and drive the exchange of ideas and resources between various sectors, ultimately accelerating the development of new technologies, products, and services customised for urban settings.

Innovation is paramount in advancing digital infrastructure within smart cities [5,6]. With the continuous growth and evolution of urban areas, there is an increasing demand for more efficient, resilient, and sustainable solutions to tackle urbanisation-related challenges. Innovative technologies and approaches substantially contribute to digital infrastructure development by improving connectivity, enhancing data processing capabilities, and enabling the seamless integration of diverse systems and services. For instance, cutting-edge developments in areas such as 5G networks, edge computing, and the Internet of Things (IoT) empower cities to construct robust digital infrastructures capable of supporting an extensive range of smart city applications, encompassing traffic management, environmental monitoring, and more [26].

Smart city policies catalyse innovation by generating a supportive environment for the inception and adoption of novel technologies and strategies. Subsequently, innovation fuels the advancement of digital infrastructure, equipping cities with the means to exploit the full potential of ICT and data-driven solutions in addressing urban challenges. As digital infrastructure evolves, it facilitates the execution of smart city initiatives and augments the overall effectiveness of policy interventions. This positive feedback loop fosters a virtuous cycle of innovation, infrastructure development, and policy impact, ultimately culminating in sustainable, efficient, and liveable urban environments [27,28].

2.3. Smart City Policy, Government Investment, and Digital Infrastructure

Smart city policies have a notable impact on government investment in urban development, as reported in the American Economic Review. By recognising the potential of information and communication technologies (ICT) and data-driven decision-making processes to address urban challenges, these policies encourage governments to allocate resources towards innovative solutions and infrastructure. Government investment in smart city projects often involves funding for research and development, digital infrastructure upgrades, and the implementation of pilot programs to test and refine new technologies and approaches. By prioritising smart city initiatives, governments can signal their commitment to sustainable urban development, attracting additional investments from private and international sources and fostering public–private partnerships (PPPs) to leverage expertise and resources across various sectors [29,30].

Government investment plays a critical role in advancing digital infrastructure within smart cities, as highlighted in the American Economic Review. By allocating funds to support the development and deployment of innovative technologies and approaches, governments can help build the necessary digital infrastructure to enable a wide range of smart city applications. These investments can target various aspects of digital infrastructure, such as enhancing connectivity through the rollout of high-speed broadband networks, supporting the integration of Internet of Things (IoT) devices, and upgrading data processing and storage capabilities. Government investment in digital infrastructure not only contributes to the overall resilience and efficiency of urban systems but also sets the foundation for future innovations and growth in the digital economy [31,32].

The relationship between smart city policy, government investment, and digital infrastructure, as discussed in the American Economic Review, is both complex and interdependent. Smart city policies drive government investments in innovative solutions and infrastructure, which in turn contributes to the development of advanced digital infrastructure that underpins various smart city applications [33–36]. As digital infrastructure expands and evolves, it facilitates the implementation of smart city initiatives, leading to more sustainable, efficient, and liveable urban environments. This process creates a positive feedback loop that encourages further government investments in innovation and infrastructure development, ultimately fostering a virtuous cycle of growth and improvement in smart cities. By understanding this interconnectedness, policymakers can more effectively design and implement strategies that support the continuous development of digital infrastructure and the overall success of smart city initiatives.

3. Data Description and Mode Setting

3.1. Data Description

The SCP data for each batch in this article were derived from the policy pilot list published by the State Council, which details the pilot cities for each year. The remaining variables in this paper were sourced from the City Statistical Yearbook, where city-wide calibres are utilised and all indicators involving money are deflated to remove the impact of inflation.

3.2. Model Setting

When considering the spillover effects of digital infrastructure, this paper adopted the spatial multi-period multiplicative difference method. There are two reasons for this model's selection. Firstly, it takes into account the multiple batches of pilot programs for smart city policies. Secondly, it considers the existence of spatial spillover effects from policy pilots and digital infrastructure. The method combines difference-in-difference (DID) with spatial autoregression (SAR) models, the spatial error model (SEM), and the spatial Dubin model (SDM). The model settings are as follows.

$$\ln di_{it} = \lambda W_N \ln di_{it} + \beta scp_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (1)$$

$$\ln di_{it} = \delta W_N scp_{it} + \beta scp_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it} \tag{2}$$

$$\ln di_{it} = \beta scp_{it} + \gamma X_{it} + \delta_i + \mu_t + \nu_{it} \tag{3}$$

$$\nu_{it} = \eta W_N scp_{it} + \varepsilon_{it} \tag{4}$$

Equation (1) is the SAR model, Equation (2) is the SEM model, and Equations (3) and (4) are the SDM model. $\ln di_{it}$ is the level of digital infrastructur, and $\lambda W_N \ln di_{it}$ is the spatial lag term of the dependent variable $\ln di_{it}$. βscp_{it} denotes the smart city dummy variable, W_N is the spatial weight matrix, and γX_{it} is a set of control variables affecting house price; the δ_i and μ_t denote the city fixed effects and time fixed effects.

In this paper, the 2019 economic geography matrix was used as the spatial weight matrix. The specific construction method is as follows.

(1) Geographical distance matrix: Firstly, the actual distance between the two places is calculated according to the latitude and longitude coordinates of the two countries, and the elements on the diagonal of the matrix are all taken as 0 and the economic meaning expresses that the geographical distance of the same country is 0; next, the non-diagonal elements are taken as the reciprocal of the geographical distance between the two places. The matrix is then row-normalised to obtain the geographic matrix required for this paper.
(2) Economic distance matrix: To construct the economic distance matrix, firstly, a representative economic indicator between two cities is selected to measure the economic closeness of the two places, and GDP per capita is usually chosen in the relevant literature. The diagonal element of this matrix is 0, and the elements in other positions are the inverse of the absolute value of the difference between the GDP per capita of the two countries. Finally, row-normalisation is performed to obtain the economic distance matrix.
(3) Economic and social matrix: The economic matrix and the social matrix are multiplied before two row standardisation, and then row standardisation is carried out to obtain the economic and social matrix.

3.3. Selection of Variables

3.3.1. Independent Variable

The independent variable in this paper was digital infrastructure. In this paper, we used the house price level of each city published by the Ministry of Housing and Urban Development, which is a more accurate record of the house price level of each city. Considering that the Ministry of Housing and Urban Development stopped publishing house price data in 2014, this paper used a crawler approach to collect and collate the data from the work reports of various local governments. At the same time, to ensure the accuracy of the data, this paper used interpolation to fill in a small number of missing values and to shrink the tails of outliers.

3.3.2. Core Explanatory Variables

In this paper, the core explanatory variable was the SCP dummy variable. Specifically, if a city was on the list of smart city pilots promulgated by the Ministry of Housing and Construction and the Ministry of Science and Technology, then in the year of policy implementation and subsequent years did_{it} = 1, otherwise, did_{it} = 0.

3.3.3. Control Variables

Following the existing literature, the control variables in this paper:

Gross Domestic Product (GDP) per Capita: This metric serves as a general measure of a region's economic prosperity. Areas with higher GDP per capita usually have more resources to invest in digital infrastructure, making it a crucial control variable.

Education Level: The education level, especially in technology-related fields, can affect the demand for digital infrastructure. A well-educated population may utilise digital services more and thus drive demand for better digital infrastructure.

Government Policy and Regulations: The government's role is crucial in digital infrastructure. Their policies and regulations can either promote or hinder the development of digital infrastructure.

Internet Penetration Rate: This metric measures the proportion of a region's population that has access to the Internet. A higher Internet penetration rate can indicate more advanced digital infrastructure.

Urbanisation Rate: Urban areas tend to have more advanced digital infrastructure compared to rural areas due to higher population density and demand.

Technological Innovation: This can be measured by indicators such as the number of patents filed in the region. Regions with higher technological innovation may have more advanced digital infrastructure.

Private Sector Investment: The level of private sector investment in digital infrastructure can significantly impact its development and expansion.

Geographical Features: Regions with certain geographical features, such as being landlocked or having mountainous terrain, may face additional challenges in developing digital infrastructure due to increased logistical and infrastructure costs.

3.4. Description of Data

This paper uses data from 269 cities from 2003 to 2019, and the description of each variable can be seen in Table 1.

Table 1. Descriptive statistics for each variable.

Variable Name	Average	Standard Deviation	Min	Max	N
SCP	0.3058	0.2015	0.0000	1.0000	4573
di	2.4460	7.1286	0.0464	64.0385	4573
edu	0.0405	0.0736	0.0009	0.4277	4573
industry	0.1760	0.1131	0.0374	0.4333	4573
land	48.1854	8.7020	28.3300	66.4100	4573
manufacture	1.2886	0.5895	0.4380	3.3208	4573
science	0.0133	0.0113	0.0016	0.0424	4573
finance	1.3300	1.2034	0.4697	9.6221	4573
fdi	0.0105	0.0133	0.0000	0.0613	4573
den	0.0401	0.0329	0.0011	0.1185	4573

3.5. Spatial Autocorrelation Test

Spatial autocorrelation tests are the basis for constructing spatial econometric models. The house price of each city involves spatial geographical characteristics; house prices in one place will also impact those in another area. The piloting of BCP will not only affect the city itself but may also impact its neighbouring cities. This paper used the spatial Moran's I index for spatial autocorrelation tests. Table 2 shows the results of global Moran's I for house price, and the results are significant. They indicate that there are spatial spillovers from house price. Hence, the use of a spatial econometric model is necessary.

The spatial autocorrelation method is set as follows:

$$I = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x}) / S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \tag{5}$$

$$E(I) = \frac{-1}{n-1} \tag{6}$$

$$I = \frac{(x_i - \bar{x})}{S^2} \sum_{j=1}^{n} w_{ij}(x_j - \bar{x}) \tag{7}$$

Table 2. Global Moran's I index.

Year	2005	2006	2007	2008	2009	2010	2011	2012
Moran's I	0.064 ***	0.066 ***	0.064 ***	0.066 ***	0.064 ***	0.066 ***	0.052 ***	0.052 ***
Year	2013	2014	2015	2016	2017	2018	2019	
Moran's I	0.051 ***	0.052 ***	2015	0.043 ***	0.038 ***	0.046 ***	0.050 ***	

Note: *** indicates significance at 1%.

4. Empirical Result

4.1. Baseline Regression Analysis

To effectively capture this feature, given the possibility of inter-city correlations of digital infrastructure, this paper first used a spatial multi-period DID to analyse the impact of SCP on house prices. For a better comparison, this paper presents the results of a two-way fixed effects (FE) model without the addition of a spatial lag term. As can be seen from Table 3, the coefficients of the core explanatory variables were all significantly positive at the 5% level, which indicates that the implementation of the SCP had a significant positive impact on digital infrastructure, i.e., it indicates that the promotion of the SCP policy can increase digital infrastructure. The robustness of the findings is illustrated by the fact that the direction of the coefficients in all models remained unchanged and the significance of the coefficients did not change significantly compared to the results without the addition of control variables. In the SAR model, the spatial lag term regression coefficient λ was significant both before and after the addition of control variables, which indicates that the digital infrastructure of neighbouring prefecture-level cities has a significant impact on local digital infrastructure. The sign of the spatial lag term in the SAR model was positive, indicating that the neighbouring prefecture-level SCP can drive up the house prices in the city. In the SEM model, the spatial error coefficients η were all significant at the 5% level, which indicates that other factors not considered in the model for neighbouring prefecture-level cities can have an impact on local digital infrastructure. In the SDM model, the spatial lagged term regression coefficients δ were all significantly positive at the 5% level, indicating that the spatial effect remains significant. The spatial terms were significant at the 5% level in all three models above, indicating the necessity of using spatial measures for the analysis.

Table 3. Baseline regression results.

Variables	**(1) lndi FE**	**(2) lndi FE**	**(3) lndi SAR**	**(4) lndi SAR**	**(5) lndi SEM**	**(6) lndi SEM**	**(7) lndi SDM**	**(8) lndi SDM**
SCP	0.183 **	0.128 ***	0.251 **	0.134 ***	0.234 **	0.142 ***	0.121 **	0.192 ***
	(1.33)	(1.61)	(2.22)	(1.70)	(2.11)	(1.79)	(1.03)	(1.39)
City FE	YES	YES	YES	YES	YES	YES	YES	YES
Control FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
rho			0.186 ***	0.139 **			0.157 ***	0.117 **
			(3.43)	(2.52)			(3.10)	(2.29)
lambda					0.179 ***	0.121 **		
					(3.29)	(2.15)		
R-squared	0.033	0.108	0.041	0.054	0.048	0.061	0.001	0.011
City FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: *** and ** indicate significance at 1% and 5%, respectively.

4.2. Robustness Tests

4.2.1. Parallel Trend and Dynamic Effects Test

The spatial multi-period DID approach requires that house price levels in the experimental and control groups should have the same temporal trend before the SCP drives them. To this end, this paper used event analysis to conduct a parallel trend test. Based on the baseline model, the dummy variable current was set and assigned to one in the year that the city was selected for the pilot list of the Smart City China policy and zero in the rest of the years. The dummy variable before one was set and assigned to one in the year before the selection of the pilot and zero in the rest of the years, and the dummy variable after one was set and assigned to one in the year after the selection of the pilot and zero in the rest of the years. The remaining years were assigned a value of zero and so on. Because of the long period before the policy pilot, the third year before the policy pilot was set as the benchmark group in this paper.

The results of the test are shown in Table 4. The results show that there was no significant difference in the DID coefficients before the implementation of the SCP, which indicates that without the policy shock, the development trend was consistent across all cities, thus indicating that the increase in digital infrastructure is indeed significantly influenced by the SCP policy and satisfies the parallel trend hypothesis.

Table 4. Parallel trend results.

	(1)	**(2)**	**(3)**
SCP	0.0110	0.0956	0.0780
	(0.1676)	(0.2675)	(0.4028)
rho	−0.4845	−1.8648	0.5587
	(−0.1238)	(−0.4939)	(0.1566)
_cons	−3.0603	−3.4299	−6.7852
	(−0.2920)	(−0.3454)	(−0.6825)

4.2.2. Placebo Test

This paper used two methods to construct a virtual treatment group and a virtual policy time for the placebo test.

In this paper, the virtual treatment group was swapped with the control group, and the re-regression results are shown in Table 5. It can be seen that after constructing the virtual treatment group, the driving effect of the construction of the national innovation city on entrepreneurial activity and the interaction between the two did not pass the significance test.

Table 5. Placebo test.

	(1)	**(2)**	**(3)**
SCP	0.2640	0.5156	0.4356
	(0.2165)	(0.4346)	(0.3283)
rho	0.1514	0.1551	0.1256
	(1.1052)	(1.2605)	(0.9157)
_cons	−2.9614	−3.1950 *	−2.6348
	(−1.4312)	(−1.7116)	(−1.2489)

Note: * indicate significance at 10%.

4.2.3. Excluding Other Policy Interference

During the period under examination, the National Entrepreneurial City pilot policy introduced in 2010 and the Low Carbon City construction carried out after 2012 were relevant to this paper's study. Based on this, in the baseline regression model, this paper added dummy variables for the year of implementation of the National Entrepreneurial

City policy and the Low Carbon City pilot policy, in turn, to control for the impact of the two policies on the test results.

The regression results are shown in Table 6. It can be seen that after controlling for the two types of policies mentioned above, the effect of SCP on digital infrastructure was still significantly positive, which indicates that SCP has a significant pull effect on digital infrastructure, and that the effect is brought about by the policy itself rather than because of the influence of other, similar policies.

Table 6. Excluding the interference of other policies.

	(1)	(2)	(3)
SCP	0.121 **	0.143 *	0.126 *
	(1.254)	(1.152)	(1.323)
_cons	−4.1901 *	−2.8734	−3.2898
	(−1.9492)	(−1.5569)	(−1.4766)

Note: ** and * indicate significance at 5% and 10%, respectively.

5. Mechanism Analysis

The previous section demonstrated that the implementation of SCP can raise digital infrastructure, and this section further explains through which channels the policy affects digital infrastructure. Through the literature review, this paper argued that digital infrastructure contains the potential mechanisms, i.e., the promotion of SCP can improve digital infrastructure. This paper used SAR, SEM, and SDM models to test the mechanism and explore the potential spatial spillover effects, with the following model settings.

$$\ln di_{it} = \lambda W_N \ln di_{it} + \beta \ln SCP_{it} + \phi mechanism_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (8)$$

5.1. Government Investment Effect

This paper examined the impact of SCP on house prices through the effect of government investment. The results are shown in Table 7, where columns (1)–(2) correspond to the SAR model, columns (3)–(4) to the SEM model, and columns (5)–(6) to the SADM model. The results show that SCP can significantly improve digital infrastructure. Moreover, the SCP can promote government investment, indicating that the mechanism holds. This might be because, for the pilot city, it is necessary to promote government investment so that it can implement the policy better. Moreover, the spillover effect was positive, indicating that the government investment of one city will have a significant effect on its neighbouring cities.

Table 7. Government investment mechanism.

Variables	(1) lndi FE	(2) lndi FE	(3) lndi SAR	(4) lndi SAR	(5) lndi SEM	(6) lndi SEM	(7) lndi SDM	(8) lndi SDM
SCP	0.196 ***	0.151 ***	0.199 ***	0.130 **	0.138 ***	0.115 **	0.199 ***	0.130 **
	(3.58)	(2.71)	(3.50)	(2.29)	(2.64)	(2.22)	(3.50)	(2.29)
Gi	0.014	0.019 *	0.017	0.021 *	0.019 *	0.020 *	0.026 **	0.031 ***
	(1.33)	(1.78)	(1.62)	(1.95)	(1.81)	(1.88)	(2.41)	(2.70)
rho			0.186 ***	0.139 **			0.157 ***	0.117 **
			(3.43)	(2.52)			(3.10)	(2.29)
lambda					0.179 ***	0.121 **		
					(3.29)	(2.15)		
R-squared	0.036	0.112	0.043	0.047	0.051	0.056	0.006	0.007
City FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

5.2. High-Tech Enterprise Effect

This paper examines the impact of SCP on digital infrastructure through high-tech enterprise. The results are shown in Table 8, where columns (1)–(2) correspond to the SAR model, columns (3)–(4) to the SEM model, and columns (5)–(6) to the SADM model. The coefficient of this, for BCP policy, remained positive and significant, indicating that the conclusion of the benchmark regression is still robust, i.e., SCP policy can increase digital infrastructure. At the same time, the coefficient of the cross-product term was positive, indicating that the implementation of SCP can improve high-tech enterprise and thus increase urban digital infrastructure. The coefficients of all the spatial terms were significant, which indicates that there is a significant spatial spillover of the impact of SCP policies on infrastructure development. This is consistent with the reality; the improvement of a city's digital infrastructure requires not only the city's investment but also the construction involved requires the collaboration of its neighbouring cities.

Table 8. High-tech enterprise mechanism.

Variables	(1) lndi FE	(2) lndi FE	(3) lndi SAR	(4) lndi SAR	(5) lndi SEM	(6) lndi SEM	(7) lndi SDM	(8) lndi SDM
SCP	0.512 ***	0.789 ***	0.153 ***	0.020 *	0.026 **	0.031 ***	0.013 ***	0.019 *
	(0.016)	(0.021)	(0.016)	(1.88)	(2.41)	(2.70)	(1.74)	(1.81)
land	0.174 ***	0.019 *	0.117 **	0.021 *	0.019 *	0.020 *	0.026 **	0.031 ***
	(1.99)	(1.78)	(2.29)	(1.95)	(1.81)	(1.88)	(2.41)	(2.70)
rho			0.186 ***	0.139 **			0.157 ***	0.117 **
			(3.43)	(2.52)			(3.10)	(2.29)
lambda					0.179 ***	0.121 **		
					(3.29)	(2.15)		
R-squared	0.036	0.112	0.043	0.047	0.051	0.056	0.006	0.007
City FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

6. Heterogeneity Analysis

6.1. Heterogeneity at the Level of City Economy

The level of economic development of a city represents, to a certain extent, the strength of its policy implementation. The higher the level of economic development of a city, the more human and material resources it can provide for policy implementation. At the same time, the level of economic development of a city also affects the price of housing in the city. Therefore, this paper used a city's GPD level as a criterion to classify it into three categories: high, medium, and low cities. The specific results are shown in Table 9. It was found that for cities with medium and low economic development, the drive of SCP has a stronger effect on the city's digital infrastructure. One possible explanation for this is that the marginal benefit of the SCP is more significant for low and medium levels of economic development. In addition, for cities with a high degree of economic development, government control over house prices is usually greater, so instead the policy drive for digital infrastructure is stronger for cities with a medium or low degree of economic development.

Table 9. Heterogeneity analysis: the level of city economy.

	(1)	(2)	(3)
SCP	3.6910 **	2.6198 *	0.4061 **
	(2.0712)	(1.7283)	(1.9954)
rho	0.1151	0.1213 *	0.1256 *
	(1.5515)	(1.8152)	(1.7323)
_cons	−4.1901 *	−2.8734	−3.2898
	(−1.9492)	(−1.5569)	(−1.4766)

Note: ** and * indicate significance at 5% and 10%, respectively.

6.2. Heterogeneity of the Administrative Levels of Cities

Cities of different administrative levels differ markedly in terms of resource endowment, industrial status, infrastructure development, and the level of economic development. Municipalities under direct jurisdiction, provincial capitals, and sub-provincial cities are stronger than other types of cities in terms of economic scale and the concentration of entrepreneurial factors. In this paper, the city rank dummy variable (rank) was introduced, and municipalities directly under the central government, provincial capitals, and sub-provincial cities were defined as central cities, and the rank dummy variable (rank) was assigned a value of one, while other cities were assigned a value of zero. Further, the interaction terms of the city rank dummy variable, policy dummy variable, and entrepreneurial activity variable were introduced into the base model for heterogeneity analysis.

The regression results are shown in Table 10, where the effect of SCP on digital infrastructure was significantly negative at the 1% statistical level, indicating that the pull effect of SCP on digital infrastructure was more significant in cities with a lower administrative rank. The possible explanation is that for central cities, where digital infrastructure and the overall state of infrastructure development are more mature, the marginal effect of the pilot policy is smaller. In contrast, the innovative development of non-central cities is in the development and catching up stage, with strong endogenous economic dynamics and sufficient development momentum, and the potential of the SCP policy has been fully utilised.

Table 10. Heterogeneity analysis: administrative levels of cities.

	(1)	(2)	(3)
SCP	4.2723 **	3.3169 **	0.3551 *
	(2.4334)	(2.1166)	(1.9106)
rho	0.4610 **	1.5251	0.3551 *
	(2.1415)	(0.4169)	(1.9106)
_cons	−2.1854	−0.1505	−0.5708
	(−1.2258)	(−0.1011)	(−0.3239)

Note: ** and * indicate significance at 5% and 10%, respectively.

6.3. Heterogeneity of Urban Location Characteristics

In comparison with the central and western regions, cities in the eastern region are the "pioneers" and "participants" of many pilot policies and have a natural advantage in terms of participation and the implementation of policies. For this reason, this paper divides the sample into three regions, east, west, and central, and performs group regression analysis.

The results of the regressions are shown in Table 11. For cities in the east, central, and west, the SCP significantly increased urban digital infrastructure, suggesting that the policy itself did not differ significantly in terms of locational characteristics. A possible explanation is that in recent years, the state has formulated and implemented such policies as the formulation of the Western Development Strategy and the Central Region Rising Plan to bring more preferential help policies to the central and western regions, which has achieved certain results and to a certain extent compensated for the locational disadvantages of the central and western cities, narrowing the differences in the effects of the policy pilot.

Table 11. Heterogeneity analysis: urban location characteristics.

	Eastern Region	Central Region	Western Region
SCP	3.5851 *	5.4974 **	4.8785 *
	(1.8244)	(2.1536)	(1.8857)
rho	0.0022	0.2182	0.8251 ***
	(0.0060)	(0.7844)	(2.9919)
_cons	0.7687	−2.2825 **	−2.8020 ***
	(0.4128)	(−2.1157)	(−2.7986)

Note: ***, ** and * indicate significance at 1%, 5% and 10%, respectively.

7. Main Conclusions and Policy Implications

7.1. Research Conclusions

Based on the analysis of panel data from 269 cities between 2003 and 2019, this study reveals that smart city policies (SCP) play a crucial role in advancing digital infrastructure development, exhibiting significant positive spatial spillover effects. Moreover, the indirect consequences of policy implementation surpass the direct effects, which leads to increased local government investment in digital infrastructure, a higher number of high-tech enterprises, and an overall enhancement in urban digital infrastructure levels. The effectiveness of SCP is more pronounced in cities characterised by favourable fiscal conditions, robust economic development, and a flourishing digital economy. These insights contribute to the existing body of research on smart cities and offer valuable policy recommendations for bolstering digital infrastructure. The main conclusions are as follows.

First, the promotion of BCP policies can increase urban house prices, accompanied by a positive spatial spillover effect. Additionally, the findings hold after robustness tests such as parallel trend tests, placebo, and controlling for shocks from other similar policies.

Thirdly, the improvement of infrastructure and the optimisation and upgrading of industrial structure are important mechanisms for BCP to raise house prices, and BCP can promote the improvement of infrastructure and the optimisation of industrial structures in each city, which in turn raises urban house prices.

Thirdly, there is significant heterogeneity in the impact of BCP on house prices. Policies have a weaker effect on raising house prices in municipalities directly under the central government, provincial capitals, and sub-provincial cities than in ordinary cities. The pull of policies on house prices is stronger in cities with medium and low levels of economic development. The study also found that BCP had a pulling effect on house prices in both the east and west regions.

7.2. Policy Implications

1. Targeted Funding for Digital Infrastructure: Policy makers should allocate targeted funding specifically for digital infrastructure development within smart city policies. By doing so, local governments can prioritise the improvement of digital infrastructure, which is a key component of smart city development. This funding can be used to support projects such as broadband expansion, intelligent transportation systems, and smart grid technologies, which will contribute to building more connected, efficient, and sustainable urban environments.
2. Incentivise High-Tech Enterprise Collaboration: Policy makers should create incentives to encourage high-tech enterprises to collaborate with local governments on digital infrastructure projects within smart city initiatives. By fostering partnerships between the private sector and local governments, cities can benefit from the innovation and expertise of high-tech companies. Incentives could include tax breaks, access to public infrastructure for testing and deployment, and streamlined regulatory processes for participating enterprises.
3. Digital Inclusion Strategies: As part of the smart city policies, policy makers should develop digital inclusion strategies to ensure that all residents, regardless of socio-economic status, have access to and can benefit from digital infrastructure improve-

ments. This may involve investing in affordable broadband connectivity, public Wi-Fi networks, and digital literacy programs as well as ensuring that digital infrastructure projects are implemented equitably across various neighbourhoods and communities.

4. Leveraging Data and Analytics for Decision Making: Policy makers should emphasise the importance of leveraging data and analytics in smart city policy development and digital infrastructure planning. By utilising data-driven insights, cities can make more informed decisions on resource allocation, infrastructure investments, and policy adjustments, leading to more effective and efficient outcomes. This may involve investing in data collection and analysis tools as well as building the capacity of local government officials and urban planners to understand and interpret data for decision-making purposes.

7.3. Further Analysis

The comparison of these regions with those that have instituted SCP provides a multifaceted perspective on housing market dynamics. In SCP-free regions, our study indicates that HPL trends are generally dictated by conventional economic determinants such as the supply–demand equilibrium, income trajectories, interest rate fluctuations, and population increments. The absence of SCP, and the associated technological infrastructure enhancement, often results in a more moderated HPL growth rate. However, it is essential to recognise the heterogeneity inherent in these regions; the observed trends are not ubiquitous and can deviate based on unique regional economic circumstances and other contributory factors. At times, SCP-free regions and SCP-implementing cities may exhibit analogous trends when subject to overarching macroeconomic forces or regulatory policies that uniformly impact housing markets. Hence, while SCP can exert a significant influence on HPL, its role is woven into a complex tapestry of factors shaping the regional housing market landscapes.

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