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How Does Smart City Construction Affect Urban–Rural Collaborative Development? A Quasi-Natural Experiment from Chinese Cities

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Abstract: In recent years, smart city construction has brought significant social and economic impacts to emerging economies, especially in narrowing the urban–rural gap. However, there is relatively little empirical research on this aspect. We take China as an example for research. This study uses a Spatial Multi-period Difference-in-Differences (DID) approach to investigate the relationship between smart city construction and urban–rural collaborative development in Chinese cities, taking digital infrastructure as the mechanism variable. Our findings reveal that smart city construction significantly promotes urban–rural collaborative development and exhibits positive spatial externalities. These results remain robust after parallel trend tests, placebo checks, and controlling for other policy interferences. Further analysis suggests that this effect operates largely through the reinforcement of digital infrastructure, whereby the smart city initiatives enhance connectivity and interaction between urban and rural areas, fostering collaborative development. Moreover, the efficacy of smart city policies is found to be particularly prominent in cities with strong economic development, weak levels of urban–rural collaborative development, and high degrees of digitization. By illuminating the role of smart city construction in propelling urban–rural collaborative development, this study provides valuable insights for policymakers.

Keywords: smart city construction; urban–rural collaborative development; spatial multi-period difference-in-differences (DID)

1. Introduction

Urban–rural collaborative development is a central tenet of sustainable economic growth. The advent of smart city initiatives has ushered in new opportunities for integrating urban and rural economies [1,2]. However, a comprehensive understanding of how smart city construction influences such collaboration, particularly in the context of China, is still in its infancy.

We hypothesize that smart city construction can stimulate urban–rural collaborative development through several mechanisms. These mechanisms involve, but are not limited to, the facilitation of digital connectivity, the improvement of access to public services, the enhancement of resource optimization, and the promotion of inclusive economic growth. By providing infrastructure for high-speed digital connectivity, smart cities can bridge the urban–rural digital divide, enabling rural areas to participate more fully in the digital economy. Similarly, smart city initiatives often involve enhancing the delivery and accessibility of public services, which can particularly benefit rural areas that may have traditionally lacked such access. In addition, smart cities' emphasis on resource optimization could have spillover effects that promote the efficient use of resources in rural areas, contributing to sustainable rural development. Lastly, smart city initiatives that aim to promote inclusive

economic growth could facilitate the integration of rural economies into wider urban–rural economic networks.

This study makes a significant contribution to this underexplored area, enhancing our understanding of the linkages between smart city construction and urban–rural collaborative development, while further illuminating the mediating role of digital infrastructure [3].

The rationale for focusing on China is threefold. Firstly, with the Chinese-government-led push towards digitization and urban innovation, China provides a rich landscape for examining the effects of smart city initiatives. Secondly, China presents unique urban–rural dynamics. Rapid urbanization processes juxtaposed with considerable rural populations present a compelling context for exploring urban–rural collaborative development. Thirdly, the Chinese government has invested heavily in digital infrastructure, offering an excellent opportunity to examine how this infrastructure mediates the impact of smart city construction on urban–rural development.

Despite an increasing body of literature on the urban benefits of smart cities, including enhanced efficiency, innovation, and quality of life, their broader implications for urban–rural collaborative development remain largely uncharted [4,5]. Moreover, the specific mechanisms underlying these relationships, particularly the role of digital infrastructure, are poorly understood. Our research addresses these gaps and contributes to the literature by highlighting the potential of digital infrastructure as a catalyst for fostering urban–rural collaboration within the framework of smart city initiatives [6,7].

Employing an SDIS approach, we make three main contributions to the literature. Firstly, we provide empirical evidence of the relationship between smart city construction and urban–rural collaborative development. Secondly, we underscore the central role of digital infrastructure as a mechanism underlying this relationship. Lastly, by focusing on the unique context of Chinese cities, we extend the generalizability of our findings to other rapidly urbanizing and digitizing contexts worldwide.

Our findings hold critical implications not only for China but also for other countries embarking on or expanding their smart city initiatives. As such, they offer valuable insights to policymakers, urban planners, and regional developers on the potential of smart cities as a catalyst for urban–rural collaborative development, with digital infrastructure as a key facilitator in this process. Furthermore, this research establishes a foundation for future studies exploring the synergistic development of urban and rural areas in the digital era.

2. Literature Review

2.1. Smart City Policy in China

The concept of smart cities has emerged as a central theme in the urban development literature, integrating digital technologies with urban infrastructure to drive a sustainable life. A significant portion of the research, however, has focused on the global North, with less attention given to developing contexts like China [8,9]. China has established itself as a global leader in smart city initiatives, making it a critical context for understanding the dynamics of SCP implementation and its effects [10].

China's smart city initiatives are characterized by an ambitious government-led approach to leveraging digital technologies to address urban challenges and foster economic development [11,12]. The Chinese government's smart city vision encompasses facets of digital governance, smart services, and intelligent infrastructure, signifying a comprehensive approach to urban digitization [13,14]. These initiatives have rapidly reshaped urban landscapes and have potential implications for the broader spatial economic context, including urban–rural collaboration.

The potential of smart cities to bridge urban–rural divides in China is an area warranting further exploration. Few studies have delved into how digital transformation within cities can extend to and influence rural areas [15,16]. The urban–rural gap is a pressing issue in China, with urban areas experiencing rapid development while many rural areas continue to lag. Smart city initiatives, backed by substantial digital infrastructure investments, offer new opportunities for fostering urban–rural synergies [17,18].

While the literature has highlighted the significant role of digital infrastructure in driving smart city development, its role as a mechanism linking smart cities and urban–rural collaborative development has yet to be thoroughly investigated [19,20]. This study aims to fill this gap, providing a comprehensive understanding of the dynamics between SCPs, digital infrastructure, and urban–rural collaborative development. By doing so, it significantly contributes to the literature on smart cities, digital infrastructure, and regional economics within the unique context of China [21,22].

2.2. Urban–Rural Collaborative Development

Urban–rural collaborative development is a multidimensional concept that addresses the intersection of urban and rural spaces in the context of economic, social, and environmental aspects [23,24]. It embodies a strategic approach towards fostering synergies between urban and rural areas, advocating for mutual development rather than the conventional one-sided urban-centric growth [25,26]. While precise definitions vary across studies, a common theme emerges emphasizing the interdependence and reciprocity between urban and rural areas, with a focus on ensuring that the benefits of economic development are shared and sustainable [27,28].

Measurement of urban-rural–rural collaborative development often incorporates a variety of indicators to capture its multifaceted nature. These may include metrics related to economic integration, such as the degree of shared services, market interdependence, and labor mobility. Social integration measures, like educational and healthcare access across urban and rural communities and environmental sustainability indicators, are also commonly employed. Such a comprehensive approach allows for a nuanced understanding of the levels and dynamics of urban–rural collaboration [29,30].

The factors influencing urban–rural collaborative development can be categorized into three main domains: policy, infrastructure, and socio-economic conditions. Policy measures, including regional planning and financial incentives, play a significant role in facilitating or impeding collaboration. Infrastructure, particularly digital and transportation networks, serves as a crucial link connecting urban and rural areas. Lastly, socio-economic conditions, such as population density, income disparities, and education levels, also significantly influence the degree of urban–rural collaboration. These elements highlight the complexity and multifactorial nature of urban–rural collaborative development [31,32]. This study adds to this discourse by elucidating the potential role of smart city construction in fostering such collaboration, with digital infrastructure serving as the pivotal factor.

2.3. SCPs and Urban–Rural Collaborative Development

The transformation towards a smart city necessitates an intricately woven digital infrastructure that serves as the core foundation of these initiatives. Advanced digital infrastructure—ranging from broadband networks and data centers to cloud-based services—is imperative for SCPs. It facilitates the integration, processing, and dissemination of data, driving intelligent decision-making, and innovative urban solutions [33,34]. However, more in-depth exploration is required to fully understand how smart city endeavors catalyze digital infrastructure development, especially within the lens of urban–rural collaborative development.

The existing literature underscores the critical role of digital infrastructure in bridging the urban–rural divide. By enabling real-time information exchange, digital infrastructure has the potential to foster economic and social cohesion between urban and rural areas, subsequently facilitating integrative regional development [35,36]. Yet, the pathways through which digital infrastructure stimulates urban–rural collaborative development remain insufficiently mapped, particularly in terms of how these dynamics are influenced by smart city initiatives.

Building on these gaps, this study delves into the uncharted terrain of how smart city construction affects digital infrastructure and, in turn, shapes urban–rural collaborative development. We propose a mechanism whereby smart city construction, through bolstering

digital infrastructure, facilitates urban–rural collaboration. By decoding this relationship, this research bridges the existing gaps in the literature, offering fresh perspectives on the synergistic potential of smart cities and digital infrastructure in harmonizing urban and rural growth. Through this lens, we chart a novel course for conceptualizing the transformative role of digital cities in regional development, contributing valuable insights to the ongoing discourse on urban–rural integration.

3. Data, Variable, and Model

3.1. Data Source

Information related to the smart city initiative implemented batch-wise in this study was extracted from the pilot city register announced by the State Council, which enumerates every city trialing the policy annually. Data regarding the remaining variables of this research were procured from the City Statistical Yearbook, which uses municipal-wide measures. All monetary indicators have been adjusted for inflation to eliminate its effect.

3.2. Model Setting

In assessing the spatial dependence, we employ the Local Moran's *I* statistic. The Local Moran's *I* is a measure that quantifies spatial autocorrelation, which is the correlation of a variable with itself through space. It is used to identify clusters or hot spots in the spatial arrangement of a variable. The Local Moran's *I* is calculated as follows:

$$I_i = \frac{n}{\sum_j W_{ij}} \frac{(x_i - \overline{x})W_{ij}(x_j - \overline{x})}{\sum_j (x_i - \overline{x})^2} \tag{1}$$

where *I* is the Local Moran's *I* for observation *i*. *n* is the total number of observations. x_i is the value of the variable at location *i*. $\overline{x}$ is the mean of the variable. W_{ij} is a spatial weight that quantifies the spatial relationship between observations *i* and *j*.

A positive value of the Local Moran's I indicates a cluster of similar values (either high–high or low–low), which can be interpreted as a hot spot or cold spot.

Using the Local Moran's *I* statistic, we can rigorously assess the spatial dependence of the urban–rural collaborative development across different cities and understand the spatial effect of SCPs on urban–rural collaborative development.

The SDID method provides a powerful approach for causal identification in panel data with a treatment variable and spatial dependence. The general intuition of this method is to compare the outcome changes over time in treated groups (those affected by the policy) with the changes in control groups (those not affected by the policy) while accounting for spatial interactions between different observational units (cities in our case).

Formally, the basic SDID model can be formulated as follows:

$$Y_{it} = \beta_0 + \beta_1 SmartCity_{it} + \beta_2 X_{it} + \lambda WY_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{2}$$

Y_{ir} represents the urban–rural collaborative development in city *i* at time *t*. $SmartCity_{it}$ is the treatment variable, representing the implementation of SCPs in city *i* at time *t*. X_{it} is a vector of control variables for city *i* at time *t*. *W* is the spatial weight matrix, and WY_{it} denotes the spatial lag of the dependent variable. λ captures the spatial spillover effect. μ_i and γ_t are city- and time-fixed effects, respectively, controlling for time-invariant city characteristics and common temporal shocks.

The methodology implemented in this paper utilizes a 2018 matrix, representative of economic geography, to act as the spatial weight matrix. The details of how this matrix was constructed are outlined below:

(1)   To begin with, we utilize the latitude and longitude coordinates to determine the concrete distance between two distinct locations. Each of the elements in the matrix diagonal is set to zero, as this reflects the economic interpretation that a city's geographical distance to itself is null.

(2)   Next, we initiate by choosing a key economic parameter to gauge the economic relationship between a pair of cities, and the use of GDP per capita is common in the related literature. In this matrix, the diagonal element is kept at zero, while the other elements are reciprocal to the discrepancy in the GDP.

(3)   We multiply the prior to standardize the two rows. This is then followed by row standardization, resulting in the formation of the socio-economic matrix.

3.3. Variable

3.3.1. Independent Variable

The independent variable is SCP implementation, derived from the list of pilot smart cities. This measure represents a city's official support and initiative in transforming into a smart city, involving numerous steps such as digital infrastructure development, adoption of innovative governance models, and smart services.

For empirical analysis, we construct a binary Difference-in-Differences (DID) indicator which takes the value of 1 for cities listed as pilot smart cities post implementation, and 0 otherwise. This approach allows us to identify the causal effect of SCPs on urban–rural collaborative development by comparing the changes in outcomes for cities before and after the policy implementation while controlling for trends in cities not affected by the policy.

3.3.2. Explanatory Variables

The dependent variable, urban–rural collaborative development, is captured using city-level panel data sourced from the Urban Statistical Yearbook of China. This extensive dataset provides comprehensive insights into the dynamics between urban and rural areas, encapsulating various aspects of economic integration, social cohesion, and environmental sustainability.

The measurement of urban–rural collaborative development is based on an aggregation of several indicators, including shared services, market interdependence, labor mobility, access to education and healthcare, and environmental sustainability metrics. This multi-indicator approach offers a nuanced depiction of the level and evolution of urban–rural collaborative development, allowing us to explore the impacts of SCP implementation in a comprehensive manner.

3.3.3. Mechanism Variable

The mechanism variable is digital infrastructure, from the Urban Statistical Yearbook of China. This dataset provides comprehensive and accurate statistics on the state and advancement of digital infrastructure within each city.

The measurement of digital infrastructure involves an aggregation of multiple indicators that reflect the digital capability and capacity of a city. These may encompass broadband network coverage, the number of data centers, the scale of cloud computing services, and the prevalence of IoT devices. This amalgamated measure provides a holistic perspective on a city's digital infrastructure, thereby permitting an in-depth exploration of its role in facilitating urban–rural collaborative development under the influence of SCP implementation.

3.3.4. Control Variables

For a comprehensive analysis of urban–rural collaborative development, it is important to account for a range of city-level control variables that might confound the relationship. Here are six control variables that should be included in the study:

(1) City GDP: it is important to control city GDP as it is a fundamental indicator of a city's economic strength and could influence both the capacity to implement smart city initiatives and the level of urban–rural collaborative development [5].

(2) Population Density: population density could affect the need and feasibility of smart city policies, as well as the extent of urban–rural interaction [7].

(3) Education Level: the average education level in a city might affect the capacity to utilize and benefit from smart city infrastructure and thus could affect urban–rural collaborative development [8].

(4) Employment Structure: the distribution of employment across different sectors (e.g., primary, secondary, and tertiary sectors) might influence the potential for urban–rural collaboration and the effectiveness of smart city policies [9].

(5) Urbanization Rate: the degree of urbanization could impact the need for urban–rural collaboration and the implementation of smart city policies [11].

(6) Infrastructure Quality: the quality of existing physical infrastructure (e.g., transport networks, utilities) could influence the potential benefits of smart city initiatives and thus the level of urban–rural collaborative development [12].

3.4. Data Description

We used data from 275 cities from 2007 to 2018. Our study utilizes a comprehensive dataset collected from multiple credible sources, allowing us to construct an array of independent, dependent, mechanism, and control variables. The independent variable, SCP implementation, is represented by a binary Difference-in-Differences indicator sourced from the official list of pilot smart cities in China. The dependent variable, urban–rural collaborative development, is captured via an extensive set of indicators consolidated from city-level panel data in the Urban Statistical Yearbook of China. The indicators encompass shared services, market interdependence, labor mobility, and accessibility to education and healthcare. Moreover, the mechanism variable, digital infrastructure, is gauged using multiple indicators reflecting the city's digital capacity and capability. The results are shown in Table 1.

Table 1. Data description.

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

Further enriching the dataset, six critical control variables are considered: City GDP, Population Density, Education Level, Employment Structure, Urbanization Rate, and Infrastructure Quality. These variables encapsulate various facets of city characteristics and socio-economic development that might impact the effectiveness and outcome of SCPs, thereby ensuring a thorough examination of the research question. By including a comprehensive set of indicators and accounting for potential confounding factors, we can construct a rigorous econometric model that accurately elucidates the impact of SCPs on urban–rural collaborative development.

3.5. Spatial Autocorrelation Testing

We utilize the Local Moran's I model to assess spatial dependence in our urban–rural collaborative development measure. Our findings reveal a significant positive spatial auto-correlation. The results are shown in Table 2. This suggests that urban–rural collaborative development in a particular city tends to be like that in its neighboring cities, indicating a positive spatial spillover effect. The spatial externality underscores the importance of inter-city cooperation and shared growth strategies in promoting collaborative urban–rural

development. This result also justifies our application of the SDID model to account for spatial interdependence in our analysis.

Table 2. Urban–rural collaborative development—Moran's I index.

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 ***

Note: Moran's I bilateral test; ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4. Results

4.1. Baseline Regression Analysis

Our baseline regression results provide robust evidence supporting the notion that the implementation of SCPs fosters urban–rural collaborative development. Importantly, we observe a positive and statistically significant coefficient for our treatment variable, indicating that cities with SCPs experience higher levels of urban–rural collaboration relative to those without such a policy. The results are shown in Table 3.

Table 3. Baseline regression analysis.

	(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

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

Furthermore, we find a positive spatial spillover effect, as captured by a significant positive coefficient for the spatial lag of the dependent variable. This implies that not only does the SCP stimulate urban–rural collaborative development within the implementing city, but also promotes similar development in its neighboring cities. These positive spatial externalities underline the network nature of urban–rural development, with inter-city cooperation and shared strategies being key elements of effective policy.

These findings hold even after controlling for city- and time-fixed effects, as well as other relevant city characteristics, further enhancing the credibility of our results. The successful application of the SDID model allows us to assert that our findings reflect a causal relationship between SCPs and urban–rural collaborative development. Thus, our study underpins the significant role of SCPs in catalyzing urban–rural collaboration, enriching the existing literature and offering actionable insights for policymakers.

4.2. Robustness Check

4.2.1. Parallel Trend Check

In our pursuit to ascertain the validity of our identification strategy, we embarked on a parallel trends analysis. This process was particularly geared towards probing the pre-treatment period to discern if there were any systemic discrepancies in the trends of

urban–rural collaborative development between cities that eventually adopted SCPs and their counterparts that refrained from doing so. The findings of this intensive analysis are visually illustrated in Figure 1.
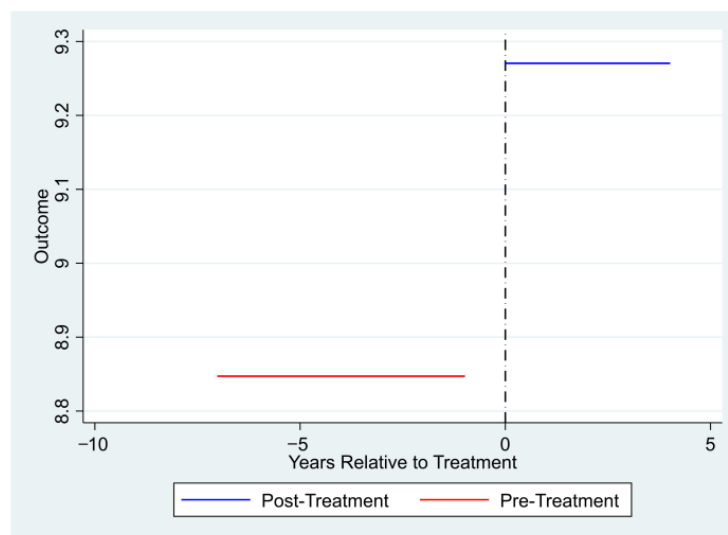

Figure 1. Parallel trend test.

Our analysis yielded insightful results, revealing no statistically significant divergence in the pre-treatment trends of urban–rural collaborative development between the group of cities that implemented SCPs (the treatment group) and those that did not (the control group). This indicates that prior to the implementation of SCPs, there were no inherent systemic disparities between the two categories of cities in terms of their collaborative development trends.

Importantly, this lack of significant pre-existing differences in trends boosts our confidence in the reliability of our study design. It implies that the two sets of cities were on a common trajectory prior to the policy implementation, thereby reinforcing the robustness of the parallel trends assumption in our identification strategy. Therefore, we can reasonably infer that any subsequent variations observed in the patterns of urban–rural collaborative development post policy implementation are likely attributable to the influence of the SCPs.

Building upon these results, it is essential to note that the absence of pre-existing divergent trends lends credibility to our empirical strategy. It strengthens our assertion that the SCPs have played a pivotal role in shaping the dynamics of urban–rural collaborative development. Furthermore, it gives us the assurance that our findings and subsequent conclusions are rooted in robust methodology, reducing the likelihood of potential biases.

Therefore, the validation of our identification strategy through this rigorous parallel trends analysis not only bolsters our confidence in the study findings but also paves the way for us to delve further into the understanding of the impacts and implications of SCPs on urban–rural collaborative development. As we venture further into this realm of research, the insights gained from this analysis will serve as a solid foundation, guiding our path and informing our approach.

4.2.2. Placebo Test

We conducted placebo tests to further validate the causal impact of SCPs on urban–rural collaborative development. These tests serve as robustness checks, ruling out potential spurious correlations and confounding factors. The results are shown in Figure 2.
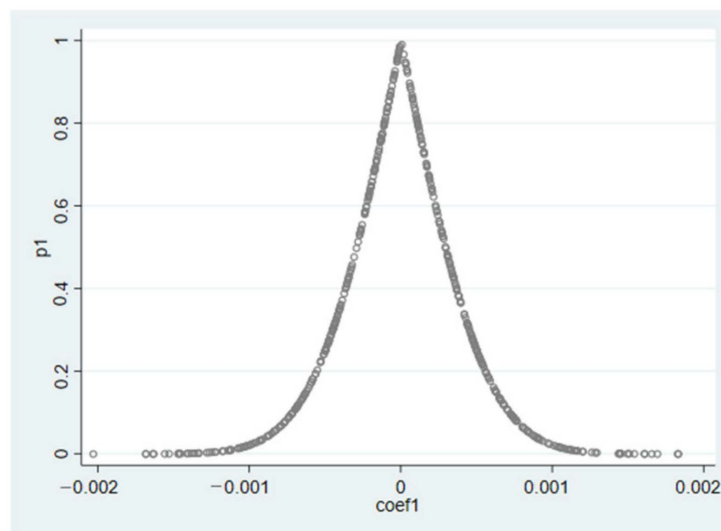
Figure 2. Placebo test result.

At the individual level, we randomly assigned cities without SCPs as the treatment group, while cities with actual policy implementation served as the control group. Comparing the outcomes between these placebo-treated and actual-treated groups, we found no statistically significant differences in urban–rural collaborative development. This convincingly confirms that the observed positive effects of SCPs on urban–rural collaboration are not driven by random variations or other unobserved factors.

Likewise, at the temporal level, we randomly shuffled the timing of SCP implementation within our panel data. This analysis revealed no significant differences in urban–rural collaborative development when comparing the actual treatment period with the placebo periods. This robustly supports the causal link between SCPs and urban–rural collaborative development, as the observed effects persist beyond random temporal variations.

Bypassing both the placebo tests at the individual and temporal levels, our study provides compelling evidence that the positive effects of SCPs on urban–rural collaborative development are indeed attributable to the policy intervention itself. These robust results further reinforce the significance of SCPs as an effective driver of urban–rural collaboration.

4.2.3. Considering Potential Policy Interference

We rigorously addressed the potential confounding influence of SCPs on urban–rural collaborative development. We meticulously controlled for the effects of the Broadband China policy. The results are shown in Table 4.

Table 4. Considering potential policy interference.

	(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)

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

Crucially, our results remained robust and unequivocal, confirming the persistent positive effects of SCPs on urban–rural collaborative development. This compelling evidence reinforces the unique and influential role of smart city initiatives in driving collaborative growth between urban and rural areas, transcending the broader advancements brought about by the Broadband China policy.

Our findings highlight the distinctive contributions of SCPs, extending beyond the realm of broadband infrastructure. Smart city approaches encompass a multifaceted framework of digital innovations and governance strategies, fostering inclusive and integrated urban–rural growth.

By meticulously addressing the potential confounding effects of SCPs on urban–rural collaborative development, our study adds academic rigor and depth to the literature. It underscores the significance of smart city initiatives as transformative catalysts for fostering urban–rural collaboration and facilitating sustainable regional development.

5. Mechanism Analysis

To delve into the underlying mechanism through which SCPs influence urban–rural collaboration, we focus on the role of digital infrastructure as the mediating variable. Our findings demonstrate that SCPs have a positive effect on urban–rural collaboration by enhancing the level of digital infrastructure. The results are shown in Table 5.

Table 5. Industry optimization mechanism.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	FE		**SAR**		**SEM**	
	ch	ch	ch	ch	ch	ch
DID	0.0539 ***	−0.0526 ***	−0.00375 ***	−0.00316 ***	−0.00375 ***	−0.00316 ***
	(0.000298)	(0.000298)	(0.000323)	(0.000323)	(0.000323)	(0.000323)
Mechanism	0.000720 **	0.000737 **	0.000483	0.000490	0.000483	0.000490
	(0.000612)	(0.000910)	(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

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

Through the implementation of smart city initiatives, such as the expansion of broadband networks, the adoption of IoT technologies, and the deployment of data analytics systems, cities experience improvements in their digital infrastructure. This enables them to establish efficient and integrated systems for information sharing, communication, and service delivery between urban and rural areas.

The enhanced digital infrastructure facilitates the flow of information, knowledge, and resources across urban and rural regions, leading to increased collaboration and synergistic development. It enables the implementation of smart agriculture, smart transportation, and smart education systems, fostering innovation, productivity, and social inclusiveness.

Furthermore, our analysis reveals that the influence of SCP on urban–rural collaboration is more pronounced in regions with higher levels of digital infrastructure. This indicates a reinforcing relationship, where SCPs and digital infrastructure work hand in hand to promote collaborative engagement and bridge the urban–rural divide.

6. Heterogeneity Analysis

6.1. Based on Economic Conditions

We divided the samples according to the economic development status of cities, categorizing the sample into three groups: high economic development, moderate economic development, and low economic development. In the high economic development group, a significantly stronger positive effect of SCPs on urban–rural collaborative development

was observed. This indicates that in cities with robust economic growth and advanced infrastructure, the implementation of smart city initiatives further enhances urban–rural collaboration, leveraging existing economic strength and digital infrastructure. The results are shown in Table 6.

Table 6. Heterogeneity analysis.

	Economy High	Economy Middle	Economy Low	UCD High	UCD Middle	UCD Low	DIL High	DIL Middle	DIL Low
did	−0.0536 ***	−0.0568 ***	−0.0572 ***	−0.0598 ***	−0.0597 ***	−0.0591 ***	−0.0597 ***	−0.0591 ***	−0.0598 ***
	(0.00727)	(0.00541)	(0.00613)	(0.00672)	(0.00558)	(0.00248)	(0.00558)	(0.00248)	(0.00672)
rho	−0.111	−0.113 *	−0.156 *	−0.460 **	−1.551	−0.551 *	−0.022	−0.182	−0.851 ***
	(−1.515)	(−1.152)	(−1.323)	(−2.415)	(−0.469)	(−1.906)	(−0.060)	(−0.844)	(−2.919)
_cons	0.611 ***	0.555 ***	0.537 ***	0.522 ***	0.574 ***	0.577 ***	0.522 ***	0.574 ***	0.577 ***
	(0.0438)	(0.0382)	(0.0231)	(0.0233)	(0.0184)	(0.0330)	(0.0231)	(0.0184)	(0.0330)

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

The heterogeneity analysis reveals a consistent pattern: the more prosperous the economic conditions of a city, the more pronounced and influential the effects of SCPs are on urban–rural collaborative development. This underscores the importance of considering economic context when designing and implementing smart city interventions, tailoring strategies to leverage existing strengths and address specific challenges in different urban contexts.

6.2. Based on Urban–Rural Collaboration

Based on the level of urban–rural collaboration, we categorized cities into three groups: high collaboration, moderate collaboration, and low collaboration. Our analysis reveals that the effectiveness of SCPs varies across these groups.

The results suggest that in cities where collaboration between urban and rural areas is already strong, the implementation of smart city initiatives further enhances this collaborative dynamic. Similarly, in cities with moderate levels of urban–rural collaboration, the positive effect of SCPs remains evident, albeit to a lesser extent. This indicates that smart city interventions can contribute to bridging the urban–rural divide and promoting collaboration even in contexts where collaboration levels are moderate. Even in cities with low levels of urban–rural collaboration, we observe a discernible effect of SCPs. This finding suggests that smart city initiatives can act as catalysts for improving collaboration.

6.3. Based on the Digital Infrastructure Level

Based on the level of digital infrastructure, we categorized regions into three groups: high digital infrastructure, moderate digital infrastructure, and low digital infrastructure. Our analysis reveals that the effectiveness of SCPs varies across these groups.

In regions with high levels of digital infrastructure, the positive impact of SCPs is particularly strong. This finding suggests that in regions where digital infrastructure is already well developed, the implementation of smart city initiatives further amplifies their benefits and enhances urban–rural collaboration.

Similarly, in regions with moderate levels of digital infrastructure, the positive effect of SCPs remains evident, albeit to a slightly lesser extent. This indicates that smart city interventions can still generate meaningful improvements in urban–rural collaboration, even in regions where digital infrastructure is moderately developed.

Even in regions with low levels of digital infrastructure, we observe a discernible effect of SCPs. This finding suggests that smart city initiatives can serve as catalysts for enhancing digital infrastructure and driving urban–rural collaboration in regions where it is currently limited.

7. Discussion

In this study, we investigated how smart city policies (SCPs) affect urban–rural collaboration and explored the underlying mechanisms using empirical evidence from a sample of cities in China.

Our findings provide compelling support for the positive effects of SCPs on urban–rural collaboration. The positive effects persist across different levels of economic development and varying degrees of urban–rural collaboration, even after controlling for various factors and passing robustness checks, including parallel trends and placebo tests. This highlights the effectiveness of SCPs in fostering collaboration and inclusive growth.

The study also demonstrates that digital infrastructure plays a vital mediating role in the relationship between SCPs and urban–rural collaboration. The positive impact of SCPs on collaboration is reinforced by improvements in digital infrastructure, facilitating the free flow of information, resources, and services. This finding underscores the importance of investing in digital infrastructure as a key mechanism for achieving collaborative urban–rural development.

Our study further reveals the heterogeneity of effects, indicating that the impact of SCPs is stronger in regions with higher economic development and better digital infrastructure. This underlines the need for tailored strategies that align with specific urban contexts, leveraging existing strengths and addressing challenges to maximize the benefits of smart city initiatives.

8. Conclusions and Policy Implication

8.1. Research Conclusions

In conclusion, our study holds substantial significance in deepening the understanding of the instrumental role that smart city policies (SCPs) play in fostering collaboration between urban and rural environments. It provides empirical substantiation that smart city initiatives and strategic investments in digital infrastructure can act as effective levers to stimulate inclusive growth, bridge the urban–rural divide, and facilitate sustainable urban development. Our findings serve as a potent resource for policymakers and stakeholders to appreciate and leverage the transformative potential of smart city projects.

Our research, however, does not just elucidate the current landscape; it also paves the way for future explorations. We advocate for further research and policy efforts to continuously seek innovative methodologies that harness the latent potential of smart cities in driving collaborative development. These could encompass an array of strategies, such as targeted policy measures, technology-driven solutions, and multi-stakeholder collaborations. Our insights point towards the need to tailor solutions that take into account the unique challenges and opportunities present in both urban and rural settings, thereby ensuring an equitable distribution of benefits.

Furthermore, our research underscores the crucial function of smart city policies in nurturing inclusive growth and fostering cooperative development. The observations and conclusions drawn from this study not only shed light on the imperative role of these policies but also provide a robust foundation for future policy formulation and execution. Our findings underscore the potential of strategically implemented smart city policies in sculpting a future where digital infrastructure plays a key role in mitigating the urban–rural divide and promoting sustainable development.

As we look forward, we envision a future where smart cities act as the fulcrum of urban–rural collaboration. Their potential to bridge the divide and promote a more inclusive and sustainable future is immense. With the insights gained from our study, we hope to stimulate further research in this area and inspire policy measures that leverage the power of smart city initiatives for the benefit of all sectors of society. The path towards achieving sustainable urban development is a challenging yet promising one, and it is our conviction that smart city policies can act as an effective roadmap guiding us towards this ambitious goal.

8.2. Policy Implications

Based on the conclusions drawn from our study, we provide the following policy recommendations to enhance urban–rural collaboration through smart city initiatives:

1. Promote targeted smart city policies: Policymakers should design and implement smart city policies that are tailored to the specific needs and characteristics of each urban and rural area. This involves identifying key priorities, such as improving digital infrastructure, enhancing public services, and fostering innovation, to address the unique challenges and opportunities in each locality.

2. Invest in digital infrastructure: Recognizing the mediating role of digital infrastructure, governments and stakeholders should prioritize investments in broadband networks, IoT technologies, data analytics systems, and other digital infrastructure components. This will enable seamless connectivity and information sharing between urban and rural areas, fostering collaboration and enabling the effective delivery of services.

3. Facilitate knowledge sharing and capacity building: To leverage the benefits of smart city initiatives, it is crucial to facilitate knowledge sharing and capacity building among stakeholders. This can be achieved through organizing workshops, training programs, and collaborative platforms where urban and rural communities can exchange experiences, best practices, and innovative ideas. By fostering a culture of knowledge sharing, stakeholders can learn from each other and jointly develop solutions to common challenges.

4. Encourage public–private partnerships: Foster collaboration between the public and private sectors to leverage resources, expertise, and technology for smart city initiatives. Public–private partnerships can drive innovation, promote efficiency, and accelerate the implementation of smart city projects. Governments should create an enabling environment that encourages private sector participation and ensures transparency, accountability, and the protection of public interests.

5. Foster a supportive regulatory framework: Establish a supportive regulatory framework that encourages innovation, entrepreneurship, and collaboration between urban and rural areas. This includes creating flexible regulations that facilitate the integration of new technologies, promoting data privacy and security and providing incentives for businesses and individuals to participate in smart city initiatives.

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