Research on the Impact of New Infrastructure Construction on Urban Resilience

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Abstract: This study utilizes panel data from 31 cities in the Yangtze River Delta and Pearl River Delta regions spanning 2012-2019, employing a multiple linear regression model to systematically examine the impact of new-type infrastructure on urban resilience while analyzing its underlying mechanisms. The findings demonstrate that new-type infrastructure development significantly enhances urban resilience levels. Mechanism analysis reveals that such infrastructure primarily strengthens urban resilience through two pathways: stimulating regional innovation and driving industrial upgrading. Economic development status serves as a positive moderating factor in the impact of new-type infrastructure on urban resilience. Heterogeneity analysis indicates that integrated infrastructure and innovation infrastructure positively influence resilience enhancement, whereas information infrastructure shows no significant effect. The study confirms that new-type infrastructure development promotes improvements in both economic and social resilience, while having no notable impact on ecological resilience.

Keywords: Digitization; New Infrastructure; Urban Resilience; Sustainable Development

1. Introduction

The world is undergoing unprecedented transformations unseen in a century. As the new wave of technological revolution and industrial transformation intensifies, China faces both emerging opportunities and growing uncertainties. Frequent occurrences of "black swan" and "gray rhino" events pose significant challenges to modernization systems and sustainable development strategies. Traditional cities, constrained by limited self-organization capabilities and inefficient resource utilization, coupled with inherent systemic complexities, often fail to effectively mitigate major risks, resulting in casualties and property losses. The recent development of resilience concepts has provided a new framework for urban governance. Resilient cities require coordinated inter-system collaboration while emphasizing human agency in risk management. By continuously integrating resources, these cities enhance their resistance, recovery capacity, and adaptability to uncertain risks. As a novel approach to sustainable development, urban resilience has become a key priority for nations worldwide.

However, as international trade becomes increasingly globalized and global supply chains grow more fragmented, leading to insufficient production capacity on the supply side [1], coupled with China's prolonged implementation of extensive economic policies, the traditional high-input, low-output development model can no longer meet the needs of urban growth. Addressing the current lack of internal driving forces in resilient city construction and providing new momentum for future development has become a critical focus in urban resilience research.

To address the pressing challenges in building resilient cities, China's 14th Five-Year Plan emphasizes leveraging new-type infrastructure to enhance modernization at the material level. In today's rapidly developing digital economy, advancing data-driven infrastructure construction not only aligns with the trend of digital transformation but also holds significant importance for improving urban resilience and advancing national sustainable development and modernization.

2. Literature Review

The term "resilience" first emerged in engineering mechanics, describing an object's ability to return to its original shape after deformation. American ecologist Holling later introduced this concept into ecological studies.

He posited that a system can exist in multiple stable states, and resilience enables it to transcend its initial state to achieve new equilibrium. As understanding of systems deepened, the adaptive cycle theory provided scholars with a fresh perspective on resilience, giving rise to evolutionary resilience. Distinct from engineering and ecological resilience, evolutionary resilience abandons the pursuit of equilibrium states, emphasizing continuous adaptation and learning capabilities. It drives systems to constantly adjust their structures to sustain development [2]. Overall, resilience theory has evolved through three phases: from "engineering resilience" to "ecological resilience" and finally to "evolutionary resilience," shifting research focus from linear thinking to multidimensional approaches rooted in adaptive cycle theory.

Urban resilience, a product of integrating resilience studies with urban systems, is defined by the ability of cities to withstand and absorb external disturbances while maintaining their original characteristics and critical functions. As resilience research evolves and our understanding of urban systems deepens, the concept of urban resilience has gained new dimensions under the perspective of evolutionary resilience. Grounded in sustainable development theory, this paper posits that urban resilience refers to a city's capacity to maintain normal operations within its original system's tolerance range when facing uncertain disturbances. Through continuous learning and structural adaptation to risk environments, cities can transcend conventional development paths and enhance their resilience thresholds to achieve long-term sustainable development. Current research on urban resilience exhibits diverse characteristics, with interdisciplinary integration enriching its analytical perspectives. Peng Chong et al. measured the network resilience of urban agglomerations in the middle reaches of the Yangtze River from the perspective of network [3]; Zheng Yan classified the resilience of cities in China and proposed differentiated development strategies based on the adaptive cycle theory from the perspective of sponge city [4].Li Na et al. conducted a comprehensive evaluation of the resilience levels of Chinese cities and studied regional heterogeneity [5]; Huang Qiong and Cui Ziyi measured the development level of urban resilience in China and analyzed regional differences, dynamic evolution, and major barrier factors [6]. With the continuous development of the digital economy, many scholars have turned to studying the empowering role of the digital economy on urban systems. Liu Jiashu and Gu Wei empirically verified the impact mechanism and effect of digital technology on urban economic resilience, and explored its threshold effect [7]. Chu Yuming and colleagues conducted a quasi-natural experiment using smart city pilot projects, employing the difference-in-differences method to examine how smart city development impacts urban ecological resilience [8]. In recent years, the emergence of new infrastructure concepts has also provided fresh perspectives for urban resilience research.

New-type infrastructure, guided by innovative development concepts and driven by technological innovation, is a system built on information networks to support high-quality development through services including digital transformation, intelligent upgrading, and integrated innovation. According to the National Development and Reform Commission's definition, it primarily comprises three categories: information infrastructure, integrated infrastructure, and innovative infrastructure. Information infrastructure specifically refers to facilities developed through next-generation information technology evolution. Integrated infrastructure involves the deep application of internet, big data, and artificial intelligence technologies to facilitate the transformation and upgrading of traditional infrastructure. Innovative infrastructure mainly consists of public-benefit-oriented facilities supporting scientific research, technological development, and product innovation. With the continuous development of the digital economy, new infrastructure construction, as a product of digitization, continues to empower economic development. Research on new infrastructure primarily examines its impact from a macro perspective; Huang Menghan and Zhang Weiguo analyzed the heterogeneity and mechanisms of new infrastructure's influence on economic growth, demonstrating significant positive spatial spillover effects through knowledge spillovers and improved innovation efficiency [9].

A review of existing literature reveals that current research on new infrastructure development predominantly adopts a digital perspective, focusing on analyzing its macro-level impacts on regional economic growth. However, under the current context, previous studies exhibit two key limitations: (1) Insufficient attention to micro-level actors. Most scholars analyze the effects of new infrastructure from a macro perspective, with provincial-level samples being the primary research focus, while urban-level assessments and studies exploring the relationship between new infrastructure investment and urban resilience remain scarce. (2) Narrow research scope. While most studies examine the mechanisms of new infrastructure's impact through economic development and modernization lenses, few explore its ecological effects or social benefits. The potential contributions of this study are as follows: (1) Expanding the scope of research by examining new infrastructure's influence on urban resilience development at the city scale. (2) Integrating new infrastructure with resilience studies to broaden analytical perspectives, providing theoretical support for future resilient city construction and offering fresh insights into their interrelationship. (3) Conducting heterogeneous comparative analyses of new infrastructure types and urban resilience dimensions, enriching research on impact pathways while clarifying transmission mechanisms.

3. Theoretical Analysis and Research Hypotheses

Different scholars have different views on the construction of urban resilience index system. It can be concluded from relevant literature that although there is no consensus on the selection of urban resilience evaluation index, the core elements can be divided into three dimensions: social resilience, economic resilience and environmental resilience. Infrastructure resilience has long been considered a key component in urban resilience assessments. However, with the advancement of digital technologies, new infrastructure represented by 5G and big data has transcended the limitations of traditional infrastructure, positively impacting urban socio-economic development through digital empowerment across multiple dimensions. Therefore, this study separates the infrastructure resilience dimension from conventional urban resilience indicators, treating it as a core factor influencing urban resilience. By incorporating and referencing other scholars' indicator systems, we identify social resilience, economic resilience, and ecological resilience as the three core levels constituting urban resilience, and conduct empirical research based on these dimensions.

3.1 The impact of New Infrastructure on Urban Resilience

New Infrastructure and Urban Economic Resilience. First, new infrastructure plays a significant role in driving high-quality economic development. The improvement of new infrastructure accelerates the flow of production factors such as human resources, logistics, and information. While enhancing regional economic development, it also boosts urban residents' income levels, effectively reducing psychological and material pressures caused by lower income during crises. The establishment of big data platforms and the widespread adoption of e-commerce have provided urban residents with more diversified consumption options. With continuous investment in new infrastructure construction, urban logistics systems are becoming increasingly sophisticated, and consumer markets will continue to expand. Second, the enhancement of new infrastructure accelerates urban digital transformation, powerfully driving industrial restructuring and upgrading. As the digital economy continues to evolve and technological innovation progresses rapidly, new infrastructure development not only propels digital industries but also creates emerging sectors through digital empowerment. On one hand, industrial development generates more job opportunities for urban residents and reduces unemployment risks; on the other hand, it provides diversified services that stimulate consumer demand and elevate overall urban consumption levels.

New Infrastructure Development and Urban Social Resilience. New infrastructure empowers public services through digital transformation, establishing a more comprehensive service system. On one hand, it accelerates information flow and enhances connectivity through improved transportation networks, reducing travel costs for urban residents while fostering closer interpersonal connections. This facilitates the exchange of ideas, gradually forming social consensus and strengthening community cohesion. On the other hand, ongoing infrastructure development strengthens social security systems. Healthcare, education, and elderly care services are becoming more equitable and accessible through digital advancements and online platforms. The deep integration of medical services with digital technologies has led to the rise of telemedicine and online consultations, breaking geographical and policy barriers while expanding service coverage and reducing healthcare costs. In education, network infrastructure improves knowledge dissemination methods, lowering learning costs. While elevating overall educational standards, widespread online training offers diverse pathways for skill enhancement, alleviating employment pressures and unemployment risks, thereby contributing to urban harmony and stability.

New Infrastructure Development and Urban Ecological Resilience. Centered on digital transformation, new infrastructure upgrades traditional systems by integrating modern information technologies. This evolution drives operational practices toward energy-efficient and high-tech directions, demonstrating superior environmental sustainability compared to conventional infrastructure [10]. Such modernization not only enhances infrastructure's direct risk-resilience capabilities but also empowers urban environments to meet diverse public needs. The recent rise of smart wetlands and eco-parks exemplifies this shift: while maintaining robust risk-absorbing capacities, these innovations effectively address both physical and psychological needs of urban residents, thereby significantly boosting the city's ecological resilience.

Hypothesis H1: New infrastructure construction plays a promoting role in improving urban resilience.

3.2 The Mechanism of New Infrastructure Construction on Urban Resilience Development

New Infrastructure Development, Regional Innovation, and Urban Resilience. In terms of cost efficiency, the construction of next-generation digital infrastructure has facilitated data flow and enhanced knowledge circulation. Digital platforms have alleviated supply-demand mismatches caused by information asymmetry to some extent. As digital cyberspace expands, two key benefits emerge: First, it significantly reduces information search and tracking costs for innovation activities, enabling innovators to make real-time market adjustments and effectively avoid sunk risks in new technology development. Second, the deployment of new infrastructure lowers data storage and transaction costs in cyberspace, breaking geographical constraints and accelerating knowledge diffusion. Regarding market dynamics, this infrastructure connects fragmented markets through AI and cloud computing technologies. By integrating online resources, it removes market entry barriers, enabling cross-temporal resource sharing and collaborative innovation. Furthermore, with ongoing advancements in internet and industrial IoT, new infrastructure is driving traditional industry transformations, creating emerging market demands and providing innovative tools to expand technological frontiers, thereby broadening the market scope for innovation.

Hypothesis H2: New infrastructure improves urban resilience through regional innovation

New Infrastructure Development, Industrial Upgrading, and Urban Resilience. On one hand, new infrastructure serves as pioneering capital with significant positive externalities and multiplier effects. The construction of such infrastructure generates new business models, while evolving consumer demands continuously raise technical requirements for products. This compels traditional industries to upgrade outdated production capacities and adjust industrial structures, thereby enhancing urban resilience through robust market competition. On the other hand, new infrastructure optimizes resource allocation through efficient distribution of production factors, accelerates cross-regional industrial clustering, and reduces transformation costs. Notably, improvements in transportation infrastructure facilitate market integration by reconfiguring spatial layouts, improving accessibility, expanding market share of related industries, and promoting technological and information exchange between sectors. Through complementary technologies, these advancements elevate overall urban productivity, ultimately strengthening cities' comprehensive resilience, recovery capacity, and adaptability.

Hypothesis H3: New infrastructure construction strengthens urban resilience through industrial upgrading.

The moderating effect of high-quality economic development on new infrastructure construction and urban resilience. First, improved economic development typically signifies increased material wealth in society. The construction of new infrastructure and its supporting facilities requires substantial investment, enabling cities with higher economic levels to effectively secure funding for both construction and maintenance. Second, cities with advanced economies demonstrate more sophisticated innovation management systems and patent protection mechanisms, which stimulate regional innovation capabilities. Moreover, these cities possess superior human resources with strong comprehension and application skills in emerging knowledge technologies, effectively accelerating the transformation of urban innovation achievements and maximizing the empowering role of new infrastructure in technological advancement. Finally, economic development is closely linked to residents 'consumption patterns. As economic growth progresses, urban residents' consumption tiers evolve from basic to higher levels. This demand upgrade not only triggers industrial chain restructuring and promotes reorganization of upstream and downstream sectors but also drives new application scenarios for emerging infrastructure like big data and artificial intelligence. These developments better meet diverse consumer demands, fostering coordinated industrial structure development through simultaneous supply-demand adjustments.

Hypothesis H4: High-quality economic development has a positive moderating effect on the impact of new infrastructure construction and urban resilience.

4. Research Design and Methodology

4.1 Variable Description and Data Source

1) The explained variable: cities resilience (Cr). At present, the comprehensive evaluation index of urban resilience is not perfect, and there is no unified measurement standard. However, its content framework mainly involves economic, social, ecological, institutional and other dimensions. This paper constructs comprehensive evaluation index of urban resilience by referring to existing studies [8-10], and measures it by entropy method. The specific indicators are shown in Table 1.

Table 1. Comprehensive Evaluation Index of Urban Resilience

Primary indicators	Secondary indicators	Third-level indicators	Unit	Symbol
Cities Resilience (Cr)	Economic Resilience (Cr1)	Retail sales per capita of consumer goods	Wan Yuan	+
		Per capita annual end deposit balance of urban and rural residents	first	+
		The proportion of added value of the tertiary industry in GDP	%	+
		Urban per capita consumption expenditure	first	+
		Per capita consumption income of urban residents	first	+
	Social Resilience (Cr2)	urban unemployment rate	%	-
		density of population	Persons/km2	+
		Number of students in regular institutions of higher learning per 100 people	human being	+
		Number of employees in public administration and social organizations	thousands of people	+
		Number of beds per 100 population in hospitals and health centers	fix	+
	Ecological Resilience (Cr3)	Industrial wastewater discharge	10,000 tons	-
		General comprehensive utilization rate of industrial solid waste	%	+
		Centralized treatment rate of sewage treatment plant	%	+
		Green coverage rate of built-up areas	%	+

2) Core Explanatory Variable: New Infrastructure Construction (infra). According to the classification standards of the National Development and Reform Commission (NDRC), new infrastructure is categorized into information infrastructure, integrated infrastructure, and innovation infrastructure. In terms of econometric methodology, we select information transmission and technical services, transportation, and power/heat production and supply industries as traditional infrastructure components. These are multiplied by integration

coefficients respectively. Scientific research and technical services are then applied to information infrastructure (infra1), integrated infrastructure (infra2), and innovation infrastructure (infra3). Finally, the total capital stock of new infrastructure construction is calculated by summing these components (in billion yuan).

3) Moderating Variables and Mediating Variables: (1) Regional Innovation Capability (inno). Measured by the annual number of patent grants per city divided by its total population at year-end (patent holders per 100 people). (2) Industrial Upgrading Level (iupg). Derived from Zhang Pei et al. [9], measured as the ratio of value added in the tertiary industry to that in the secondary industry. (3) Economic Development Level (pergdp). Quantified using per capita GDP.

4) Control Variables: (1) Capital Stock (fin). Calculated by dividing total fixed asset investment by the total population at year-end. (2) Openness Level (trade). Measured by the ratio of import-export volume to regional GDP. (3) Financial Development Level (fia). Defined as the sum of RMB loan balances and deposits in financial institutions at year-end divided by regional GDP. (4) Marketization Index (mi). Derived through comprehensive scoring of six key factors including government-market coordination and non-state-owned economic development. (5) Government Intervention Level (gi). Quantified by fiscal expenditure as a percentage of GDP. (6) Urbanization Rate (Cr). Measured by the permanent urban population as a percentage of total resident population.

5) Data Samples and Sources: This study selects the Beijing-Tianjin-Hebei Urban Agglomeration, Yangtze River Delta Urban Agglomeration, and Pearl River Delta Urban Agglomeration as core research units. Considering data availability and the inherent characteristics of each region, the Beijing-Tianjin-Hebei cluster was excluded due to severe data gaps. In the Yangtze River Delta, seven prefecture-level cities-Changzhou, Suzhou, Nantong, Yancheng, Yangzhou, Zhoushan, and Taizhou-were removed due to incomplete datasets. Shanghai was also excluded as a municipality directly under the central government, where data volumes differ significantly from other cities, potentially affecting research outcomes. Consequently, this study focuses on 31 prefecture-level cities in both regions, covering the period 2012-2021. Statistical data are primarily sourced from the EPS database, Guotai An database, local statistical yearbooks, and official bulletins. Control variables (capital stock) and moderating variables (logarithmic GDP per capita) were transformed to address heteroskedasticity. Missing data were filled using linear interpolation. Descriptive statistics for key variables are illustrated in Table 2.

Table 2. Descriptive Statistics of Main Variables

Variable	Quantity	Mean	Standard error	Least value	Crest value
Cr	310	0.257	0.134	0.065	0.758
Infra	310	621.38	524.305	44.793	2556.958
Infra1	310	38.568	59.403	0	427.049
Infra2	310	531.214	433.159	42.427	2157.824
Infra3	310	51.598	57.533	1.297	317.923
Inno	310	0.575	0.641	0.012	4.446
Iupg	310	1.024	0.389	0.336	2.753
lnfin	310	11.034	0.496	9.659	12.611
Trade	310	0.97	1.468	0.01	11.22
Fia	310	3	0.973	1.505	6.299
Mi	310	12.876	2.438	7.175	19.03
Gi	310	0.146	0.052	0.07	0.36
Ur	310	0.694	0.145	0.396	1

4.2 Research Methods

4.2.1 The entropy approach

1) Suppose there are m evaluated objects and each evaluated object has n evaluation indicators, the judgment matrix is constructed as follows:

$$X=\left(x_{ij}\right)_{m\times x}\left(i=1,2,\cdots,m;j=1,2,\cdots,n\right) \quad (1)$$

2) Standardization of the judgment matrix. As all indicators in this paper are positive indicators, therefore:

$$Y_{ij}=\frac{X_{ij}-\min(X_i)}{\max(X_i)-\min(X_i)} \quad (2)$$

3) Calculate information entropy

$$E_j=-k\sum_{i=1}^{m} p_{ij}\ln p_{ij} \quad (3)$$

Where:$p_{ij}=\frac{Y_{ij}}{\sum_{i=1}^{m}Y_{ij}}$;$k=\frac{1}{\ln m}$ (4)

4) Determine the weight of each index and calculate the weight of each index through information entropy

$$w_j=\frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \quad (5)$$

In the formula:

$$w_j\in[0,1],\ \sum_{j=1}^{n}(w_j)=1 \quad (6)$$

5) According to the calculation results, the weight of each index is multiplied by its dimensionless value and summed up, and finally the urban resilience development level is obtained

$$I=\sum_{j=1}^{n}W_jY_j \quad (7)$$

4.2.2 Regression model.

This paper adopts a two-factor fixed effects model to verify the impact effect of new infrastructure on cities. The specific model is as follows:

$$cr_{it}=\alpha_0+\alpha_1 infra_{it}+\alpha_c X_{it}^{control}+\mu_i+\eta_t+\varepsilon_{it} \quad (8)$$

In this model, i represents the city code, cr_{it} $infra_{it}\alpha_1 X_{it}^{control}\mu_i\eta_t\alpha_0$ t denotes the year (as the dependent variable indicating urban resilience level), and is the core explanatory variable representing the level of new infrastructure construction (corresponding to its parameter). The control variables group includes, while and respectively denote the city fixed effects and time fixed effects, with being the intercept term.

4.2.3 Mediating effect model.

This paper constructs the following mediating effect model.

$$N_{it}=\beta_0+\beta_1 infra_{it}+\beta_c X_{it}^{control}+\mu_i+\eta_t+\varepsilon_{it} \quad (9)$$

$$cr_{it}=\gamma_0+\gamma_1 infra_{it}+\gamma_2 N_{it}+\gamma_c X_{it}^{control}+\mu_i+\eta_t+\varepsilon_{it} \quad (10)$$

Among N_{it} them, represents the intermediate variable, and the meaning of other variables is the same as the above formula.

4.2.4 Moderation Model.

To further examine the moderating effect of economic development level on the impact of new infrastructure on urban resilience, this study extends the benchmark regression model by incorporating economic development level as a moderating variable, along with the interaction term between economic development level and new infrastructure construction level into the model:

$$cr_{it}=\alpha_0+\alpha_1 infra_{it}+\alpha_2 lnpergdp_{it}+\alpha_3 infra_{it}\times lnpergdp_{it}+\alpha_c X_{it}^{control}+\mu_i+\eta_t+\varepsilon_{it} \quad (11)$$

In this formula $pergdp_{it} infra_{it}\times pergdp_{it}$, represents the per capita GDP of prefecture-level city i in t year, and represents the cross product of new infrastructure and economic development level of prefecture-level city i in t year.

5. Evidential Analysis

5.1 Benchmark Regression Results.

This study employs Stata17 to conduct benchmark regression on Equation (1), with the results presented in Table 3. Columns (1)-(5) display the significance changes of new infrastructure's impact on urban comprehensive resilience when controlling for variables versus after gradual inclusion. The table reveals that all estimated parameters for new infrastructure demonstrate statistically significant positive correlations with urban resilience enhancement, confirming Hypothesis 1. However, the control variable analysis shows that social capital stock negatively impacts urban resilience development, contradicting initial assumptions. This may stem from urban agglomeration intensifying the suction effect of central cities, disrupting intercity collaborative development ecosystems. In the internet era, data dominance grants cities developmental advantages, leading to fierce competition for social resources. This indicates capital stock's influence on resilience primarily reflects intercity coordination challenges. Openness level proves detrimental to urban resilience development. Cities with higher openness are more vulnerable to external shocks. As anti-globalization trends intensify and trade protectionism rises, these external factors increase urban development risks and uncertainties, hindering resilience cultivation. Urbanization rate shows significant positive correlation with resilience, while financial development and government intervention coefficients remain statistically insignificant.

Table 3. Benchmark Regression Empirical Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cr	Cr	Cr	Cr	Cr	Cr	Cr
Infra	0.046***	0.046***	0.044***	0.044***	0.044***	0.044***	0.044***

	(8.333)	(8.734)	(8.300)	(8.231)	(8.220)	(8.212)	(8.744)
Lnfin		0.044***	0.040***	0.039***	0.039***	0.040***	0.057***
		(-5.093)	(-4.525)	(-4.432)	(-4.428)	(-4.425)	(-6.261)
Trade			-0.003**	-0.003**	-0.003**	-0.003**	0.004***
			(-2.455)	(-2.339)	(-2.234)	(-2.201)	(-3.083)
Fia				0.002	0.002	0.002	0.009*
				(0.461)	(0.481)	(0.281)	(1.745)
Mi					-0.001	-0.001	-0.001
					(-0.251)	(-0.194)	(-0.503)
Gi						0.019	-0.005
						(0.322)	(-0.086)
Ur							0.207***
							(5.393)
Individual Fixation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Capacity	310	310	310	310	310	310	310
R^2	0.881	0.891	0.893	0.894	0.894	0.894	0.904

***p<0.01", "**<0.05", "*p<0.10

5.2 Stability Tests

In order to ensure the authenticity and reliability of the regression results, this paper adopts the following three methods to test the stability of the benchmark regression results: first, replace the measurement method of the explained variable; second, lag the core explained variable; third, partial regression, with the results presented in Table 4.

1) Revising the measurement framework for the dependent variable. Given the inherent ambiguity in current urban resilience evaluation metrics, differing calculation methods may introduce substantial discrepancies, potentially compromising the validity of regression results. We employ principal component analysis (PCA) to recalibrate urban resilience levels, replacing the entropy-based measurement. As demonstrated in Table (1), the coefficient for new infrastructure development maintains a statistically significant positive correlation with urban resilience enhancement. This alignment with established findings validates the reliability of new infrastructure's role in driving urban resilience development.

2) Lagged Core Explanatory Variable. Given the substantial investment scale, extended construction duration, and phased nature of new infrastructure, current urban resilience levels are influenced not only by immediate new infrastructure investments but also by their lagged effects from prior phases. To address this, we incorporate a one-period lagged core explanatory variable into the regression model. As shown in Table (2), the lagged variable maintains a statistically significant positive coefficient, demonstrating its positive impact on enhancing urban resilience.

3) Regression Analysis. The concept of new-type infrastructure was first introduced at the 2018 Central Economic Work Conference, which emphasized accelerating 5G commercialization and strengthening the development of emerging infrastructure such as artificial intelligence, industrial internet, and Internet of Things (IoT). Influenced by this conference, local governments began increasing investments in new-type infrastructure construction. Therefore, this study conducts a regression analysis on the impact relationship between new-type infrastructure development and urban resilience using data from 2018 to 2021. As shown in Table (3), the influence of new-type infrastructure on urban resilience remains statistically significant.

Table 4. Results of Robustness Tests

	(1)	(2)	(3)
	Rrincipal component analysis	Lagging core explanatory variables	Partial restitution
Infra	0.087**		0.081***
	(2.120)		(5.584)
L.infra		0.052***	
		(9.315)	

Controlled Variable	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes
N	310	279	124
R2	0.894	0.902	0.865
***p<0.01", "**<0.05", "*p<0.10			

6. Expansive Analysis

6.1 Heterogeneity Analysis

1) Heterogeneity of New Infrastructure Types. According to the classification by the National Development and Reform Commission (NDRC), new infrastructure is divided into three categories: information infrastructure, integrated infrastructure, and innovation infrastructure, with their impacts on urban resilience being studied. The regression results are shown in Table 5. All parameters estimating urban resilience from information infrastructure, integrated infrastructure, and innovation infrastructure were significantly positive, with the regression coefficient of integrated infrastructure being larger than those of information and innovation infrastructure. Information infrastructure enhances cities' data collection and processing capabilities by accelerating the dissemination rate of data elements, effectively driving urban digital transformation. Meanwhile, information technology, characterized by rapid circulation and strong penetration, can be effectively applied across urban industries, thereby enhancing overall urban resilience through technological empowerment. Integrated infrastructure promotes deep integration between digital technology and physical industries, empowering rapid real economic development and providing strong momentum for urban growth through industrial restructuring and upgrading. Innovation infrastructure, centered on technological innovation, accelerates industrial chain integration and drives industrial transformation through investments in technology development and scientific research, while continuously injecting vitality into the development of urban comprehensive resilience [10].

Table 5. Empirical Results of New Infrastructure Type Differences

	(1)	(2)	(3)
	Cr	Cr	Cr
Infra1	0.105***		
	(3.364)		
Infra2		0.052***	
		(8.528)	
Infra3			0.281***
			(6.351)
Controlled Variable	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes
N	310	310	310
R^2	0.881	0.903	0.893

***p<0.01", "**<0.05", "*p<0.10

2) Heterogeneity in Urban Resilience Dimensions. As urban resilience encompasses multiple dimensions including economic, social, ecological, and institutional aspects, a single study focusing on the impact of new infrastructure on urban resilience yields incomplete results. This paper conducts an in-depth analysis of the heterogeneous effects of new infrastructure across three dimensions: economic resilience, social resilience, and ecological resilience. Table 6 reveals statistically significant positive coefficients for new infrastructure's impact on urban economic and social resilience, aligning with previous hypotheses. By integrating next-generation information technology with industrial systems, new infrastructure creates innovative industrial ecosystems and application frameworks that empower traditional industries, reshape consumption patterns, and inject new momentum into urban economic development. With continuous investment in new infrastructure construction, the spatial networks of urban production, living, and social facilities have been progressively optimized. Notably, new infrastructure projects like urban rail transit systems enhance interpersonal connections by reducing spatial distances, thereby strengthening community cohesion. However, new infrastructure shows a significant negative impact on urban ecological resilience, likely due to irrational investment allocation and layout patterns. On one hand, massive investments in new infrastructure may burden urban ecosystems; on the other hand, unscientific network layouts could weaken the self-sustaining cycles and recovery capabilities of urban ecosystems. On

the other hand, the development period of green production technology generated by new infrastructure construction is long and the application cost is high, so it is difficult to be popularized in urban enterprises, and the green effect brought by technological innovation cannot be fully activated, thus hindering the improvement of urban ecological resilience in the short term.

3) Regional Heterogeneity. This study categorizes the sample into two major urban clusters based on their respective regions: the Yangtze River Delta and Pearl River Delta city clusters, to better compare their differences. As shown in Table 7, regarding new infrastructure classification heterogeneity, both clusters exhibit significantly positive coefficients for the impact of integrated infrastructure and innovation infrastructure on urban resilience. This indicates that investments in these two types of infrastructure contribute to enhancing urban resilience. In terms of information infrastructure, the Yangtze River Delta cluster demonstrates a significant positive correlation between information infrastructure development and urban resilience, while the Pearl River Delta cluster shows no significant impact. This suggests underutilized potential in information infrastructure development within the Pearl River Delta, requiring increased investment. Regarding urban resilience heterogeneity in Table 8, findings align with previous results: new-type infrastructure construction significantly boosts economic and social resilience in both clusters. Notably, the Yangtze River Delta cluster exhibits a significant negative correlation between new-type infrastructure development and ecological resilience, whereas the Pearl River Delta cluster shows no significant impact.

Table 6. Empirical Results of Urban Resilience Dimension Differences

	(1)	(2)	(3)
	Cr1	Cr2	Cr3
Infra	0.027***	0.020***	-0.002***
	(7.334)	(6.984)	(-2.602)
Controlled Variable	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes
N	310	310	310
R^2	0.905	0.674	0.534

***p<0.01", "**<0.05", "*p<0.10

Table 7. Empirical Results on the Impact of New Infrastructure Type Differences on Resilience of Cities in Yangtze River Delta and Pearl River Delta

	Yangtze River Delta	Pearl River Delta	Yangtze River Delta	Pearl River Delta	Yangtze River Delta	Pearl River Delta
	Cr	Cr	Cr	Cr	Cr	Cr
Infra1	0.089***	0.051				
	(3.326)	(0.630)				
Infra2			0.030***	0.068***		
			(4.589)	(5.123)		
Infra3					0.172***	0.434***
					(4.024)	(4.720)
Controlled variable	Yes	Yes	Yes	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes	Yes	Yes	Yes
N	220	90	220	90	220	90
R^2	0.929	0.905	0.932	0.932	0.931	0.929

***p<0.01", "**<0.05", "*p<0.10

Table 8. Empirical Results of the Impact of New Infrastructure on Resilience Dimension of Cities in Yangtze River Delta and Pearl River Delta

	Yangtze River Delta	Pearl River Delta	Yangtze River Delta	Pearl River Delta	Yangtze River Delta	Pearl River Delta
	Cr1	Cr1	Cr2	Cr2	Cr3	Cr3
Infra	0.021***	0.016*	0.007**	0.043***	-0.001*	0.001
	(6.147)	(1.949)	(1.983)	(9.694)	(-1.769)	(0.396)
Controlled Variable	Yes	Yes	Yes	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes	Yes	Yes	Yes
Time is Fixed	Yes	Yes	Yes	Yes	Yes	Yes

N	220	90	220	90	220	90
R^2	0.946	0.933	0.658	0.896	0.636	0.410

***p<0.01", "**<0.05", "*p<0.10

6.2 Analysis of Intermediary Mechanism

1) New Infrastructure Development, Regional Innovation, and Urban Resilience. This study employs an mediation model to examine the mechanisms through which new infrastructure development, regional innovation, and urban resilience interact. As shown in Table 9 (1) and Table (2), the estimated parameters for new infrastructure demonstrate a statistically significant positive correlation with regional innovation, indicating that new infrastructure enhances regional innovation capabilities. When incorporating urban resilience into the analysis, both new infrastructure and regional innovation show statistically significant positive impacts on urban resilience. This suggests that regional innovation partially mediates the relationship between new infrastructure and urban resilience, demonstrating that new infrastructure can improve urban resilience through regional innovation (Hypothesis 2 is thus validated). Through digital platform construction, new infrastructure achieves dual effects: First, it effectively transforms fragmented and unstructured data into interconnected explicit and tacit knowledge, accelerating R&D processes. Second, leveraging 5G networks 'high throughput and low latency capabilities, it enhances information transmission efficiency while reducing data circulation costs and innovation transaction costs. Additionally, new infrastructure overcomes geographical and temporal constraints to expand market boundaries, connecting developed and underdeveloped regions to achieve complementary resource advantages. This eliminates "iceberg costs" in intercity R&D investments, providing innovative impetus for urban resilience enhancement. The mediating effect of new infrastructure on regional innovation's promotion of urban resilience reaches 0.235×0.033, with the explanatory power of regional innovation channels accounting for 23.19% (0.235×0.033/0.036).

Table 9. Analysis of Mediation Mechanisms

	(1)	(2)	(3)	(4)
	Inno	Cr	Iupg	Cr
Infra	0.253***	0.036***	0.239***	0.038***
	(4.221)	(7.447)	(7.470)	(6.860)
Inno		0.033***		
		(6.822)		
Iupg				0.027***
				(2.841)
Controlled Variable	Yes	Yes	Yes	Yes
Individual Fixation	Yes	Yes	Yes	Yes
Time Fixed	Yes	Yes	Yes	Yes
N	310	310	310	310
R^2	0.647	0.919	0.694	0.907

***p<0.01", "**<0.05", "*p<0.10

2) New Infrastructure Development, Industrial Upgrading, and Urban Resilience. This study employs an mediation model to empirically analyze the mechanisms through which new infrastructure development, industrial upgrading, and urban resilience interact. As shown in Table 9 (3) and (4), the coefficient of new infrastructure's impact on industrial upgrading is significantly positive, indicating that new infrastructure effectively drives industrial upgrading. When urban resilience is introduced as a moderating factor, both new infrastructure development and industrial upgrading demonstrate significant positive effects on urban resilience levels, demonstrating that new infrastructure enhances urban resilience through industrial upgrading, thus validating Hypothesis 3. New infrastructure empowers traditional industries with digital technology to achieve comprehensive and multi-dimensional "disruptive" transformation, achieving highly intelligent operations. On one hand, it upgrades urban infrastructure through digitalization, improving overall operational efficiency and management standards. On the other hand, by enhancing resource utilization efficiency, it eliminates price disparities and drives industrial chain innovation and structural upgrading through product price transmission mechanisms [1]. The mediating effect of new infrastructure on urban resilience through industrial upgrading is 0.239×0.027, with the explanatory power of industrial upgrading as a mediating channel reaching 16.98% (0.239×0.027/0.038).

6.3 Analysis of Regulatory Effect

The moderating effect of high-quality economic development on urban resilience in new infrastructure construction. The table below presents the regression results with high-quality economic development as a moderating variable. As shown in Table 10, the interaction term between high-quality economic development and new infrastructure construction demonstrates a significant positive impact on urban resilience, with a regression coefficient of 0.053. Meanwhile, new infrastructure construction itself maintains a significant positive effect on urban resilience, with a regression coefficient of 0.019. This indicates that high-quality economic development acts as a positive moderating factor in the promotion of urban resilience through new infrastructure construction, thus validating Hypothesis H4.

Table 10. Analysis Results of Regulatory Mechanisms

	(1)	(2)
	Cr	Cr
Infra	0.044***	0.019***
	(8.562)	(2.836)
Lnpergdp	-0.001	0.002
	(-0.064)	(0.149)
Infra×Lnpergdp		0.053***
		(5.632)
Controlled Variable	Yes	Yes
Individual Fixation	Yes	Yes
Time Fixed	Yes	Yes
N	310	310
R^2	0.904	0.915

***p<0.01", "**<0.05", "*p<0.10

7. Conclusions

7.1 Research Conclusions

This study employs panel data analysis of 31 prefecture-level cities in the Yangtze River Delta and Pearl River Delta urban clusters from 2012 to 2021 to investigate the impact of new-type infrastructure development on urban resilience. The research further explores the heterogeneous effects and underlying mechanisms of such infrastructure development on urban resilience levels. Key findings include: (1) New-type infrastructure construction enhances overall urban resilience. (2) Heterogeneous analysis reveals that different types of new infrastructure exert distinct impacts: integrated infrastructure and innovation infrastructure positively influence resilience enhancement, while information infrastructure shows negligible effect. The study demonstrates that new-type infrastructure promotes economic and social resilience but has no significant impact on ecological resilience. (3) Mediating effects exist in the relationship between new-type infrastructure and resilience. Specifically, it accelerates regional innovation capabilities and speeds up R&D cycles to boost urban resilience. Additionally, digital empowerment through new infrastructure facilitates the transformation and upgrading of traditional industries, phasing out outdated production capacities, and enhancing overall urban output-thereby providing momentum for resilience improvement. (4) Moderating effects are observed: cities with higher economic development quality exhibit more pronounced resilience-enhancing effects from new-type infrastructure.

7.2 Policy Proposal

1) Increase investment in new-type infrastructure development and optimize its spatial distribution. Research findings indicate that new-type infrastructure construction can significantly enhance urban resilience. Therefore, prefecture-level cities should actively promote the development of next-generation information technology-driven infrastructure to leverage its supportive role in urban resilience. Meanwhile, construction plans should be tailored to regional resource endowments and actual conditions. Taking this study as an example, information infrastructure shows no significant impact on enhancing resilience in the Pearl River Delta urban agglomeration. Consequently, the Pearl River Delta region should prioritize information infrastructure development to improve data transmission efficiency and utilization rates, thereby better leveraging its foundational support role in urban resilience during the big data era.

2) Accelerate the transition to green technologies and harness the empowering role of new infrastructure in urban ecosystems. Research indicates that new infrastructure has reduced urban ecological resilience, likely due to insufficient utilization of green technologies enabled by such infrastructure. To address this, enterprises should increase R&D investments in green innovation technologies to enhance environmental benefits from technological outputs. Meanwhile, governments must promote green production technologies through policy support to facilitate corporate transformation.

For instance, implementing stricter tax policies for high-polluting enterprises while offering tax incentives to low-polluting businesses adopting clean energy or advanced technologies could effectively guide sustainable production practices.

3) Fully leverage the crucial role of new infrastructure development in enhancing innovation capabilities and driving industrial upgrading. Research findings indicate that new infrastructure contributes to urban resilience by boosting regional innovation capacity and accelerating industrial transformation. Therefore, as new infrastructure continues to improve, governments should encourage enterprises to engage in technological exchanges, capitalize on its advantages in data transmission and integration, enhance the efficiency of innovation resource circulation, and effectively shorten R&D cycles for innovative technologies. Simultaneously, strengthening talent reserves will provide sufficient human capital for information technology development. On the other hand, accelerating industrial digitalization and digital industrialization will expand application scenarios for emerging technologies while phasing out outdated production capacities, thereby providing an inexhaustible driving force for enhancing urban resilience.

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