

Impact of Network Infrastructure on Urban Resilience: A Quasi-Natural Experiment of “Broadband China” Pilot Policy

Aibo Yang^{1,*}, Ruobing Sun²

¹ Business School, East China University of Political Science and Law, Shanghai, China

² School of Communication, East China University of Political Science and Law, Shanghai, China

*AiboYang2021@163.com

Abstract

Research background: In the post-epidemic era and the critical period of digital transformation, improving urban resilience is conducive to social stability and economic development. **Research methods:** Based on the panel data of 280 prefecture-level and above cities in China from 2010 to 2020, this paper regards the establishment of “Broadband China” demonstration city as a quasi-natural experiment from the perspective of network infrastructure, and uses the multi-period Differences-in-Differences (DID) method to deeply investigate the impact of network infrastructure on the resilience of Chinese cities and its internal mechanism. **Conclusion:** Network infrastructure can exert the effects of digital transformation, entrepreneurship and technological innovation, thereby enhancing urban resilience. Heterogeneity analysis found that network infrastructure has a more significant effect on the resilience of eastern regions and resource-based cities. In addition, we also calculate urban sensitivity indicators (si) from 2019 to 2020, and finds that cities with a higher level of Internet development are more resilient and can ease the downward pressure on the economy during the epidemic. The research suggests that strengthening network infrastructure building is an effective measure to improve urban resilience and resist external shocks in the post-epidemic era.

Keywords

Network Infrastructure; Urban Resilience; Broadband China; Differences-in-Differences.

1. Research Background

Under the requirements of new development concepts and high-quality development, “new infrastructure” such as network infrastructure has provided China with the driving force for digital, intelligent and high-end transformation, and has gradually become a key factor in China’s high-quality economic development (Han and Zhu, 2014). In 2013, the Chinese government released the “Broadband China” strategy implementation plan, planning and deploying the development path of network infrastructure. In order to implement this strategy, relevant government departments have successively approved three batches of “Broadband China” demonstration cities. With the advancement of the strategy, China is gradually becoming a network power: by the end of 2021, the number of Internet broadband access ports in China will reach 1.018 billion; mobile Internet access traffic will reach 221.6 billion GB.

In addition, with the accelerated urbanization process, cities face more uncertain factors, such as epidemics, floods, earthquakes and other emergencies. The concept of urban resilience has attracted the attention of all sectors of society and often appears in government documents of various countries (Chen, 2022). For example, China’s 14th Five-Year Plan proposes to build “sponge cities and resilient cities”. This is the first time that the central document proposes to

build resilient cities. Therefore, improving urban resilience and promoting stable economic development have become urgent problems to be solved in current urban development.

Existing studies have pointed out that network infrastructure will promote urban economic development and efficiency improvement by transforming the development mode (Zheng et al., 2014; Guo and Luo, 2016). In addition, broadband plays a greater role in economic growth during the global epidemic than in normal times (Zhang, 2021), so network infrastructure may have a positive role in urban crisis resistance and economic recovery (Katz and Jung, 2022). We focus on the question: Can network infrastructure improve urban resilience? Further, through what mechanism does network infrastructure affect urban resilience? In response to the above problems, we regard the establishment of “Broadband China” demonstration cities as an exogenous policy impact. Based on the panel data of 280 prefecture-level and above cities in China from 2010 to 2019, we empirically study the impact of network infrastructure building on the resilience of Chinese cities and its internal mechanism.

The possible marginal contributions of this article are as follows: First, nearly 300 cities in China have provided us with a considerable number of samples, ensuring that the conclusion has high credibility. Second, the instrumental variable method has eased the endogenous problem to a certain extent. Third, it analyzes the impact of Internet development on urban resilience from a multi-dimensional perspective, enriching the path to improve urban resilience. Fourth, it evaluates the role of broadband networks on China's urban resilience during the epidemic, which is helpful to provide policy reference for economic development in the post-epidemic era.

2. Theory and Research Hypothesis

Resilience refers to the ability of a system to maintain its own stability and restore its original state after experiencing external shocks. In the literature of evolutionary economic geography, urban resilience is considered to be the ability of the city's economic-social-infrastructure-ecosystem to resist, adapt, recover, innovate and transform when affected by external long-term mitigating disturbances and short-term sudden shocks (Martin and Sunley, 2015). Due to the increasing number of emergencies in the world, many scholars have begun to pay attention to urban resilience and have made preliminary explorations on its influencing factors. Network infrastructure can break the space-time limitation and speed up the flow of information elements. In addition, it has network externalities, which can accelerate knowledge spillovers and increase innovation output (Sun and Xu, 2018), thereby promoting economic growth (Zheng et al., 2014), and promoting productivity (Guo and Luo, 2016; Huang et al., 2019). Further, it will have a positive effect on urban resilience (Chen, 2022). Combining with the existing literature, we expect that network infrastructure will affect urban resilience through the following paths:

2.1. Digital Transformation Effect

The “Broadband China” policy will increase the number of broadband users, improve the network operation speed, expand the network coverage, and provide an equipment base for the utilization and dissemination of digital elements, so urban information and communication technology (ICT) can develop rapidly. Digital technologies such as big data, artificial intelligence, and cloud computing are combined with the real economy to promote the digital transformation of industries. The mode of urban development has been transformed, and the level of the digital economy has been improved (Zhao et al., 2020). Further, the digital economy is conducive to the improvement of urban resilience (Zhu and Sun, 2021). First, digital transformation will facilitate the production, operation, management and trading of enterprises, while integrating various resources and improving the resilience of the industrial chain (Modgil et al., 2021). Second, as a new economic growth point, the digital economy can

enhance the competitiveness of the urban economy and provide a material basis for urban resilience. Finally, the application of digital technology to urban management and social services enables cities to adapt and recover quickly after being hit (Garcia-Perez et al., 2022).

2.2. Entrepreneurial Effect

With the implementation of the “Broadband China” strategy, the scale of Internet users in pilot cities will expand, which can promote information integration, improve the efficiency of resource utilization, lower the threshold for small and micro enterprises to start businesses, and stimulate entrepreneurial enthusiasm (Zhao et al., 2020). Entrepreneurship will generate new industries, promote the diversified development of regional industries, and make the economic system more adaptable, thus improving urban resilience (Xu and Zhang, 2019). In addition, new start-ups can absorb surplus labor and improve the matching rate between supply and demand in the labor market. Full employment can ensure the normal life of residents, thus enhancing urban resilience (Su and Zhao, 2020).

2.3. Technological Innovation Effect

Because of its spatial externalities, network infrastructure can shorten the spatial and temporal distance of knowledge acquisition, promote knowledge dissemination and cooperative innovation between cities (Zhong et al., 2022), and thus improve the level of urban technological innovation. In addition, technological progress has the potential to enhance the resilience of cities (Bristow and Healy, 2017). First, new technologies such as intelligent early warning and dynamic monitoring can effectively prevent risks (Nazarnia et al., 2020). Second, innovation can easily form new economic growth points in order to better cope with external shocks (Martin and Sunley, 2015). Finally, technological innovation is conducive to cities to quickly adapt to new situations and problems, seek new development opportunities in the economic recovery stage, and realize the transformation of development mode, which is also the key to enhance the urban resilience (Bristow and Healy, 2017).

Based on the above analysis, we propose four theoretical hypotheses as follows:

H1: Network infrastructure can improve urban resilience.

H2: Network infrastructure can improve urban resilience by promoting urban digital transformation.

H3: Network infrastructure can improve urban resilience by stimulating entrepreneurial activity.

H4: Network infrastructure can improve urban resilience by increasing the level of technological innovation.

3. Research Design

3.1. Econometric Model

In order to identify the causal relationship between network infrastructure and urban resilience, and to overcome the interference of endogenous problems to a certain extent, we regard the “Broadband China” pilot implemented in China since 2014 as an exogenous policy shock. We follow Zhong et al. (2022) and apply the multi-period DID approach to gain insights into the influences of network infrastructure on urban resilience, as follows:

$$ur_{it} = \alpha_0 + \alpha_1 net_{it} + \delta \sum cv_{it} + city_i + year_t + u_{it} \quad (1)$$

In model (1), ur_{it} is the dependent variable, which represents the urban resilience of city i in year t . net_{it} is the independent variable, which Measures the level of network infrastructure. If

city i has been selected as a “Broadband China” pilot city in year t , then $netit = 1$, or $netit = 0$. $cvit$ is a group of control variables which may affect $urit$. $cityi$ and $yeart$ are the city and year fixed effects respectively and uit is the random error term.

3.2. Variables and Data

Explained variable: urban resilience (ur). Urban resilience is demonstrated by the ability to resist and recover exhibited by highly complex system comprising human and environmental elements in response to crises (Vale, 2014; Zhao et al., 2020). We follow Zhu et al. (2019) and use a comprehensive index system to measure urban resilience. This paper selects four dimensions of economy, society, living facilities and ecology to construct an index system, and uses entropy method to measure the comprehensive index of urban resilience level. Please refer to Table 1 for details.

Table 1. Indicator system for evaluating urban resilience

Indicators	Indicator selection	Effect on ur
Economic resilience		
Economic scale	Per capita regional GDP	Positive
Fiscal level	Local general budgetary revenue	Positive
Urban construction	Total fixed asset investment	Positive
Market potential	Total retail sales of consumer goods	Positive
Industrial diversity	Proportion of the secondary and tertiary industries' total output value	Positive
Social resilience		
Social potential risks	Proportion of registered urban unemployed at year-end	Negative
Self-resistance of residents	Average salary of employees	Positive
	Per capita savings balance of urban and rural residents at year-end	Positive
Medical security capability	Number of beds in hospitals and clinics per 10,000 people	Positive
	Number of urban basic medical insurance participants per 10,000 people	Positive
Education equity	Number of students in regular higher education institutions per 10,000 people	Positive
Social risk response capability	Number of employees in public management and social organizations per 10,000 people	Positive
Engineering resilience		
Social power supply status	Total electricity consumption	Positive
Transportation capacity	Road area per capita	Positive
Public transportation	Number of urban public transportation vehicles per 10,000 people	Positive
Flood prevention capacity	Drainage pipe density	Positive
Ecological resilience		
Industrial water pollution level	Industrial sulfur dioxide emissions	Negative
	Industrial wastewater discharge	Negative
	Industrial smoke (dust) emission	Negative
Urban greenery level	Per capita park and green space area	Positive
	Green coverage rate of built-up areas	Positive
Resource recycling ability	Harmlessness rate of domestic waste treatment	Positive
Resource utilization rate	Comprehensive utilization rate of general industrial solid waste	Positive
Water quality	Concentrated treatment rate of sewage treatment plants	Positive

Core independent variable: network infrastructure (net). With reference to Zhong et al. (2022), this paper regards the “Broadband China” demonstration city as a quasi-natural experiment as a measure of network infrastructure. The value of the pilot city is 1, the value of the non-pilot city is 0, the value of the year of implementation and all subsequent years is 1, and the value before implementation is 0. The list of demonstration cities is from the website of the Ministry of Industry and Information Technology of China (<http://www.miit.gov.cn/>).

Control variables. We also add the following variables to the model for control. Population density (*pop*). Economic agglomeration (*agg*) which is the ratio of GDP to land area. Government expenditure (*gov*), measured by the ratio of fiscal expenditure to GDP. Foreign investment (*fdi*), measured by the ratio of the actual amount of foreign investment to GDP. Human capital (*hum*) which is the logarithm of the number of books in public libraries per 100 people. To eliminate measurement errors caused by price changes, we convert nominal variables involving prices into real variables with 2010 as the base period.

The sample is 280 cities in China from 2010 to 2019. The data are mainly from the China City Statistical Yearbook and the CSMAR database. The statistical characteristics of each variable are shown in Table 2. It is worth mentioning that because the statistical caliber of some data indicators in the China City Statistical Yearbook for 2020 is different from previous years, it is impossible to extend the data to 2020 and beyond. For this reason, the last year of the observation period in this article is 2019. However, starting from the end of 2019, the global epidemic has had a huge impact and impact on Chinese cities. Can the development of the Internet cope with the impact in the epidemic? We will conduct exploratory research through other methods in further discussion.

Table 2. Descriptive statistics

Variable	N	Mean	SD	Min	Max
<i>ur</i>	2800	0.1143	0.1054	0.0096	0.8067
<i>net</i>	2800	0.1886	0.3912	0.0000	1.0000
<i>pop</i>	2800	0.0442	0.0344	0.0005	0.2759
<i>agg</i>	2800	0.3051	0.6851	0.0021	12.8812
<i>gov</i>	2800	0.1959	0.1036	0.0439	1.4852
<i>fdi</i>	2800	0.0171	0.0178	0.0000	0.1988
<i>hum</i>	2800	3.6897	0.9327	-0.1278	7.3890

4. Analysis of Results

4.1. Regression Results Of the DID Model

Table 3. Estimation results of DID model and Mechanism analysis

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	<i>ur</i>	<i>dige</i>	<i>ur</i>	<i>entrep</i>	<i>ur</i>	<i>inv</i>	<i>ur</i>
<i>net</i>	0.0075*** (0.0027)	0.0101** (0.0044)	0.0069*** (0.0026)	23.0290*** (7.2364)	0.0065** (0.0026)	0.9942*** (0.2748)	0.0055** (0.0024)
<i>dige</i>			0.0443* (0.0267)				
<i>entrep</i>					0.0001*** (0.0000)		
<i>inv</i>							0.0047*** (0.0010)
Constant	0.1530*** (0.0256)	0.1241*** (0.0025)	0.1463*** (0.0247)	72.8637*** (2.2294)	0.1496*** (0.0242)	0.4664*** (0.1019)	0.1356*** (0.0235)
<i>cv</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2800	2770	2770	2760	2760	2800	2800
Adj-R ²	0.6598	0.1389	0.6624	0.4108	0.6715	0.1962	0.7089

Note: Cluster robust standard errors are shown in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01; The following tables are the same.

From the regression results in column (1) of Table 3, it can be seen that the coefficient of the policy dummy variable is significantly positive at the level of 1%. This shows that compared with non-demonstration cities, the level of urban resilience of “Broadband China” demonstration cities will increase by 0.75%. The conclusion is that network infrastructure building will significantly improve the level of urban resilience, and hypothesis 1 is confirmed.

4.2. Mechanism Analysis

According to the existing literature, network infrastructure may have an impact on urban resilience through digital transformation, entrepreneurial effects, and technological innovation effects (H2, H3, and H4). In order to verify these three hypotheses, we follow Baron and Kenny (1986) to build a mediating effect model and adopt a three-stage stepwise regression method to test the mechanism. We take the previous model (1) as the first stage, and build a two-stage and three-stage model on the basis of model (1):

$$med_{it} = \beta_0 + \beta_1 net_{it} + \delta \sum cv_{it} + city_i + year_t + u_{it} \quad (2)$$

$$ur_{it} = \gamma_0 + \gamma_1 net_{it} + \gamma_2 med_{it} + \delta \sum cv_{it} + city_i + year_t + u_{it} \quad (3)$$

In models (2) and (3), *medit* represents the mechanism variable, and all other variables are unchanged. The mechanism variables selected in this paper are as follows:

Digital transformation effect - digital level (*dige*). Following the research of Zhao et al. (2020), this paper uses Principal Component Analysis (PCA) to measure the comprehensive development level of urban digital economy.

Entrepreneurial effect - entrepreneurial active level (*entrep*). The number of newly registered enterprises per 10,000 people in the city.

Technological innovation effect - invention patent (*inv*). Every 10,000 people in the city have the number of invention patent licenses.

Column (2) - (7) of Table 3 reports the results of mechanism analysis. Column (2), (4) and (6) list the impact of the “Broadband China” policy pilot on mechanism variables. It can be found that the coefficients of *net* are significantly positive at least at the level of 5%, indicating that network infrastructure can indeed promote the digital transformation of cities, improve the level of entrepreneurship, and the level of technological innovation. Column (3), (5) and (7) add mechanism variables to the model (1). The coefficients of mechanism variables are all significantly positive at least 10% level, indicating that network infrastructure can improve urban resilience through urban digital transformation, entrepreneurial activities, and technological innovation. Therefore, H2, H3 and H4 are confirmed.

4.3. Robustness Test

4.3.1. Parallel Trend Test

DID need to satisfy the assumption of parallel trends. To this end, this paper refers to the “event research method” of Jacobson et al. (1993), and adds the time dummy variable before and after the establishment of the “event” of the “Broadband China” demonstration city to the original regression model (1) for regression analysis, so as to test whether the DID model satisfies the parallel trend hypothesis. Fig. 1 is the results of the parallel trend test in this paper. It plots the impact of temporal dummy variables on urban resilience before and after the policy pilot and the 95% confidence interval. The horizontal axis is the number of years before and after the pilot, and 0 represents the year of the pilot. As shown in the figure, in the 5 years before the implementation of the policy, the impact of the “Broadband China” strategy on urban resilience

was not significant, indicating that there was no significant difference between the experimental group and the control group in urban resilience before the implementation of the policy. It can be determined that the model in this paper passed the parallel trend test.

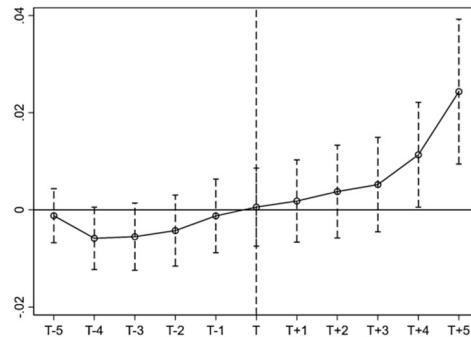


Fig. 1 Parallel Trend Test

4.3.2. Instrument Variable and the Treatment of Endogenous Problems

To alleviate the endogenous problem to a certain extent is a work that cannot be ignored in economic research. For this reason, we use instrumental variables and Two-stage least squares (2SLS) methods to estimate model (1) again to prove the robustness of the conclusion. The number of post offices in Chinese cities in 1984 is selected as a cross-section instrumental variable. Network infrastructure is related to communication needs. Early residents communicated through post offices. Later, post offices served as executive departments to lay fixed telephone lines for dial-up Internet access, and network infrastructure was gradually developed. Therefore, the correlation requirements are met. Historical variables cannot affect the current urban resilience, so they meet the exogenous requirements. However, this variable does not change with time and cannot be used in panel data. Therefore, this paper uses the product of the number of post offices in each prefecture-level city in 1984 and the number of Internet access ports in the country as an instrumental variable (iv).

The relevant estimation results are shown in Table 4. The results of the second stage show that after alleviating the endogenous problem, the implementation of the “Broadband China” strategy still has a significant positive impact on urban resilience, which implies that the previous estimation results are robust. In addition, the first stage F statistical value of 88.423 is far greater than the 10% threshold of the experience value, indicating that there is no “weak instrumental variable”. Therefore, the selection of instrumental variables is reasonable and effective.

Table 4. 2SLS regression results using instrumental variable

Variable	(1) The Second Stage	(2) The First Stage
	<i>ur</i>	<i>net</i>
<i>net</i>	0.1450*** (0.0192)	
<i>iv</i>		0.2374*** (0.0336)
Constant	0.0724* (0.0383)	-2.6117*** (0.4768)
<i>cv</i>	Yes	Yes
City FE	Yes	Yes
Year FE	Yes	Yes
<i>N</i>	2220	2220
Adj- <i>R</i> ²	—	0.3914
The First Stage F Statistical Value		88.4230

4.3.3. Placebo Test

In order to exclude the interference of other unobservable factors, we re-randomly assigned the experimental group and the control group to conduct a placebo test. Specifically, the new policy treatment group was randomly selected in 280 cities in this paper and repeated 500 times. From this, we obtained the estimated coefficients of the false treatment group in 500 “Broadband China” demonstration cities. The specific distribution of the estimated coefficients and the corresponding p-values are shown in Figure 2. The randomly generated estimated coefficients show a normal distribution around 0, and most p-values are greater than 0.1. At this time, the estimated coefficients of the real processing group in the benchmark regression ($\alpha = 0.0075$) are outliers. This shows that the improvement in the level of urban resilience is caused by the implementation of the “Broadband China” strategy, rather than other random factors. The placebo test proves the robustness of the benchmark conclusion.

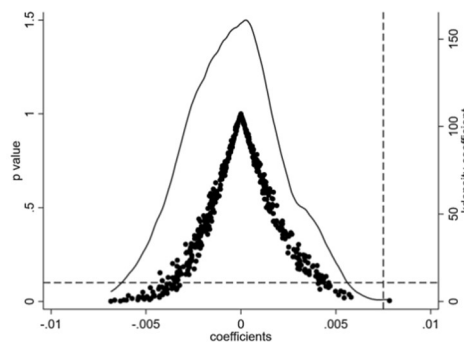


Fig. 2 Placebo Test

4.4. Heterogeneity Analysis

4.4.1. Regional Heterogeneity

This paper divides the eastern, central and western regions to explore the impact of the “Broadband China” strategy on the resilience of cities in different regions. According to the relevant regression results reported in columns (1) - (3) of Table 5, the coefficient of the dummy variable of the “Broadband China” pilot policy in the eastern region is significant at the level of 10%, indicating that the network infrastructure has significantly improved the resilience of cities in eastern China, but has no significant effect on cities in the central and western regions.

4.4.2. Urban Heterogeneity

Table 5. Regression results of heterogeneity analysis

Variable	east	middle	west	resource-based	non-resource-based
	(1)	(2)	(3)	(4)	(5)
	<i>ur</i>	<i>ur</i>	<i>ur</i>	<i>ur</i>	<i>ur</i>
<i>net</i>	0.0083*	0.0041	0.0051	0.0072*	0.0069*
	(0.0044)	(0.0030)	(0.0066)	(0.0039)	(0.0035)
Constant	0.2600***	0.0772***	0.0719	0.0268	0.2033***
	(0.0495)	(0.0178)	(0.0465)	(0.0175)	(0.0283)
<i>cv</i>	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
<i>N</i>	890	1330	580	1130	1670
Adj-R ²	0.7304	0.7705	0.6166	0.6723	0.6862

The development of resource-based cities mostly relies on natural resources and is easy to fall into industrial path lock. Such cities may not be able to use network infrastructure for digital transformation. This article divides cities into resource-based cities and non-resource-based cities to explore the differentiated impact of network infrastructure. According to the National Sustainable Development Plan for Resource-based Cities (2013-2020), there are 262 resource-based cities in China up to now. 113 resource-based cities are included in the 280 city samples in this paper. From columns (4) and (5) of Table 5, it can be seen that the coefficients of resource-based cities are slightly larger, indicating that network infrastructure building is more helpful for resource-based cities to improve their own resilience.

5. Further Discussion: Examining the Role of Network Infrastructure During the Impact of the Epidemic

5.1. Measurement of Sensitivity Index

As mentioned earlier, due to the problems of data availability and statistical caliber, this article cannot extend the data sample beyond 2019 in the benchmark regression. However, it should be considered that since the end of 2019, the sudden global epidemic has had a huge impact on China’s urban economy and society. In order to investigate whether the network infrastructure has an impact on urban economic resilience during the epidemic, this paper refers to the design of Chen (2022), constructs a sensitivity index (si) of urban resilience from 2019 to 2020, and uses a new econometric model to study.

The sensitivity indicator formula is: $si_{i,2019-2020} = (\ln gdp_{i,2020} - \ln gdp_{i,2019}) - (\ln gdp_{2020} - \ln gdp_{2019})$ [23]. $gdp_{i,2020}$ is the regional GDP of city i in 2020. gdp_{2020} is the national GDP for 2020. Subscription 2019 indicates this indicator for 2019. If $si_{i,2019-2020} > 0$, then GDP of city i will grow faster (or decline more slowly) between 2019 and 2020 compared with the country as a whole, indicating greater resilience; otherwise, it will be less resilient. Figure 3 depicts the distribution of si in various cities from 2019 to 2020. It can be found that the si distribution is left-sided, indicating that the si of most cities during the epidemic is less than 0, that is, the GDP growth rate of most cities is lower than the national level, and the number of low-resilience cities is large. The first year of the epidemic has caused a huge impact on China’s urban economy.

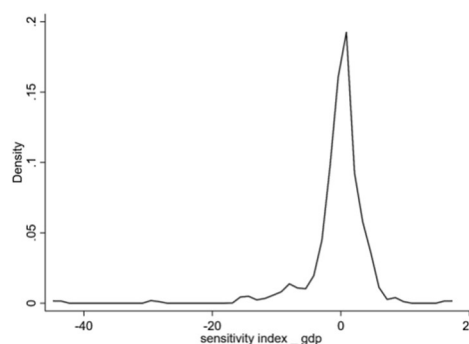


Fig. 3 Kernel Density of Sensitivity Indicator Distribution from 2019 to 2020

5.2. New Econometric Models

The new econometric models are as follows:

$$si_{i,2019-2020} = a_1 + b_1 \ln internet_i + \delta \sum cv_i + u_i \tag{4}$$

$$si_{i,2019-2020} = a_2 + b_2 \ln mobile_i + \delta \sum cv_i + u_i \tag{5}$$

sii,2019-2020 as a sensitivity indicator, representing the city's ability to resist shocks during the epidemic. interneti and mobilei indicate the level of network infrastructure development, respectively, the number of Internet broadband access users, the number of mobile phone users at the end of the year. cvit is the same group of control variables as in previous sections. uit is the random error term.

The econometric model here uses cross-sectional data, so it is no longer possible to regard the "Broadband China" pilot policy as a quasi-natural experiment. According to the development goal in the "Broadband China" Strategy and Implementation Plan issued by the State Council: "By 2020, ... broadband applications are deeply integrated into production and life, and the mobile Internet is fully popularized", it can be found that the goal of network infrastructure building is the popularity of fixed broadband and mobile Internet. Therefore, we choose "the number of Internet broadband access users" and "the number of mobile phone users at the end of the year" as proxy variables for the level of network infrastructure here.

In order to mitigate the reverse causality caused by the downward pressure on the economy caused by the impact of the epidemic, all explanatory variables use indicators before the outbreak of the epidemic (that is, indicators before the economy have begun to decline). Specifically, the average value from 2016 to 2018 is used. The average value is used to avoid the impact of outliers that may exist in a given year.

5.3. Results of New Models

The regression results are shown in Table 6. From the estimated coefficients in columns (1) - (6), it can be seen that the coefficients of the network infrastructure are significantly positive at least 10% level regardless of whether control variables are added. The results show that the network infrastructure played a positive role during the epidemic, which is similar to the research conclusion of Zhang (2021). After excluding Wuhan, which will be most affected by the epidemic in 2020, the estimated results have not changed significantly. It shows that this conclusion is basically correct.

The regression results above show again: Cities with higher penetration of fixed broadband and mobile phones have higher urban resilience, can have stronger resilience when the urban economy is hit by the epidemic, and fully resolve the crisis brought about by the downward pressure of the economy. This finding complements the conclusions of the previous chapters and also provides policy inspiration for the stable operation of China's economy in the future.

Table 6. The role of network infrastructure during the impact of the epidemic

Variable	(1)	(2)	(3)	(4)	(5) excluding Wuhan	(6) excluding Wuhan
	$S_{i,2019-2020}$	$S_{i,2019-2020}$	$S_{i,2019-2020}$	$S_{i,2019-2020}$	$S_{i,2019-2020}$	$S_{i,2019-2020}$
lninternet	0.6716**	1.3074***			1.3611***	
	(0.3336)	(0.4791)			(0.4777)	
lnmobile			0.5771*	0.9652**		1.0136**
			(0.3251)	(0.4760)		(0.4744)
Constant	-4.9755**	-11.6828***	-3.8345*	-8.5972***	-12.2581***	-9.0891***
	(2.4332)	(3.6725)	(2.0467)	(2.9950)	(3.6557)	(2.9799)
cv	No	Yes	No	Yes	Yes	Yes
N	277	277	277	277	276	276
Adj-R ²	0.0118	0.0419	0.0079	0.0309	0.0456	0.0339

6. Conclusion

Based on the panel data of 280 prefecture-level and above cities in China from 2010 to 2019, this paper regards the pilot of "Broadband China" demonstration city as a quasi-natural

experiment, empirically tests the impact of network infrastructure building represented by the “Broadband China” strategy on the resilience of Chinese cities, and discusses the internal mechanism of action.

The results found that: First, network infrastructure building has significantly improved the resilience level of Chinese cities, and this conclusion is still valid after a series of robustness tests and endogenous treatment. Second, network infrastructure building can play a digital transformation effect, entrepreneurial effect and technological innovation effect, which can affect urban resilience. Third, network infrastructure building has a more significant effect on the resilience level of eastern regions and resource-based cities. Fourth, we also used the 2019-2020 sensitivity index to measure the resilience of Chinese cities during the epidemic. The results show that cities with better network infrastructure development are more resilient, able to resist economic shocks during the epidemic and recover quickly.

Based on the conclusions drawn from the above research, we propose the following policy implications:

First, the government should continue to support the investment and construction of network infrastructure. The implementation of the “Broadband China” strategy points out the direction for the next step of Internet development. China can follow the successful experience of this strategy and continue to move towards the development goal of a network power and a digital China. In the post-epidemic era and the critical period of economic transformation, we should play the positive role of network infrastructure in the smooth operation of the urban economy, release the dividend of the digital economy, and promote the construction of resilient cities and the high-quality development of the urban economy. At the same time, the government should also promote the coordinated development of regional broadband networks, especially give backward regions policy preferences and preferential policies. Only in this way can the regional development gap and the “digital divide” be narrowed.

Second, China should continue to explore the multi-dimensional path of broadband network facilities to enhance urban resilience. The government should focus on the needs of economic and social digital transformation, further improve the capacity and quality of network services, promote the deep integration of network technology with various fields, and form an economic system that combines numbers and reality. The full integration of broadband applications into production and life can help the digital transformation of urban economy and industries, and continue to promote the development of emerging industries such as big data, cloud computing, and artificial intelligence. In terms of innovation and entrepreneurship, various entities can rely on network facilities and Internet platforms to realize innovation and entrepreneurship. On this basis, we will continue to explore ways to improve the city’s innovation and transformation ability, and strive to build a socially stable and ecologically coordinated urban system.

Third, in the post-epidemic era, the government should grasp the critical period and development opportunities of digital transformation, make up for the shortcomings of network development in various regions, improve the overall level of urban broadband network development, and make technological innovation and industrial competitiveness reach the world’s advanced level. China can rely on advanced technology and advanced industries to support sustainable economic and social development and promote long-term economic stability and improvement.

References

- [1] Han, B., & Zhu, P. 2014. Empirical analysis of the impact of broadband on China’s economic growth. *Statistical Research*, 31(10): 49-54.
- [2] Chen, A. 2022. Agglomeration and urban economic resilience in China. *The Journal of World Economy*, 45(01): 158-181.

- [3] Zheng, S., Zhou, L., & He, W. 2014. Telecommunication infrastructure and China's economic growth. *Economic Research Journal*, 49(05): 77-90.
- [4] Guo, J., & Luo, P. 2016. Does the Internet promote China's total factor productivity. *Management World*, 10: 34-49.
- [5] Zhang, X. 2021. Broadband and economic growth in China: an empirical study during the COVID-19 pandemic period. *Telematics and Informatics*, 58, 101533.
- [6] Katz, R., & Jung, J. 2022. The role of broadband infrastructure in building economic resiliency in the United States during the COVID-19 pandemic. *Mathematics*, 10, 2988.
- [7] Martin, R., & Sunley, P. 2015. On the notion of regional economic resilience: conceptualization and explanation. *Journal of Economic Geography*, 15(1): 1-42.
- [8] Sun, Z., & Xu, Y. 2018. Can information infrastructure building improve the innovation efficiency of China's high-tech industry? -Empirical analysis based on the panel data of 17 sub-sectors of high technology from 2002 to 2013. *Nankai Economic Studies*, 2: 72-92.
- [9] Huang, Q., Yu, Y., & Zhang, S. 2019. Internet development and manufacturing productivity improvement: Internal mechanisms and China's experience. *China Industrial Economics*, 8: 5-23.
- [10] Zhao, T., Zhang, Z., & Liang, S. 2020. Digital economy, entrepreneurial active level and high-quality development -Empirical evidence from Chinese cities. *Management World*, 36(10): 65-76.
- [11] Zhu, J., & Sun, H. 2021. Does the digital economy improve the resilience of the urban economy. *Modern Economic Research*, 10: 1-13.
- [12] Modgil, S., Gupta, S., Stekelorum, R., & Laguir, I. 2021. AI technologies and their impact on supply chain resilience during COVID-19. *International Journal of Physical Distribution & Logistics Management*, 52(2), 130-149.
- [13] Garcia-Perez, A., Cegarra-Navarro, J. G., Sallos, M. P., Martinez-Caro, E., & Chinnaswamy, A. 2023. Resilience in healthcare systems: Cyber security and digital transformation. *Technovation*, 121, 102583.
- [14] Xu, Y., & Zhang, L. 2019. The economic resilience and origin of Chinese cities: From the perspective of industrial structure diversification. *Finance & Trade Economics*, 40(07): 110-126.
- [15] Su, R., & Zhao, X. 2020. Manufacturing development, entrepreneurial vitality and urban economic resilience. *Finance & Economics*, 9: 79-92.
- [16] Zhong, Z., Gao, Z., & Qin, C. 2022. Network infrastructure building and cooperation innovation between cities-Evidence from the pilot of "Broadband China" and its promotion. *Journal of Finance and Economics*, 48(03): 79-93.
- [17] Bristow, G., & Healy, A. 2018. Innovation and regional economic resilience: an exploratory analysis. *The annals of regional science*, 60(2): 265-284.
- [18] Nazarnia, H., Sarmasti, H., & Wills, W. O. 2020. Application of household disruption data to delineate critical infrastructure resilience characteristics in the aftermath of disaster: A case study of Bhaktapur, Nepal. *Safety science*, 121: 573-579.
- [19] Vale, L. J. 2014. The politics of resilient cities: whose resilience and whose city?. *Building Research & Information*, 42(2): 191-201.
- [20] Zhu, S., Li, D., & Feng, H. 2019. Is smart city resilient? Evidence from China. *Sustainable Cities and Society*, 50, 101636.
- [21] Baron, R. M., & Kenny, D. A. 1986. The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, 51(6), 1173.
- [22] Jacobson, L. S., LaLonde, R. J., & Sullivan, D. G. 1993. Earnings losses of displaced workers. *The American economic review*, 685-709.
- [23] Based on the availability of data and the severity of the impact of the epidemic, GDP is selected here to measure the resilience of cities during the epidemic. In order to facilitate quantitative regression and display, this paper multiplies the sensitivity index by 100.