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Digital Infrastructure on Urban Economic Resilience within the Yangtze River Economic Belt Perspective : Evidence from the "Smart City Pilot" Policy

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Abstract

In the rapid process of urbanization, various uncertainties threaten urban development, and how to enhance cities' absorption, resilience, adaptation, and learning capabilities is a pressing issue. Resilient cities, as an emerging paradigm for cities to cope with uncertainty risks, offer guidance for improving urban resilience and adaptability. This paper takes 107 prefecture-level cities in the Yangtze River Economic Belt as its research object, using "smart city pilot" cities as quasi-natural experiments to construct a multi-phase DID model to investigate whether and how digital infrastructure affects urban economic resilience. This paper intends to divide the Yangtze River Economic Belt into three major urban agglomerations: the Yangtze River Delta urban agglomeration, the middle reaches of the Yangtze River urban agglomeration , and the Chengdu-Chongqing urban agglomeration, and study the heterogeneous impact of digital infrastructure on urban economic resilience in these three urban agglomerations . This paper aims to explore the mechanism of digital infrastructure 's role in sustainable urban development and provide policy recommendations on the relationship between digital infrastructure and urban economic resilience.

Keywords

Smart City Pilot Project; Yangtze River Economic Belt; Difference-of-Factory.

1. Background

As a typical complex ecosystem of nature, society, and economy, the rapid development of cities has given rise to a highly open and dynamically evolving complex human-land relationship. Population agglomeration and exponential growth in economic activity are continuously exceeding the system's carrying capacity, exacerbating the risk of imbalance in the human-land relationship. This not only threatens the efficiency of contemporary social development but also poses an intergenerational challenge to sustainability. Currently, the frequent occurrence of global disasters reflects the widespread predicament of insufficient resilience in urban systems: on the one hand, natural disasters such as extreme weather events (e.g., heat waves, massive floods, super typhoons) and earthquakes and tsunamis induced by climate change; on the other hand, man-made disasters such as geopolitical conflicts and public health crises all have a compound impact on the socio-economic foundation, human survival security, and system stability. The United Nations predicts that by 2050, the global urbanization rate will exceed 70%, with China's urban population reaching 75.8%. This rapid urbanization process

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will inevitably intensify the contradictions in the human-land system, making future society face more uncertain and disruptive challenges. Against this backdrop, constructing a dynamic adaptation mechanism for urban systems to mitigate the negative effects of disturbances has become a core scientific proposition in the field of risk governance. Therefore, urban economic resilience, as a crucial dimension of urban resilience, is key to further promoting urban development in China. Furthermore, urbanization, as a core driver of modern economic development and a significant indicator of social progress, inevitably involves the concentration of population in cities. However, rapid urbanization poses serious challenges to the harmonious coexistence of human society and the natural environment [7, 9]. Over the past 20 years, China's urbanization rate has jumped from 36.9% to 63.9%, but lagging infrastructure development has led to prominent problems such as structural imbalances, environmental pollution, and inefficient resource allocation in urban development. To address these challenges, China is actively exploring smart city management models, aiming to promote sustainable urban development through digital means.

As a pioneer in global smart city development, China has been implementing its smart city pilot policies in three phases since 2012: the first phase was launched in November 2012, the second in August 2013, and the third in April 2015, focusing on improving air quality. To date, more than 290 cities have participated in the pilot programs. This policy layout reflects China's strategic exploration of an orderly, efficient, and sustainable urbanization path under the conditions of a massive population, severe environmental constraints, and structural contradictions.

This study uses the Yangtze River Economic Belt as its empirical subject. This region covers 21% of China's land area, contributes over 40% of the country's GDP, and spans three of China's most heterogeneous regions, making it a typical sample for studying spatial equilibrium and coordinated regional development. Based on the consistency of administrative boundaries and data availability, 107 cities were selected as the research sample. Urban economic resilience was measured using GDP and its volatility. A difference-in-differences (DID) model was constructed by establishing a dummy variable for "smart city pilot policy demonstration cities" to empirically test the impact mechanism of digital infrastructure construction on economic resilience. Furthermore, given the intrinsic link between urban economic vitality and economic resilience, the study innovatively introduces nighttime light data as a proxy variable for economic vitality.

2. Literature Review and Theoretical Assumptions

2.1. Literature Review

This article is closely related to two areas: digital infrastructure development and urban economic resilience.

Existing literature has extensively studied the definition of economic resilience and its influencing factors. Regarding the definition of economic resilience, Crawley et al.(2025)introduced it into spatial economic systems, pointing out that resilience is the ability of an economic system to withstand external shocks without affecting its organizational functions[3]. D'Ambrosio et al. (2025), based on the perspective of evolutionary resilience, defined economic resilience as resistance, adaptability, and renewal capacity[4]. As for the factors influencing economic resilience, empirical research mainly focuses on industrial diversity and technological innovation. Chen et al. (2025) pointed out that the role of industrial diversity in economic resilience lies not only in diversifying risks and resisting shocks, but also in helping cities to restructure[2]. In this process, different types of industrial cluster networks intertwine, improving urban infrastructure and supply chain facilities. Therefore, limited human, material, and financial resources can be concentrated on product and service R&D,

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accelerating the pace of industrial restructuring and upgrading, thereby enhancing the city's ability to withstand shocks [5]. Considering the progress of China's digital infrastructure construction, this paper uses the implementation of the "Smart City Pilot" policy as a dummy variable to measure the development of digital infrastructure.

In the digital age, research on the impact of digital infrastructure construction on urban development mainly focuses on the following aspects: First, a good level of digital infrastructure construction can improve the flexibility, control, and support of decision-making processes in urban industrial sectors. Second, a sound digital infrastructure is an external driving force for social entrepreneurial activities. Higher entrepreneurial vitality can improve the efficiency of resource flow and consumption vitality within the city in the face of risk shocks, thereby ensuring the city's ability to cope with uncertain shocks. Finally, the technological upgrades brought about by digital infrastructure construction can improve the city's ability to perceive and detect external risks, break down barriers in the urban dimension, establish large-scale databases, and enhance the ability of different sectors to jointly cope with risk crises. In addition, good digital construction can also effectively improve the livability of cities, thereby attracting floating populations and active capital, and enhancing the city's own economic strength. Chen et al. (2026), using cities in the Yangtze River Delta as a sample, found that the impact of digital infrastructure on improving economic resilience is the most significant[1].

As one of the most dynamic sectors of economic development, China's digital infrastructure has maintained rapid growth over the past decade. Many scholars have conducted research on the relationship between digitalization and resilience. Yan et al. (2024) studied the resilience of digitalization to external risk shocks from a corporate perspective, finding that accelerating corporate digital transformation is crucial for economic recovery and improving urban resilience[10]. Lv et al. (2023) conducted research by establishing a simulation decision-making framework, finding that digitalization can ensure sufficient resilience in urban supply chains to cope with risk shocks and maintain adequate performance levels[6]. However, there is a lack of research that categorizes the resilience of different industries and compares it with urban economic resilience. Furthermore, only a few scholars have used the DID model to study the relationship between digital infrastructure construction and economic resilience. However, previous studies mainly used indicator-based methods to evaluate urban economic resilience, which struggles to overcome potential causal confounding issues. Therefore, this paper argues that it is essential to examine the impact of digital infrastructure on urban economic resilience using non-indicator-based methods.[7]

2.2. Theoretical Assumptions

First, digital infrastructure enhances urban resilience by improving the quality of economic development. The construction of digital infrastructure offers numerous advantages for economic development, such as processing large-scale data and reducing transaction costs, all of which contribute to increased urban innovation and thus enhance economic resilience. Second, digital infrastructure improves economic resilience by maximizing resource allocation efficiency. The use of digital technologies significantly reduces spatial and temporal barriers in labor market matching, thereby contributing to improved resource allocation efficiency and urban economic resilience[11]. Finally, digital infrastructure enhances urban economic resilience by impacting global value chains. Furthermore, optimizing resource allocation and promoting technological innovation are crucial for improving the position of urban enterprises in the global value chain, thereby enhancing urban economic resilience.

This paper proposes the hypothesis that digital infrastructure has enhanced the resilience of China's urban economy.

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3. Research Design

3.1. Model Setting

(1) The resilience of urban economies is measured by comparing changes in economic output with their economic strength. Combining the measurement method of Tsiotas et al. (2025) and the above theoretical analysis[8], this paper sets up the following model:

$$\mathrm{Resilience}_{it} = \mathrm{gdp} \times \Delta \mathrm{gdp} \times 100\% \tag{1}$$

Among them, Resilience is the explanatory variable, GDP is the normalized GDP after removing price factors from the 2010 base , and Δgdp is the normalized value of the absolute change in China's GDP growth rate. The larger the value, the higher the resilience of the city's economy.[9]

(2) This paper uses the DID method to examine the impact of digital infrastructure construction on urban economic resilience. The baseline regression model is as follows:

$$\mathrm{Resilience}_{it} = \alpha_0 + \alpha_1 \mathrm{Digital}_{it} + \lambda \mathrm{Controls}_{it} + u_i + v_t + \varepsilon_{it} \tag{2}$$

Here, Resilience is the dependent variable, measuring the degree of urban economic resilience. Digital is the explanatory variable, represented as a binary dummy variable based on whether the city participates in the "Smart City Pilot" policy in year t . Control represents different control variables, with λ as its coefficient. The constant term, city fixed effect, year fixed effect, and error term are represented by , u_i, v_t, and , ε_{it}respectively α_0.

(3) An important premise of using the DID method is that, before the policy is implemented, there is no significant difference in the rate of change of economic resilience between the experimental group and the control group, and the development trends of economic resilience of the two groups should remain parallel. In order to test the parallel trend hypothesis, this paper constructs equation (3) with 2014, the year the policy was launched, as the base year. By comparison φ_k, the parallel trend test is carried out.

$$\mathrm{Resilience}_{it} = \varphi_0 + \sum_{k \geq -3}^{6} \varphi_k \, \mathrm{Policy}_{it}^{k} + \lambda \mathrm{Controls}_{it} + u_i + v_t + \varepsilon_{it} \tag{3}$$

Here, "Policy" is a dummy variable. It is assigned a value of 1 if the city participates in the "Smart City Pilot" policy in year t , and 0 otherwise . k<0, k=0, and k>0 represent the years before, during, and after policy implementation, respectively. This paper primarily focuses on the coefficient before $\varphi_k$the policy implementation year (k<0) . If it is not significant when k<0 , the parallel trend test is passed. As shown in the equation, when k<0 , the confidence interval includes 0, indicating that the coefficient is not significant. This study can only use the DID method if the parallel trend assumption is met, and the empirical results are reliable.

3.2. Core Explanatory Variables

Using the "Smart City Pilot" policy launched in 2012 as a quasi-natural experiment, a policy dummy variable was constructed. If a city was included in the smart city pilot list in a certain year, the Policy value for that year and subsequent years would be 1; otherwise, the value would be 0.

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3.3. Control Variables

To accurately assess the net effect of core variables on environmental well-being outcomes, this study controlled for a range of variables with proven significant influence: urban registered population per million inhabitants (People) and urbanization level (Urban), thus capturing the effects of agglomeration economies and demographic structure. It also controlled for the primary sector's share of GDP (Primary), an indicator reflecting the stage of economic development and industrial structure characteristics. Fisdecentration (Fisdecentra) was used to assess the impact of local government fiscal autonomy on resource allocation and development orientation. The number of employees in the rental and business services sector per 10,000 people (Number) and the value of goods exports per 100 billion yuan (Export) were used as proxy variables for regional high-end human capital and market vitality. Railway passenger traffic per 10 million people (Passenger) and telecommunications revenue per 100 billion yuan (Revenue) were used to measure the level of physical and digital infrastructure, respectively. Science and technology expenditure per 100 billion yuan (Tec) reflects differences in government investment in innovation.

4. Empirical Results

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics . The maximum value of the explained variable, Resilience , is 0.3811, and the minimum value is 0.0014, indicating significant differences in Resilience among the sample cities. Furthermore, the mean Resilience is 0.0514 , and the standard deviation is 0.0437 , suggesting that the overall Resilience level is high, but certain differences still exist between cities.

Table 1. Descriptive Statistics

Variable	Observations	average value	Standard deviation	Minimum value	Maximum value
Resilience	3519	0.0514	0.0437	0.0014	0.3811
DID	3519	0.1182	0.3229	0.0000	1.0000
People	3519	1.9234	2.0210	0.0300	36.0700
Urban	3519	46.3277	25.2478	0.0000	508.1930
Fisdecentra	3519	1.2465	1.5270	0.0676	20.8904
Number	3519	1.3406	5.3037	0.0040	150.4640
Export	3519	0.3863	1.7034	0.0000	33.6686
Passenger	3519	0.8981	2.9388	0.0000	78.3030
Primary	3519	0.1281	0.0789	0.0020	0.4989
Tec	3519	0.7677	2.6189	0.0047	52.8052
Revenue	3519	3.6864	5.6775	0.0002	96.6959

4.2. Benchmark Regression

Table 2 presents the empirical results for formula (1): Model (1) only includes the DID term with fixed effects on city and year; Model (2) adds all control variables. The results show that the DID coefficient is significantly positive at the 1% significance level, indicating that the "Smart City Pilot" policy significantly enhances local economic resilience. The estimated values of the control variables are consistent with existing studies, verifying the robustness of the model. According to Model (2) in Table 3, after the pilot cities of the "Smart City Pilot" policy

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were designated, the absolute level of economic resilience in these cities increased by approximately 1.42 percentage points. Therefore, the hypothesis 1, which states that digital infrastructure enhances the economic resilience of Chinese cities, is statistically and economically significant.

Table 2. Benchmark regression results

variable	(1)	(2)
	Resilience	Resilience
DID	0.0187***	0.0142***
	(0.0050)	(0.0053)
People		0.0048**
		(0.0021)
Urban		-0.0004**
		(0.0001)
Fisdecentra		0.0104***
		(0.0029)
Number		-0.0006***
		(0.0002)
Export		0.0009
		(0.0008)
Passenger		0.0006***
		(0.0001)
Primary		-0.0404
		(0.0322)
Tec		0.0007
		(0.0012)
Revenue		0.0007**
		(0.0003)
constant term	0.0489***	0.0459***
	(0.0007)	(0.0063)
Urban fixed	yes	yes
Fixed year	yes	yes
Sample size	3,519	3,519
R^2 value	0.7326	0.7425

Note : The values in parentheses are the robust standard errors of clustering at the city level . *** , ** , and * indicate significance at the 1% , 5% , and 10% statistical levels , respectively .

4.3. Parallel Trend Test

Using the DID model is that there is no systematic difference in economic resilience between cities that have established "smart city pilots" (treatment group) and cities that have not established "smart city pilots" (control group) before the policy implementation, and they show

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similar development trends. To test this parallel trend hypothesis, this paper uses Equation (3) for empirical analysis. According to the results in Figure 1, the variables before the establishment of "smart city pilot" cities are statistically insignificant, which indicates that there is no significant difference in economic resilience between the treatment group and the control group cities before the establishment of "smart city pilot" cities , thus satisfying the parallel trend hypothesis.

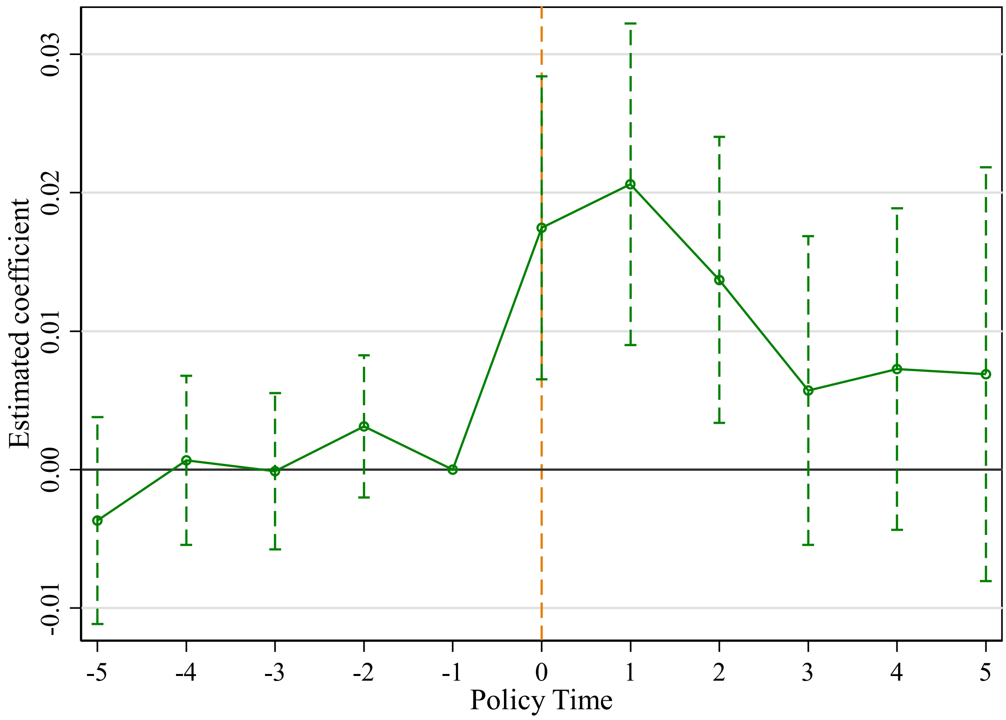

Figure 1. Temporal Heterogeneity of the Policy Effects of "Smart City Pilot Projects"

Figure 1 shows the changes in the coefficients of the variables in equation (3) $\varphi_k$over time (confidence level of 95%) . The results show that from the first to the second year after the policy was established, the "Smart City Pilot" policy had a significant effect on promoting urban economic resilience ; however, from the third year onwards, the effect gradually weakened and became insignificant. Overall, the driving effect of the "Smart City Pilot" policy on urban economic resilience showed a dynamic trend of " first strengthening and then weakening " .

4.4. Robustness Test

Table presents robustness tests in the following four aspects: ① Outliers in economic resilience were corrected by tailing the samples with the highest and lowest economic resilience in the top 1%, and model (1) reports the corresponding test results; ② Model (2) controls for province-specific fixed effects and year-specific fixed effects, model (3) controls for province-specific fixed effects, year-specific fixed effects, and city-specific fixed effects, while model (4) controls for province-specific fixed effects, year-specific fixed effects, and the interaction between province and year-specific fixed effects. Overall, the coefficient of the variable DID remains statistically significant.

Table 3. Outlier Detection Results

variable	(1) Tail contraction	(2) Fixed effects of controlling provinces	(3) Fixed effects of controlling provinces and cities	(4) Fixed effects controlling for the interaction between province and year
DID	0.0125***	0.0258***	0.0142***	0.0325***
	(0.0046)	(0.0057)	(0.0053)	(0.0082)
constant term	0.0453***	0.0403***	0.0459***	0.0381***
	(0.0103)	(0.0073)	(0.0063)	(0.0091)
control variables	yes	yes	yes	yes
Urban fixed	yes	no	yes	no
Fixed year	yes	yes	yes	yes
Provinces are fixed	no	yes	yes	yes
Province × Year	no	no	no	yes
Sample size	3,519	3,519	3,519	3,434
R^2 value	0.7542	0.4273	0.7425	0.4703

5. Conclusion and Recommendations

Based on panel data from 108 prefecture-level and above cities in the Yangtze River Economic Belt from 2011 to 2020, and using the "Smart City Pilot" policy as a quasi-natural experiment, this paper employs a difference-in-differences model to systematically explore the impact, mechanism, and heterogeneity characteristics of digital infrastructure on urban economic resilience, drawing the following core conclusions:

First, digital infrastructure has a significant positive empowering effect on the economic resilience of cities in the Yangtze River Economic Belt, effectively enhancing the city's economic system's ability to withstand shocks, recover, adapt, and transform. This conclusion has been robustly tested and has strong reliability.

Second, the "smart city pilot" policy can strengthen the positive effect of digital infrastructure on urban economic resilience, and the two have a synergistic enabling effect. By providing institutional guarantees and application scenarios, the smart city pilot policy promotes the full release of the enabling effect of digital infrastructure, further enhancing urban economic resilience.

Based on the above research findings and in light of the actual development of cities in the Yangtze River Economic Belt, the following targeted policy recommendations are proposed to optimize the layout of digital infrastructure, improve smart city pilot policies, and enhance urban economic resilience:

(1) Optimize the layout of digital infrastructure and narrow the regional digital divide.

First, we will increase support for digital infrastructure construction in the middle and upper reaches of the Yangtze River Economic Belt, focusing on extending infrastructure such as 5G base stations, big data centers, and industrial internet to cities in the central and western regions, improving the supporting system for digital infrastructure, and gradually narrowing

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the digital gap with downstream regions. Second, we will implement differentiated construction strategies based on city size and development needs: large cities will focus on promoting the intelligent upgrading of digital infrastructure to create core carriers of the digital economy; small and medium-sized cities will focus on full coverage of basic digital infrastructure to improve the accessibility of digital services; and resource-based cities will focus on building digital infrastructure that is compatible with industrial transformation to promote the digital transformation of resource industries. Third, we will establish a regional collaborative construction mechanism for digital infrastructure to promote the interconnection, sharing, and co-construction of digital resources among cities in the Yangtze River Economic Belt, thereby improving the overall utilization efficiency of digital infrastructure.

(2) Improve smart city pilot policies and enhance collaborative empowerment effects.

First, expand the scope of smart city pilot projects, focusing on the middle and upper reaches of the Yangtze River, small and medium-sized cities, and resource-based cities. Improve supporting measures for pilot policies and provide support in terms of funding, technology, and talent to ensure the effective implementation of pilot policies. Second, strengthen the synergy between smart city pilot policies and digital infrastructure construction. Use the level of digital infrastructure development as an important indicator for the selection and evaluation of pilot cities, guiding them to increase investment in digital infrastructure and promote the deep integration of digital technology with urban governance, industrial development, and public services, fully releasing their synergistic empowering effect. Third, summarize the successful experiences of pilot cities to form replicable and scalable models, and promote them throughout the Yangtze River Economic Belt to improve the quality and efficiency of smart city construction.

(3) Focus on intermediary pathways to enhance the enabling effectiveness of digital infrastructure.

First, we will leverage digital infrastructure construction to drive industrial upgrading, increase support for emerging industries such as the digital economy, artificial intelligence, and new energy, promote the deep integration of traditional industries with digital technologies, optimize industrial structure layout, and enhance industrial resilience. Second, we will strengthen the supporting role of digital infrastructure in technological innovation, improve incentive mechanisms for technological innovation, increase R&D investment, build digital technology R&D platforms, attract technological innovation talent, stimulate urban technological innovation vitality, and enhance the core competitiveness of the urban economy. Third, relying on digital infrastructure, we will improve the mechanism for the flow of factors of production, break down spatial and temporal limitations, promote the efficient flow of capital, talent, and technology among cities in the Yangtze River Economic Belt, optimize resource allocation efficiency, and enhance the flexibility and adaptability of the urban economic system.

(4) Based on the heterogeneous characteristics, implement differentiated resilience enhancement strategies.

First, differentiated policies will be implemented for different regions: downstream regions will focus on promoting the intelligent upgrading of digital infrastructure and the in-depth construction of smart cities to create core areas of regional economic resilience; midstream regions will focus on improving supporting digital infrastructure, promoting the digital transformation of industries, and enhancing economic resilience; upstream regions will increase policy support and financial investment to address shortcomings in digital infrastructure and enhance the economy's ability to withstand shocks. Second, development paths will be optimized for cities of different sizes: large cities will focus on the integrated development of the digital economy and smart cities to create benchmarks for resilient development; small and medium-sized cities will focus on improving basic digital

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infrastructure and public services to enhance their economic recovery capabilities; small cities will rely on regional collaboration and leverage the digital resources of surrounding cities to enhance their own economic resilience. Third, precise policies will be implemented for different types of cities: non-resource-based cities will continue to strengthen the empowerment of digital infrastructure to promote diversified industrial development; resource-based cities will rely on digital infrastructure to accelerate industrial transformation, reduce resource dependence, and enhance the sustainability of economic resilience.

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