RESEARCH ARTICLE

Research on smart city construction and rural revitalization strategy in urban and rural planning and land space governance

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The inclusion of smart city programs (SCPs) has emerged as an important strategy to improve rural-urban collaboration and meet the needs of coordinated growth in rapidly developing regions. SCPs leverage technology to improve governance, encourage resource sharing, and bridge the gap between urban and rural areas. Recent studies have shown that SCPs improve rural-urban interactions, but a thorough understanding of their processes and impacts on collaborative development remains unexplored. Previous studies have focused primarily on technical elements, often overlooking the socioeconomic consequences of SCP implementation. Despite the recognized advantages of SCPs, significant difficulties remain in determining their effectiveness, particularly in terms of spatial dependence and the role of policy frameworks. There is an urgent need to understand the causal relationship between SCP implementation and the dynamics of rural-urban collaboration. The objectives of this study were to explore the impact of SCPs on collaborative growth in rural-urban areas and to understand how these programs promoted inter-regional collaboration. Furthermore, this study aimed to fill the gap in previous research by providing empirical evidence of the role of SCPs in promoting sustainable regional growth. This study used a difference-in-difference (DID) approach and a spatially differential difference-in-difference (SDID) model to study panel data of 275 cities from 2007 to 2022 in China. The regression evaluation, parallel trend validation, and placebo tests were applied. The results suggested that SCP significantly improved rural-urban cooperation and generated positive regional spillover effects. This study expanded the body of knowledge by providing insights into the effectiveness of SCP as a revolutionary tool for regional growth and its practical implications for policymakers seeking to promote long-term rural-urban partnerships.

Keywords: smart city; rural revitalization; land space governance.

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Introduction

Due to the trend of development and modernization, many old industrial areas in China have disappeared. However, the rise of smart city projects provides an opportunity to give these areas a new lease of life using new technologies and urban planning approaches [1]. Smart city initiatives are making this change possible. As part of China's smart city development, Botti *et al*. explored the pros and cons of restoring old industrial areas and urban industrial history [2]. Zhu *et al*. specifically focused on the rehabilitation of urban industrial heritage [3]. Many researchers are interested in the idea of "smart cities" and how these places try to achieve sustainable development (SD). A study by Xia *et al*. investigated how to combine a geographic information system (GIS) and building information modeling (BIM) in digital twin technologies for towns and found that the year 2022 highlighted the potential of this integration for the creation of smart cities that were environmentally friendly [4]. The goal of smart city is to learn how to use the self-organizing feature map (SOFM) model to figure out how rural regional functions are identified and changed, which may give us a better understanding of how rural regions are developing in China's central plains urban agglomeration [5]. In addition, Vardopoulos *et al*. looked at how culture could lead to sustainable cities in smart tourist spots and how that related to the world's real estate market [6]. Another study shed light on how culture could help cities growing sustainably and emphasized how important public libraries were for smart city ideas as places for people to meet and share information [7]. Mohamed *et al*. investigated the possibilities for sustainable government in Addis Ababa and the nearby area to shed light on the issues and shift landscape of Ethiopia's urban growth [8]. One way to explore the power relations and social effects of smart towns was through genealogy, which was done with a critical view. The results suggested that there was lack a clear and unified meaning of a smart city, which made people wonder what qualities and conditions made a city smart [9]. As a result of its alignment with the broad objectives of contemporary urbanization, the notion of a smart city seeks to overcome the issues that are confronted by modern urban areas *via* the usage of new technology. These goals include long-term economic growth, good social conditions, protecting the environment, and making good use of resources.

Smart city research includes governance, technology, and sustainability. Čolić *et al*. examined urban governance frameworks in Serbia, emphasizing the Interreg SMF project's impact on smart city policies [10]. Colding *et al*. proposed a system viewpoint, integrating social, ecological, and technological factors for viable urban growth [11]. Shirowzhan *et al*. highlighted the importance of digital twin technology and CyberGIS in improving urban infrastructure planning [12], while Ribeiro *et al*. suggested technological solutions to enhance urban mobility [13]. Further, Quijano *et al*. presented a KPI-driven framework for smart city assessment that was consistent with environmental objectives [14], while Shafiullah *et al*. addressed energy effectiveness difficulties in Southeast Asia [15]. In addition, Tahir and Malek highlighted important requirements for smart city growth [16], which was aided by research findings from Carrera *et al*. who utilized a meta-regression framework to forecast energy use [17], and the reports from Patel and Padhya [18]. Kovalev *et al*. investigated how political models influenced initiatives in cities like Vienna and Lyon, emphasizing the significance of collaborative governance [19]. In a previous study, the scientist criticized urban innovation and the intersection of place and politics [20], whereas Correia *et al*. evaluated the cutting-edge technology applied in Portugal [21]. In China, Shen *et al*. explored how smart cities could improve urban living [22], while Wang investigated execution tactics [23]. Further, Li *et al*. distinguished physical, digital, and smart cities, presenting an in-depth comprehension of the technological environment and community engagement in smart city implementation across multiple regions [24, 25].

Collectively, these studies demonstrated the complex nature of smart city growth in various areas, providing insights into governance, technology, and community engagement. However, previous studies focused primarily on technical elements, often overlooking the socioeconomic consequences of smart city program (SCP) implementation. Despite the recognized advantages of SCPs, significant difficulties remain in determining the effectiveness, particularly in terms of spatial dependence and the role of policy frameworks. There is an urgent need to understand the causal relationship between SCP implementation and the dynamics of rural-urban collaboration. This study aimed to explore the impact of SCPs on collaborative growth in rural-urban areas and understand how these programs promoted inter-regional collaboration using a difference-in-difference (DID) approach and a spatially differential difference-in-difference (SDID) model to study panel data of 275 cities in China from 2007 to 2022. This study would fill the gap in previous research by providing empirical evidence of the role of SCPs in promoting sustainable regional growth.

Materials and methods

Data source

This study used the pilot city registration form issued by the State Council of China to obtain information on the phased implementation of smart city plans. This register tracked the performance of each pilot city every year. Other factors in this study came from the City Statistical Yearbook, which used measurement data applicable to the entire city. The data covering 275 places from 2007 to 2022 was used for this study, which included cities of Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou. The information was applied in several processes, control, independent, and dependent factors, which covered shared services, worker movement, market dependency, and getting to school and the doctor. Digital infrastructure, the mechanism variable, was also measured to show the digital capacity and skill of the place.

Model setting

The Local Moran's Index calculates how much two things depend on each other spatially, which is a way to find out how physically separated two sets of data are from each other. This number illustrates how much spatial variation there is between two variables at different locations. This method was used to find hot spots or groups in how variables were organized in space as follows.

$$I_i = \frac{n}{\sum_j W_{ij}} \frac{(x_i - \overline{x}) W_{ij} (x_j - \overline{x})}{\sum_j (x_i - \overline{x})^2}$$

where W was the neighborhood Moran's indexes for studying purposes. I was the value of local Moran’s index in a city. n was the sum of all the findings. The value of the variable at that point was shown by x. A certain amount of the local Moran's values that were very close to each other were identified, and the distances i and j were calculated. In addition, how SCPs affected the growth of partnerships between cities and rural areas could be learned. If the panel data had treatment variable and regional dependencies, the SDID method was a good way to find relationships or direct links between variables, while cities, as an example, communicated with each other in space were considered. The main idea behind the SDID model could be expressed as below.

$$Y_{it} = \beta_0 + \beta_1 SmartCity_{it} + \beta_2 X_{it} + \lambda WY_{it} + \mu_i + \gamma_t + \varepsilon_{it}$$

where Y was the city development index for city i at the time t. $SmartCity_{it}$ was the policy variable in SDID method, representing smart city construction. X_{it} was the control variable. β_1 was the coefficient estimate, which had a positive value that indicated the smart city construction in urban and rural areas. μ_i was the time fixed effect, while ε_{it} was the random error term and γ_t was the location fixed effect. Those factors were used to account for things in a city that did not change over time and for quick changes in time. As the geographic weight matrix, this study used a 2022 matrix that was based on economic geography. The vertical of the matrix had been filled with zeros because, from an economic point of view, a city was at rest when it came to its distance. An important economic factor was then chosen, which would be helpful to figure out how economically connected the two places were. GDP per person was often used in this topic. In this case, the vertical element stayed at zero, and the changes in the GDP were used to fill in the other parts.

Identification of variables

(1) Independent variable

This measure showed how much help and effort from the government had been put into the process to make a city become a smart city. This change happened in stages, such as building digital infrastructure, switching to new ways of running the government, and offering smart services. A binary Difference-in-Differences (DID) measure was employed for the actual study with the testing smart cities that were set to 1 after the program had been put in place, while the other cities were set to 0. With this method, the effects that SCPs had on the growth of collaboration between cities and rural areas were figured out.

(2) Explanatory variable

A lot of different things about economic unity, social harmony, and natural survival were included in this study. These markers demonstrated how much teamwork was performed between cities and rural areas. This multi-indicator approach made it possible to look into the effects of SCP implementation in a more complete way.

(3) Mechanism variable

The Urban Statistical Yearbook of China identified that the technology infrastructure was the feature that showed how the system worked. Each city's digital infrastructure was analyzed to obtain both comprehensive and accurate information on its current status and progress. It was important to gather a set of signs that showed the digital skills and abilities of the company to correctly evaluate a city's digital infrastructure. This combined measure gave a full picture of a city's digital infrastructure when SCP was put into action and played a role in promoting common urban and rural development.

(4) Control variable

To fully study how cities and rural areas grew together, many city-level control factors were considered including rates of population density, level of knowledge, the rate of urbanization, and the grade of the infrastructure, which might affect both the ability to begin smart city projects and the amount of cooperation between cities and rural areas. The rate of population density might change the interaction of towns and agricultural areas and estimated whether smart city plans were needed or helpful. The level of knowledge, also known as education level, decided how well people could use and benefit from smart city facilities, which might limit how much cooperation between towns and rural places could grow. The rate of urbanization might affect how much teamwork was needed between cities and towns and how smart city policies were put into place. The grade of the infrastructure, such as the energy and transportation networks, determined the advantages of smart city projects and how much cities and towns worked together.

Statistical analysis

SPSS version 25 (IBM, Armonk, NY, USA) was employed for statistical analysis of this research. The Difference in Difference (DID) method was used for analyzing the revitalization strategy of smart city and urban planning.

Results and discussion

Basic data distribution

The distribution of the data used in this study was shown in Table 1. Many different parts of city life and socioeconomic growth among these things could affect how well and how quickly SCPs worked. A complete statistical model was proposed to clearly show how SCPs affected the growth of both urban and country places by including different variables and considering anything that could go wrong.

Spatial autocorrelation

As part of effort for joint growth, the Spatial autocorrelation was performed, and the results showed a strong positive regional scatter among other things (Table 2). Because of the spatial externality, teamwork between cities and similar growth plans became more important when trying to encourage joint development between cities and rural areas. This result supported the use of the SDID model in this research, which

Table 1. The distribution of the data.

Variable Name	Average	Standard Deviation	Min	Max	n
policy	0.3058	0.4994	0.0000	1.0000	3300
urcd	9.0216	0.95279	6.5845	11.3206	3300
lnnos	7.8439	1.3416	2.2192	11.3389	3300
mechanism	1.4466	0.3108	0.7504	2.2343	3300
lnfepc	5.9815	0.6025	3.9894	7.7519	3300
lntrt	4.8716	0.7712	2.7440	7.5956	3300
lntplbc	4.8601	0.9635	2.7080	7.5951	3300
lnwpc	5.6581	0.3609	3.4351	6.4339	3300
lninno	5.9247	0.9348	1.9242	6.9043	3300

Table 2. Moran's I index was used to measure urban-rural collaborative development.

Year	2007	2008	2009	2010	2011	2012
Moran I	0.327 ***	0.332 ***	0.334 ***	0.332 ***	0.336 ***	0.324 ***
Year	2013	2014	2015	2016	2017	2018
Moran I	0.327 ***	0.330 ***	0.326 ***	0.325 ***	0.337 ***	0.338 ***

considered how the factors were related to each other in terms of space.

Baseline regression analysis

The results of treatment variable showed positive and statistically significant, which meant that cities with SCPs had better interaction between towns and rural areas than cities without such a program (Table 3). In addition, a positive regional spread effect was found by a large positive estimate for the dependent variable's spatial lag, which was important and indicated that the SCP not only promoted growth between cities and rural areas in the city that put it into action, but it also did the same for the neighborhood cities. These good spatial effects demonstrated that urban and rural development worked as a network and showed the importance for cities to work together and use the same tactics for policy to work. The findings indicated a link between SCPs and joint growth between cities and rural areas when the SDID model was used correctly and suggested that SCPs played a substantial role in fostering cooperation between urban and rural areas. This study contributed to the expansion of the current body of literature and provided policymakers with insights that could be put into practice.

Table 3. The study of baseline regression.

	(1)	(2)	(3)	(4)	(5)	(6)
	FE		SAR		SEM	
Variables	ch	ch	ch	ch	ch	ch
DID	−0.0539 ***	−0.0525 ***	−0.00373 ***	−0.00313 ***	−0.00373 ***	−0.00313 ***
	(0.000391)	(0.000433)	(0.000391)	(0.000433)	(0.000391)	(0.000433)
Rho			0.850 ***	0.730 ***		
			(0.0105)	(0.0144)		
Lambda					−3.242 ***	−3.231 ***
					(0.0464)	(0.0466)
Observations	3300	3300	3300	3300	3300	3300
Number of cities	275	275	275	275	275	275
City FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y

Robustness check

(1) Parallel trend check

The parallel trend of two sample cities was examined and the results demonstrated that, before SCPs were put in place, there were no structural differences between the two types of towns in how likely they were to work together on growth. There were no changes between the two groups of towns. However, a significant difference was observed after the SCPs, which confirmed the effectiveness of SCPs for joint growth between cities and towns after the policy was put in place (Figure 1). The results indicated that the SCPs were very important in urban and rural communities growing together and confirmed the certainty of the SCPs. The strategy identified through this study has been tested and proven its effectiveness, which opens the door for future studies about how SCPs affect collaborative development between cities and rural areas.

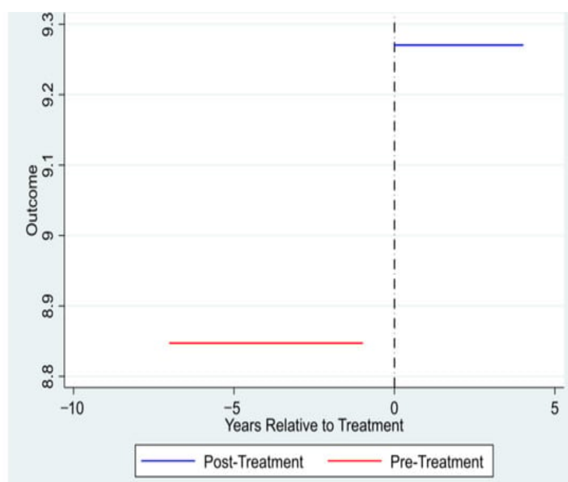

Figure 1. Parallel trends test.

(2) Placebo test

The placebo experiments were carried out to further validate the causal influence that SCPs had on the growth of urban-rural joint projects.

These tests made sure that the results were correct by removing any fake associations and factors that could change the results (Figure 5). There was no significant change in the combined urban and rural growth between the placebo group and the treatment group. However, there was a strong case that SCPs improved teamwork between urban and rural areas, and that changes not visible in the panel data or other factors randomly altered the timing of SCP deployment. The study didn't find any big differences in the growth of partnerships between cities and rural areas between the treatment and control periods. The effects observed lasted longer than chance variations in time, supporting the idea that SCP promoted joint urban and rural development. This study skipped both individual and temporal control testing to show that policy change was what made SCPs help the growth of collaboration between cities and rural areas. However, these strong results showed that SCPs were successful at promoting partnerships between cities and rural areas.

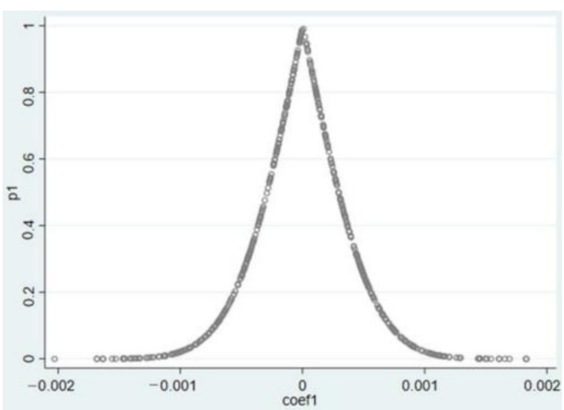

Figure 2. Placebo test result.

(3) Potential policy interference

Thinking about getting involved with policy was integrated into this study. The results showed that it was consistent with the consideration of policy interference and proved that SCPs continued to improve urban-rural collaboration. This persuasive evidence highlighted smart city projects' unique and powerful role in encouraging urban-rural collaboration, surpassing broadband China policy achievements (Table 4). The results of this research shed light on the unique contributions that SCPs had made, which went beyond the sphere of information technology infrastructure. To support fair and balanced urban-rural growth, smart city methods used a wide range of digital tools and government efforts. This research contributed to the existing body of literature by adding academic rigor and depth by methodically examining the possible confusing effects of SCPs on the establishment of collaborative efforts between urban and rural areas. It showed the importance that smart city efforts were as game-changing ways to get people from cities and rural areas to work together and support long-term regional growth.

Conclusion

A complicated urban system consisted of issues, goals, methods, underpinnings, settings, support systems, and safety measures, which had similar features on three levels that touched each other as real space, social space, and virtual space. The different growth stages that smart towns went through were another factor that affected these traits. New information technologies have completely changed how information is sent, which has had a huge impact on operating systems, organizational systems, and institutional systems in cities. The sharing of information has caused these changes. This study explored the growth of smart towns in China. At the academic level, three steps of smart city growth were demonstrated. Smart City 1.0 focused on recording information because new information technologies were growing so fast, which laid the groundwork for everything to be linked and for everyone to see everything and full intelligence. Smart City 2.0 was built by getting rid of data hurdles between departments, letting a lot of different types of data from different sources being combined and used, and encouraging smart improvement and change of many fields. Business and industry will always

Table 4. Consideration of getting involved with policy.

	(1)	(2)	(3)
	Broadband city	Broadband city × SCP	No broadband city
did	−0.0539 ***	−0.0525 ***	−0.00306 ***
	(0.000613)	(0.000910)	(0.000372)
_cons	0.560 ***	0.567 ***	0.0677 ***
	(0.000433)	(0.00510)	(0.00624)

have the power to grow. Building smart cities makes it easy for new ways of living in places to appear. Smart City 3.0 reserved the best part of Smart City 2.0 with the goal of making city life better as its foundation to meet the goals of unity, happiness, and smart cities, which related to the importance for people to be active in running towns.

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