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Spatiotemporal Evolution and Convergence Analysis of Urban Economic Resilience in China—A Case Study of Jiangsu Province

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Abstract: Increased external uncertainties and growing tensions within the urban economic system pose new challenges to the urban economy. How to improve the quality of urban economic development and enhance the resilience of urban economies has become a new goal for sustainable urban development. Therefore, taking Jiangsu Province as an example, this study aims to explore the evolutionary trend of urban economic resilience and provide valuable references for cultivating and enhancing urban economic resilience. Initially, a system of indicators is established based on three dimensions: resistance, adaptability, and resilience. Then, combined with the entropy method, coefficient of variation method, kernel density method, natural break-point method, and Theil index, the spatial and temporal differences of economic elasticity of 13 cities in Jiangsu Province from 2006 to 2021 are analyzed. Finally, exploratory spatial data analysis and spatial convergence models are applied to investigate the spatial correlation and convergence of urban economic resilience. The results show an upward trend in the economic resilience of the cities in Jiangsu Province, but with significant regional differences and agglomeration. A downward trend in the level of economic resilience is observed from Southern Jiangsu to Northern Jiangsu. The spatial convergence model suggests that the economic resilience growth of cities will gradually converge to the same stable level, and the regional differences have a trend of reduction. In the future, the Jiangsu region needs to strengthen regional cooperation, enhance the role of the central city to drive, and continuously improve the economic resilience of the city to promote high-quality economic development.

Keywords: urban economic resilience; spatiotemporal evolution; spatial convergence; Jiangsu Province; China

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1. Introduction

Recently, the trend toward urbanization continues to advance around the world, with cities growing in size and the trends of population, resources, and other factors in cities becoming more pronounced [1]. At the same time, global warming has caused extreme disasters related to climate change to occur more frequently around the world, posing huge challenges to the safety of cities [2,3]. Specifically, in 2023, China experienced a series of natural disasters that affected about 0.95 billion people and caused direct economic losses amounting to 345.45 billion RMB [4]. In addition, world conflicts have escalated further, and new trade protectionism and "anti-globalization" thoughts have become widespread. Thus, the global economic situation is characterized by high volatility, instability, complexity, and ambiguity [5,6]. International trade is exhausted, and global economic growth is facing great challenges [7]. Therefore, the question of how cities can achieve resilient development under various risks and challenges has become an urgent one to be answered [8].

"Resilience" is based on the Latin term "resilio", which translates as "return to an initial state" [9]. Holling first applied the definition of "resilience" into the realm of ecology to describe ecological systems' stability [10]. Due to its universality, many scholars in psychology, meteorology, geohazardology, and urban planning have also introduced the concept into their own research to explain some characteristics of their fields [11–13], and the application range of resilience has been expanding. In 2020, the Fifth Plenary Session of the 19th Central Committee of China officially proposed the construction of "resilient cities" for the first time. In 2021, Chapter 29 of the Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 proposed "building livable, innovative, smart, green, humanistic, and resilient cities" [14]. In 2022, the report of the 20th National Congress explicitly called for adhering to the people's city for the people, expediting a shift in the development pattern of super-large cities, and creating livable, resilient, and smart cities [15]. Building resilient cities is essential to address the risks facing cities, maintain their stable functioning, and enhance their vitality [16]. In this process, urban economic resilience is at the center, which plays a significant role in ensuring residents' lives and property safety, promoting urban economic transformation and development, and enhancing its competitiveness in the global economy [17,18].

There are three main categories of existing research methods on measuring the economic resilience of cities. One is the sensitivity index method, where the commonly used core observational variables are mainly the indicators of urban GDP, employment, and trade volume [19,20]. Second, economic resilience is measured by the difference between actual and predicted levels of regional output or unemployment rates [21]. Third, the composite indicator method is proposed, which establishes a comprehensive system of evaluation indicators to measure economic resilience. However, because of the various focuses of resilience research by different researchers, which has led to some differences in the selection of indicators, a unified assessment model has not yet been formed. Dinh et al. (2017) [22] constructed an index system, including manpower, social, natural, physical, financial capital stock, economic variety, and service centers' accessibility, and used principal component analysis to generate an economic resilience index. Bruneckiene et al. (2018) [23] proposed to construct six index systems, including insight ability, regional governance ability, knowledge and innovation ability, learning ability, network and cooperation ability, and infrastructure ability, to evaluate economic resilience. Overall, the indicator system approach has strong coverage, avoids the one-sided problem of a single indicator, reflects the long-term capacity of an economy to adapt to uncertainty, and is widely used.

Throughout the existing studies, many scholars have introduced the resilience theory into urban systems. However, most of them focus on urban resilience, and research on urban economic resilience is still lacking. Due to the inconsistencies in the disciplines and research fields of various scholars, there is no effective and unified connotation of urban economic resilience. Secondly, the existing indicator system for measuring the economic resilience of cities rarely embodies the whole course of economic resilience and is mostly characterized based on the state. Few researchers have conducted long-term studies on urban economic resilience from a temporal and spatial evolution perspective, and most of them are static horizontal comparisons.

Therefore, with a view to addressing the above issues, this paper establishes a set of comprehensive assessment indicator systems for urban economic resilience based on a PSR framework to quantify the level of economic resilience of cities in Jiangsu Province. Then, the method of spatial analysis is applied to clarify the spatiotemporal evolution characteristics of the economic resilience level of 13 cities in Jiangsu Province. Furthermore, a spatial convergence model is used to explore the urban economic resilience convergence mechanism and investigate the spatial effects.

As a new development paradigm, the quantitative assessment of economic resilience is important for advancing the process of sustainable development. By enhancing economic resilience, we can better address challenges and ensure stable and sustainable economic growth. To a certain extent, this study enriches the research on urban economic resilience, and the established indicator system has a certain reference value. Meanwhile, the conclusions can provide reference for similar regions, promoting coordinated and balanced regional development.

2. Materials and Methods

2.1. Construction of the Urban Economic Resilience Evaluation Indicator System

2.1.1. Construction of the Indicator System

The "Pressure–State–Response" (PSR) model originated from the pressure–response framework proposed by Rapport and Friend, a famous Canadian statistician, in 1979. In the 1990s, the United Nations Environment Program and the Organization for Economic Co-operation and Development jointly explored and obtained the PSR model, which is used in ecological and environmental research. Because the PSR framework can reflect the dynamic evolution process and internal logic of things, it is now widely used in sustainable development, environmental protection, ecological safety, security assessment, and other research fields [24–26]. Its research logic and action mechanism are highly relevant to the research on the economic resilience of cities, and this research framework of the model can be fully used in the study of economic resilience. In view of this, what we define as urban economic resilience is the cyclical process by which urban economic systems continue to increase their adaptability in the face of risks and disruptions. It covers all phases, from coping with shocks and maintaining stability, to rapid recovery and even turning challenges into opportunities to promote innovative development. As shown in Table 1, we divided the resilience process into 3 stages and selected 33 indicators, with reference to existing studies.

Table 1. Urban economic resilience evaluation index system.

Domains	Indicators	Unit	Nature	Reference
Stress-resistance resilience	Primary sector as a proportion of GDP	%	−	[27]
	Industrial structure concentration	%	−	[28]
	Proportion of persons employed in resource industries	%	−	[29]
	Foreign trade dependence	%	−	[30]
	Registered unemployment rate	%	−	[31]
	Ratio of deposits and loans to financial institutions	%	−	[32]
	Overall energy consumption per 10,000 GDP	ton	−	[33]
	Development intensity of construction land per 10,000 GDP	ha	−	[34]
	Industrial wastewater discharge per 10,000 GDP	ton	−	[35]
	Industrial SO_2 emissions per 10,000 GDP	ton	−	[35]
	Industrial dust emissions per 10,000 GDP	ton	−	[35]
State-adapted resilience	Per capita GDP	CNY	+	[36]
	Per capita deposits in savings at end of year	CNY	+	[37]
	Urbanization rate	%	+	[38]
	Average wage of employees	CNY	+	[37]
	Per capita disposable income	CNY	+	[39,40]
	Per capita sales of retail social consumer goods	CNY	+	[32]
	Per capita fixed asset investment	CNY	+	[41]
	Per capita imports and exports	CNY	+	[42]
	Social insurance coverage rate	%	+	[21]
	Financial self-reliance rate	%	+	[43]
	Per capita regional financial spending	CNY	+	[28]
Response–recovery resilience	International Internet households per 100 population	households	+	[44]
	Mobile phones per 100 population	unit	+	[37,45]
	Tertiary sector as a percentage of GDP	%	+	[46]
	Advanced level of industrial structure	%	+	[47]
	Rate for consolidated utilization of industrial solid waste	%	+	[48]
	Rate of non-hazardous treatment of living waste	%	+	[49]
	Rate of reuse of industrial wastewater	%	+	[27]
	Proportion of R&D investment in GDP	%	+	[33]
	Proportion of science and education expenditures to fiscal expenses	%	+	[37,50]
	Number of patents granted per 10,000 persons	patents	+	[32]
	Number of students enrolled in regular colleges per 10,000 persons	person	+	[51]

2.1.2. Data Sources and Processing

This study utilized statistical data from 13 cities within the research area, covering the period from 2007 to 2022 as the sample for analysis. The data primarily originated from relevant provincial and municipal statistical yearbooks and bulletins. For individuals lacking data, the multi-year average growth rate and interpolation method were used to supplement.

2.2. Methodology

2.2.1. Entropy Method

In order to avoid the interference of subjective factors, reflecting the objectivity of the results, this paper used state16 software to assign weights to the evaluation index system via the entropy method. The formula refers to the study of Cui et al. (2023) [52], and the steps are as follows:

(1) Data standardization

Structure a raw data matrix:

$$X = \{x_{ij}\}_{n\times m} \quad (i = 1, 2, \ldots, n;\ j = 1, 2, \ldots, m), \tag{1}$$

with n cities and m evaluation factors. In this paper, n and m were 13 and 33, respectively.

Indicator data standardization:

$$x^*_{ij} = \begin{cases} \dfrac{x_{ij} - \min\{x_j\}}{\max\{x_j\} - \min\{x_j\}}, & \text{positive indicators} \\ \dfrac{\max\{x_j\} - x_{ij}}{\max\{x_j\} - \min\{x_j\}}, & \text{negative indicators} \end{cases} \tag{2}$$

Among them, x^*_{ij} is the normalized value, and $\max\{x_j\}$ and $\min\{x_j\}$ are the maximum and minimum values of the index j of the city i, respectively.

(2) Determination of indicator weights

Indicator data normalization:

$$p_{ij} = x^*_{ij} / \sum_{i=1}^{n} x^*_{ij} \tag{3}$$

Calculating an indicator's entropy value:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \,(e_j \geq 0) \tag{4}$$

Calculating the information entropy redundancy level of the indicator:

$$g_j = 1 - e_j \tag{5}$$

Calculating the weight of an indicator:

$$w_j = g_j / \sum_{j=1}^{m} g_j \tag{6}$$

(3) Calculating the composite score

Calculating urban economic resilience scores:

$$s_i = \sum\nolimits_{j=1}^{n} w_j x^*_{ij} \tag{7}$$

2.2.2. Kernel Density Estimation Method

As a non-parametric statistical method, kernel density estimation may be used to describe this distribution of variables by constructing continuous density functions. It can better show the distribution of the shape of the variables over time, and intuitively reflect the overall development of the economic resilience of cities in Jiangsu Province. Drawing on the research of Han et al. (2023) [53], the formula is as follows:

$$f_n(x) = \frac{1}{nh_n}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h_n}\right) \quad (8)$$

Among them, $f_n(x)$ is the kernel density estimation, $K\left(\frac{x-x_i}{h_n}\right)$ is a kernel function, in this paper the Gaussian kernel function, n is the number of study cities, and h_n is the bandwidth.

2.2.3. Theil Index

The Theil index subdivides the overall gap into intra- and inter-regional gaps. It can better identify the sources of the gap. In order to deeply reveal the size, source, and contribution of the differences in economic resilience, this paper introduced the Theil index and its decomposition to measure the economic resilience of cities in Jiangsu Province from 2006 to 2021. Drawing on the research of Chen et al. (2023) [54], the formula is as follows:

$$T = T_B + T_W = \sum_{k=1}^{K} y_k \ln\left(\frac{y_k}{n_k/n}\right) + \sum_{k=1}^{K} y_k \left(\sum_{i \in g_k} \frac{y_i}{y_k} \ln\left(\frac{y_i/y_k}{1/n_k}\right)\right) \quad (9)$$

Among them, T, T_B, and T_W are the total, intra-group, and inter-group gaps, n is the number of study cities, K cities are grouped into groups, with each group represented by g_k, n_k is used to represent the count of cities in group K, while y_k and y_i indicate the proportion of the economic resilience degree of group K, city i, and the total resilience degree of Jiangsu Province.

2.2.4. Exploratory Spatial Data Analysis (ESDA)

ESDA aims at describing the spatial distribution of data, determining the relationship between regions through the spatial matrix, and determining the correlation between a certain attribute in the study region and its neighboring regions. Drawing on the research of Schuster et al. (2024) [55], in this paper, ESDA was used to explore the fluctuating trends in spatial aggregation of economic resilience exhibited by 13 cities in Jiangsu Province during the study period.

(1) Global spatial autocorrelation analysis:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(s_i - \bar{s})(s_j - \bar{s})}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}(s_i - \bar{s})^2} \quad (10)$$

Among them, I is the global autocorrelation index, s_i and s_j are the urban economic resilience of the city and neighboring regional cities, respectively, $\bar{s}$ is the mean value, n is the number of cities, and W_{ij} is a spatial matrix. Moran's I > 0 shows the existence of a positive spatial correlation; otherwise, it is a negative correlation. If it is 0, it indicates no correlation.

(2) Local spatial autocorrelation analysis:

$$I_i = \frac{n(s_i - \bar{s})\sum_{j=1}^{n} W_{ij}(s_j - \bar{s})}{\sum_{i=1}^{n}(s_i - \bar{s})} \quad (11)$$

Among them, I_i is the local autocorrelation index, and the other variables mean the same as in Formula (11). Local Moran's I mainly showed "H-H", "H-L", "L-L", and "L-H" agglomeration patterns, which reflected the local spatial correlation degree of each region.

2.2.5. Spatial β Convergence Model

Referring to the study of Cui et al. (2021) [56], this research employed the β convergence model to analyze the change in the regional gap of urban economic resilience over time, and the influence of spatial factors was considered to evaluate its convergence characteristics more accurately.

(1) Traditional absolute β convergence model:

$$\ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) = \alpha + \beta \ln s_{i,t} + \mu_i + \nu_t + \varepsilon_{it} \tag{12}$$

(2) Spatial absolute β convergence model:

$$\text{SRA: } \ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) = \alpha + \beta \ln s_{i,t} + \rho \sum_{j=1}^{n} W_{ij} \ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) + \mu_i + \nu_t + \varepsilon_{it} \tag{13}$$

$$\text{SEM: } \ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) = \alpha + \beta \ln s_{i,t} + \mu_i + \nu_t + \varepsilon_{it} \quad \varepsilon_{it} = \lambda \sum_{j=1}^{n} W_{ij} \varepsilon_{jt} + \sigma_{it} \tag{14}$$

$$\text{SDM: } \ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) = \alpha + \beta \ln s_{i,t} + \rho \sum_{j=1}^{n} W_{ij} \ln\left(\frac{s_{i,t+1}}{s_{i,t}}\right) + \theta \sum_{j=i}^{n} W_{ij} \ln s_{i,t} + \mu_i + \nu_t + \varepsilon_{it} \tag{15}$$

Among them, $s_{i,t+1}$ and $s_{i,t}$ are the resilience values for city i in year t + 1 and year t, β is the absolute convergence coefficient, W_{ij} is a spatial matrix, μ_i, ν_t, and ε_{it} are the area fixed effects, time fixed effects, and random perturbation terms, respectively, while ρ and λ are the spatial lag coefficient and the spatial error coefficient.

The traditional and spatial conditional convergence models were added to the right of the absolute convergence model; that is, the control variables were added.

3. Results

3.1. Temporal Evolution Analysis

3.1.1. Level of Urban Economic Resilience in Jiangsu Province

The entropy value method was used to measure the index system and comprehensively derive the economic elasticity level of 13 cities in Jiangsu Province from 2006 to 2021, as shown in Table 2.

Table 2. Level of urban economic resilience measurement in Jiangsu Province.

ID	City	2006	2011	2016	2021	Mean	Growth
1	Nanjing	0.3024	0.4646	0.5781	0.7668	0.5235	6.40%
2	Wuxi	0.2597	0.4423	0.5380	0.6567	0.4755	6.38%
3	Xuzhou	0.1526	0.2438	0.3399	0.4418	0.2905	7.34%
4	Changzhou	0.2280	0.3710	0.4933	0.6341	0.4283	7.06%
5	Suzhou	0.3249	0.4887	0.5646	0.7817	0.5349	6.03%
6	Nantong	0.1625	0.3169	0.4085	0.5396	0.3515	8.33%
7	Lianyungang	0.1411	0.2196	0.3052	0.3892	0.2629	7.00%
8	Huaian	0.1311	0.2117	0.3212	0.4116	0.2690	7.93%
9	Yancheng	0.1461	0.2239	0.3229	0.4514	0.2772	7.81%
10	Yangzhou	0.1685	0.2890	0.3931	0.5105	0.3372	7.67%
11	Zhenjiang	0.1895	0.3122	0.4466	0.5277	0.3694	7.06%
12	Taizhou	0.1546	0.2531	0.3597	0.5106	0.3114	8.29%
13	Suqian	0.1084	0.1890	0.2667	0.3709	0.2297	8.55%

It can be noticed that the economic resilience was steadily increasing in 13 cities, showing a good momentum in the development of economic resilience in Jiangsu Province. Nanjing, Wuxi, Changzhou, Suzhou, Nantong, and Zhenjiang were among the most resilient cities in the province. Suqian, Lianyungang, Huaian, and Xuzhou ranked the last four cities in the province. Further observation of the last four cities over the four years shows that Suqian, Yancheng, and Huaian had a faster development rate, while Lianyungang and Xuzhou had a relatively slow growth rate. Therefore, over the sample period, the economic resilience of cities in Jiangsu Province showed a certain rule of evolution in time, and the change in urban ranking also reflected the evolution of its existence in space, providing a basis for further study.

3.1.2. Temporal Evolution Analysis Based on Regional Dimension

From the perspective of urban economic resilience, Southern Jiangsu showed strong economic resilience, exceeding the average level of Jiangsu Province. However, economic resilience in the Central and Northern Jiangsu regions was relatively low, with neither reaching the average level of the province. In terms of evolutionary trends, the city's economic resilience in Jiangsu Province overall, and in each of the regions of Southern, Central, and Northern Jiangsu, showed the growth trend over the period 2006–2021. Specifically, the average annual increases in the mean resilience values of Jiangsu Province, Central Jiangsu, Northern Jiangsu, and Southern Jiangsu were 7.18%, 8.09%, 7.69%, and 6.53%, respectively. It can be seen that the economic resilience of cities in Jiangsu Province improved significantly during the sample period, and the imbalance of economic resilience among cities in the province was gradually alleviated, with the gap between regions narrowing, as shown in Figure 1.

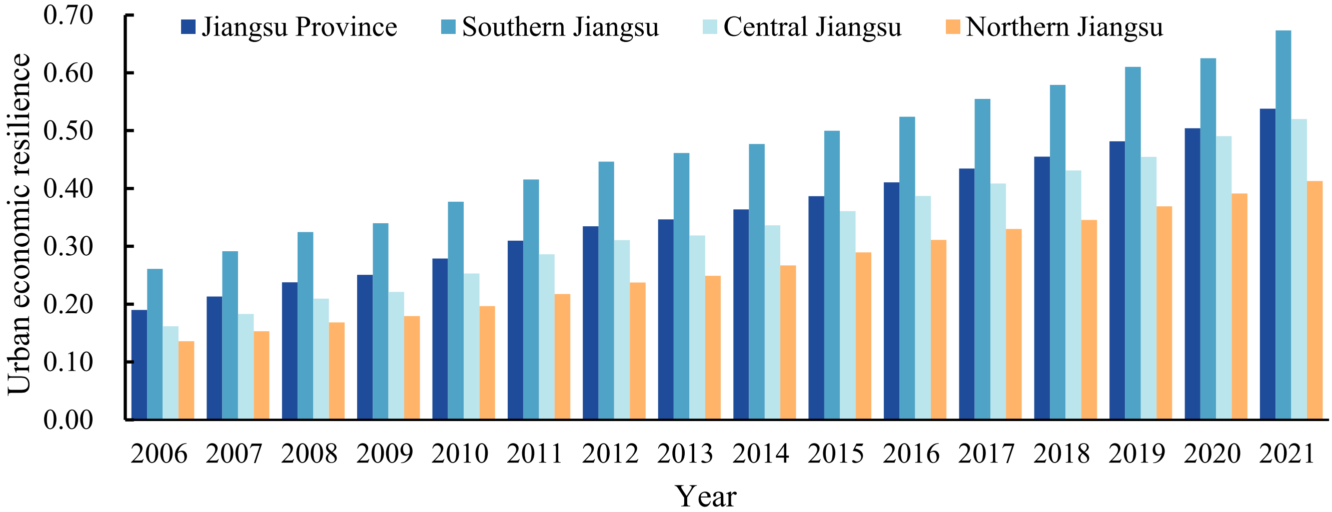


Figure 1. Time series changes of urban economic resilience mean values.

3.1.3. Temporal Evolution Analysis Based on Each System Layer

The resilience of the economy in Jiangsu Province overall and in various regions showed growth in 2006–2021, but there were marked differences among the regions. To clarify the specific performance of these differences in different dimensions, the values of urban economic resilience strength across three dimensions of pressure resistance, state-adaptation, and response–recovery in Jiangsu Province were derived from a comprehensive evaluation indicator system for urban economic resilience. Additionally, the evolutionary trends of different system layers were further studied. According to Figure 2, the state-adaptive resilience had the highest average annual growth rate of 9.56%, followed by response–recovery resilience, which was 8.42%. They both had a higher impact on the overall economic resilience strength of Jiangsu Province.

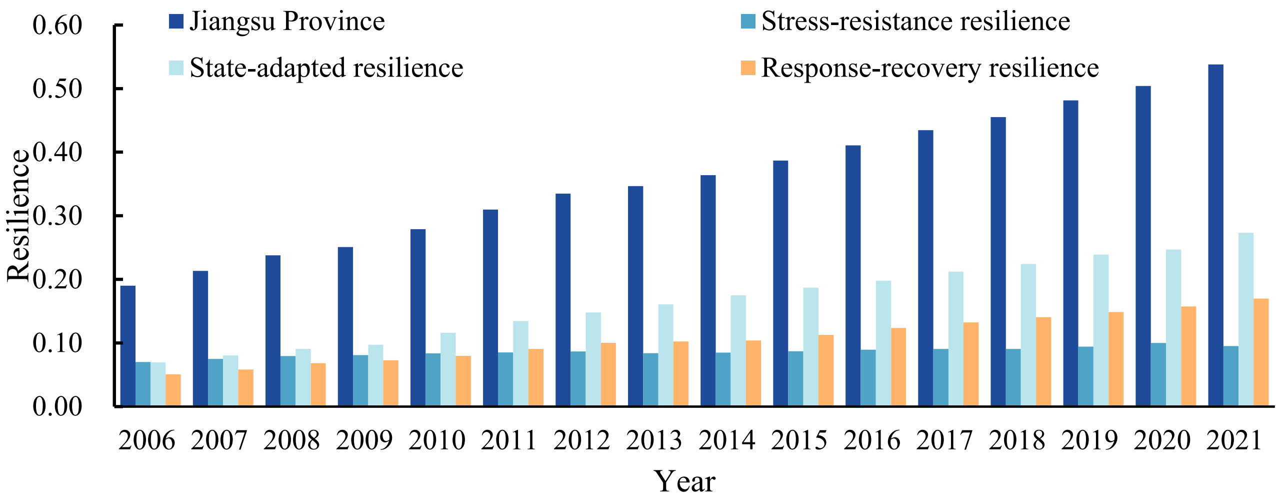


Figure 2. Temporal changes in dimensional economic resilience.

3.1.4. Temporal Evolution Analysis Based on Coefficient of Variation

From the perspective of the evolution trend, the variation coefficients of Jiangsu Province as a whole and of various regions had a decreasing trend to different degrees, indicating that the dispersion of economic resilience between regions decreased, and the level gap of economic resilience narrowed. From a regional perspective, the coefficient of variation in Northern Jiangsu had the most obvious decline, reaching 2.83%, followed by 2% in Southern Jiangsu and 1.92% in Central Jiangsu. This shows that the gap between the economic resilience of cities in the area shrank in turn. Looking at the time period, the situation was different in different regions. However, in 2021, there was a "tailing off" phenomenon, indicating that the differences between regions increased, as shown in Figure 3.

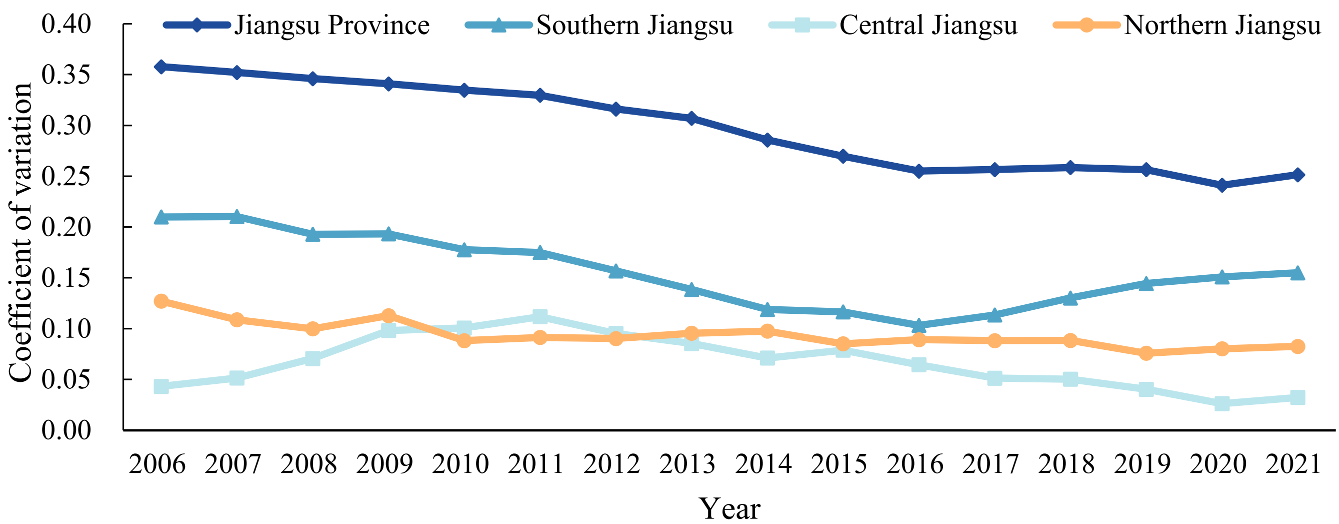


Figure 3. The variation coefficients of urban economic resilience changes.

3.1.5. Temporal Evolution Analysis Based on Kernel Density Estimation

As shown in Figure 4, to explore the evolution of economic resilience in depth, the research estimated the kernel density of economic resilience for each city in 2006, 2011, 2016, and 2021 with the help of state16 software. Between 2006 and 2021, the distribution shape of urban economic resilience in Jiangsu Province changed, as the peak value of this curve decreased and moved to the right, reflecting the fact that while the overall level of economic resilience of cities increased, the absolute gap and divergent trends of economic resilience between regions also increased significantly.

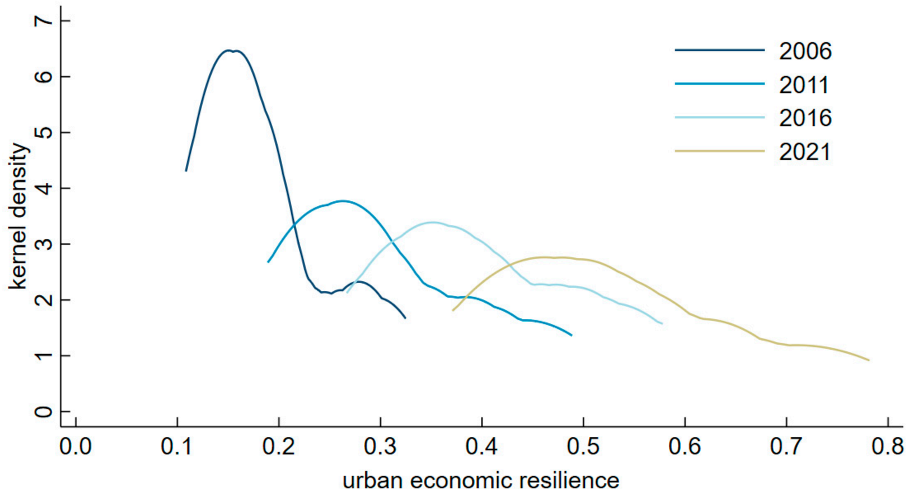


Figure 4. Estimation of urban economic resilience core density in Jiangsu Province.

3.2. Spatial Evolution Analysis

3.2.1. Spatial Distribution Analysis

This paper selected four time points of 2006, 2011, 2016, and 2021, and divided the urban economic resilience into five grades by using the equal-interval method. The detailed classification is shown in Table 3.

Table 3. Classification standard for urban economic resilience measurement.

Classification	I	II	III	IV	V
	Low Resilient	**Lower Resilient**	**Medium Resilient**	**Higher Resilient**	**High Resilient**
Resilience	<0.2430	0.2430–0.3777	0.3778–0.5124	0.5125–0.6470	0.6471–0.7817

Then, the ArcGIS 10.2 software was used to express it visually, and a comprehensive analysis of the spatial distribution characteristics related to the economic resilience of 13 cities in Jiangsu Province is presented, as illustrated in Figure 5.

In 2006, there was a low level of economic resilience in Jiangsu Province as a whole, among which Xuzhou, Lianyungang, Suqian, Huaian, Yancheng, Yangzhou, Taizhou, Nantong, Zhenjiang, and Changzhou were low-resilient cities, while Nanjing, Wuxi, and Suzhou, with relatively high levels of economic resilience, were classified as lower-resilient cities. At this stage, urban economic resilience was shown to radiate from south to north.

In 2011, the level of urban economic resilience in Jiangsu Province improved to a certain extent, and medium-resilient cities emerged. Among them, Xuzhou, Yangzhou, Taizhou, Nantong, Zhenjiang, and Changzhou were transformed from low-resilient cities to lower-resilient cities, and the former lower-resilient cities, Nanjing, Wuxi, and Suzhou, were transformed into medium-resilient cities. At this time, the economic resilience gap was initially reflected, and the level of economic resilience in Southern Jiangsu and Central Jiangsu improved rapidly.

In 2016, the economic resilience level of cities in Jiangsu Province was greatly improved, with Lianyungang, Suqian, Huaian, and Yancheng changing from low-resilience to lower-resilience cities, Yangzhou, Nantong, Zhenjiang, and Changzhou changing from lower-resilience to medium-resilience cities, and the original medium-resilience cities, Nanjing, Wuxi, and Suzhou, transforming into higher-resilience cities. During this period, the phenomenon of spatial differentiation of economic resilience was significant, showing a gradual decline from Southern Jiangsu to Northern Jiangsu.

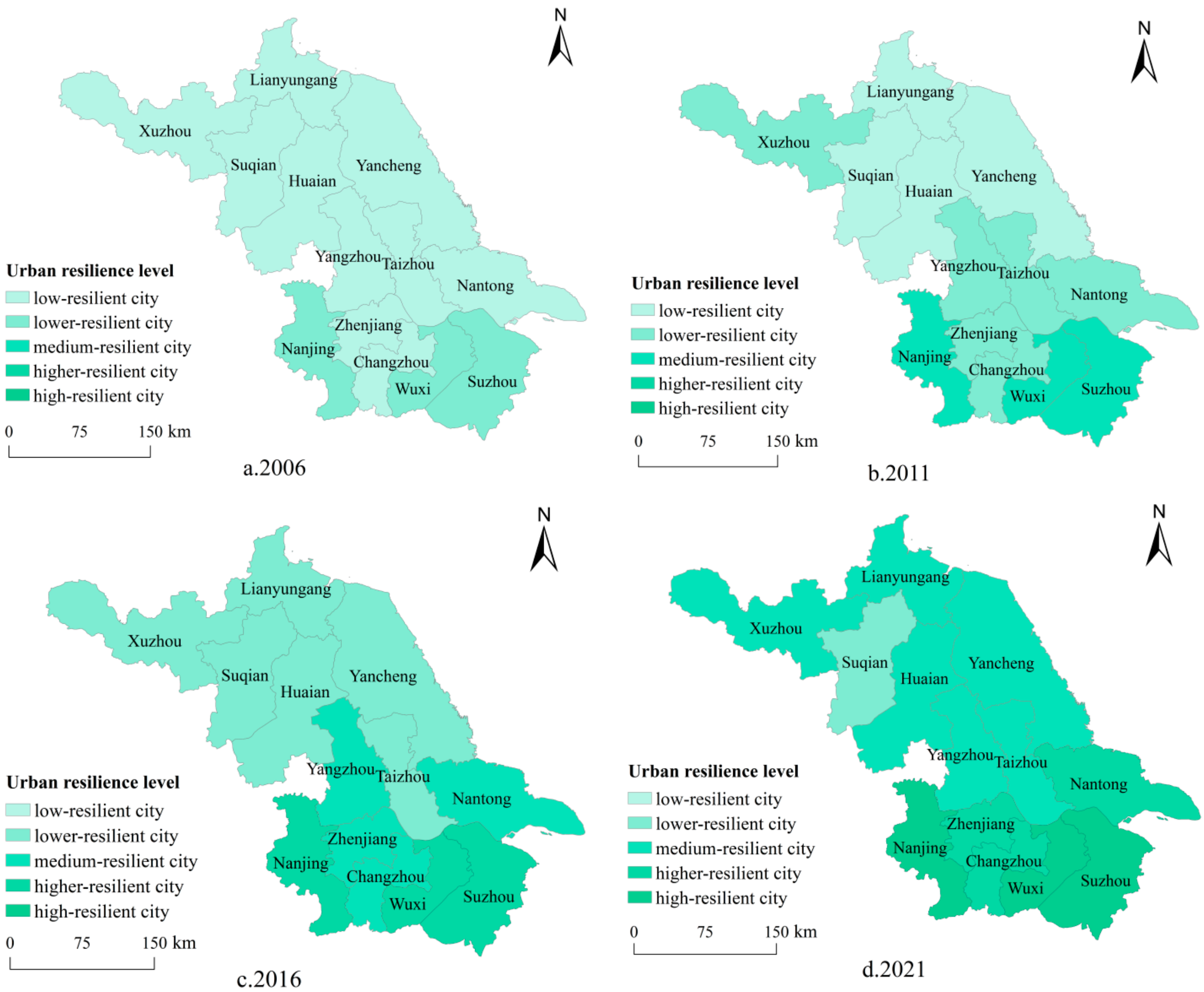


Figure 5. (**a**) 2006, (**b**) 2011, (**c**) 2016, and (**d**) 2021 Jiangsu Province urban economic resilience spatial distribution maps.

In 2021, the economic resilience of Jiangsu Province continued to improve, with Xuzhou, Lianyungang, Huaian, Yancheng, and Taizhou changing from lower-resilience cities to medium-resilience cities, Nantong, Zhenjiang, and Changzhou changing from medium-resilience cities to higher-resilience cities, and the original higher-resilience cities of Nanjing, Wuxi, and Suzhou changing to high-resilience cities. At this time, as the time passed by, the regional economic resilience gap further widened, showing a clear spatial differentiation pattern.

3.2.2. Spatial Difference Analysis

As shown in Table 4, in terms of overall differences, the Theil index of urban economic resilience decreased from 0.0554 in 2006 to 0.0283, indicating that the overall difference in urban economic resilience showed a decreasing trend in most years. It can be seen that urbanization development and industrial structure upgrading improved the overall momentum of cities with weak economic resilience, thus driving the harmonious development of urban economic resilience in Jiangsu Province. It should be noted that the Theil index of each region in 2021 also showed a clear "tailing off", and further attention needs to be paid to its future trends.

Table 4. Theil index and contribution rate of urban economic resilience in Jiangsu Province, 2006–2021.

Year	Overall Difference	Intra-Regional Differences					Inter-Regional Differences	
		Southern Jiangsu	Central Jiangsu	Northern Jiangsu	Contribution	Proportion (%)	Contribution	Proportion (%)
2006	0.0554	0.0179	0.0006	0.0067	0.0114	20.62	0.0440	79.38
2007	0.0535	0.0179	0.0009	0.0049	0.0109	20.46	0.0425	79.54
2008	0.0522	0.0151	0.0017	0.0041	0.0094	17.94	0.0429	82.06
2009	0.0509	0.0152	0.0032	0.0051	0.0100	19.66	0.0409	80.32
2010	0.0495	0.0130	0.0034	0.0031	0.0083	16.76	0.0412	83.24
2011	0.0484	0.0126	0.0042	0.0034	0.0083	17.23	0.0400	82.77
2012	0.0447	0.0101	0.0030	0.0033	0.0067	15.07	0.0380	84.93
2013	0.0424	0.0079	0.0024	0.0037	0.0056	13.19	0.0368	86.83
2014	0.0369	0.0058	0.0017	0.0039	0.0044	11.83	0.0326	88.14
2015	0.0329	0.0055	0.0021	0.0030	0.0041	12.31	0.0288	87.69
2016	0.0296	0.0043	0.0014	0.0033	0.0034	11.42	0.0262	88.58
2017	0.0298	0.0052	0.0009	0.0032	0.0037	12.38	0.0261	87.62
2018	0.0302	0.0070	0.0009	0.0032	0.0045	14.98	0.0257	85.02
2019	0.0294	0.0086	0.0005	0.0023	0.0050	16.93	0.0244	83.07
2020	0.0261	0.0092	0.0002	0.0026	0.0052	20.03	0.0208	79.97
2021	0.0283	0.0098	0.0003	0.0027	0.0056	19.76	0.0227	80.24

From the decomposition results, the contribution rate of inter-regional differences showed a trend of first rising and then falling from 2006 to 2021, with the annual average contribution rate reaching 83.71%. The overall difference in urban economic resilience in Jiangsu Province mainly came from inter-regional differences. The reason may be that Southern Jiangsu contains the capital city and the central city of Jiangsu Province, with priority concentration of various social and economic resources, strong support from colleges and universities, and a high level of overall urban development, while Northern Jiangsu has poor circulation of social and economic resources and insufficient reserves of human resources. Although the development trend was good in recent years, and the economic resilience continued to improve, its development still lags behind that of other regions. Therefore, the issue of coordinated inter-regional development needs urgent attention. In addition, from 2006 to 2021, the contribution rate of intra-regional differences on the whole followed a downward and then upward trend, reaching 20.03% in 2020, close to the initial level in 2006. At present, the problem of intra-regional differences is becoming increasingly prominent.

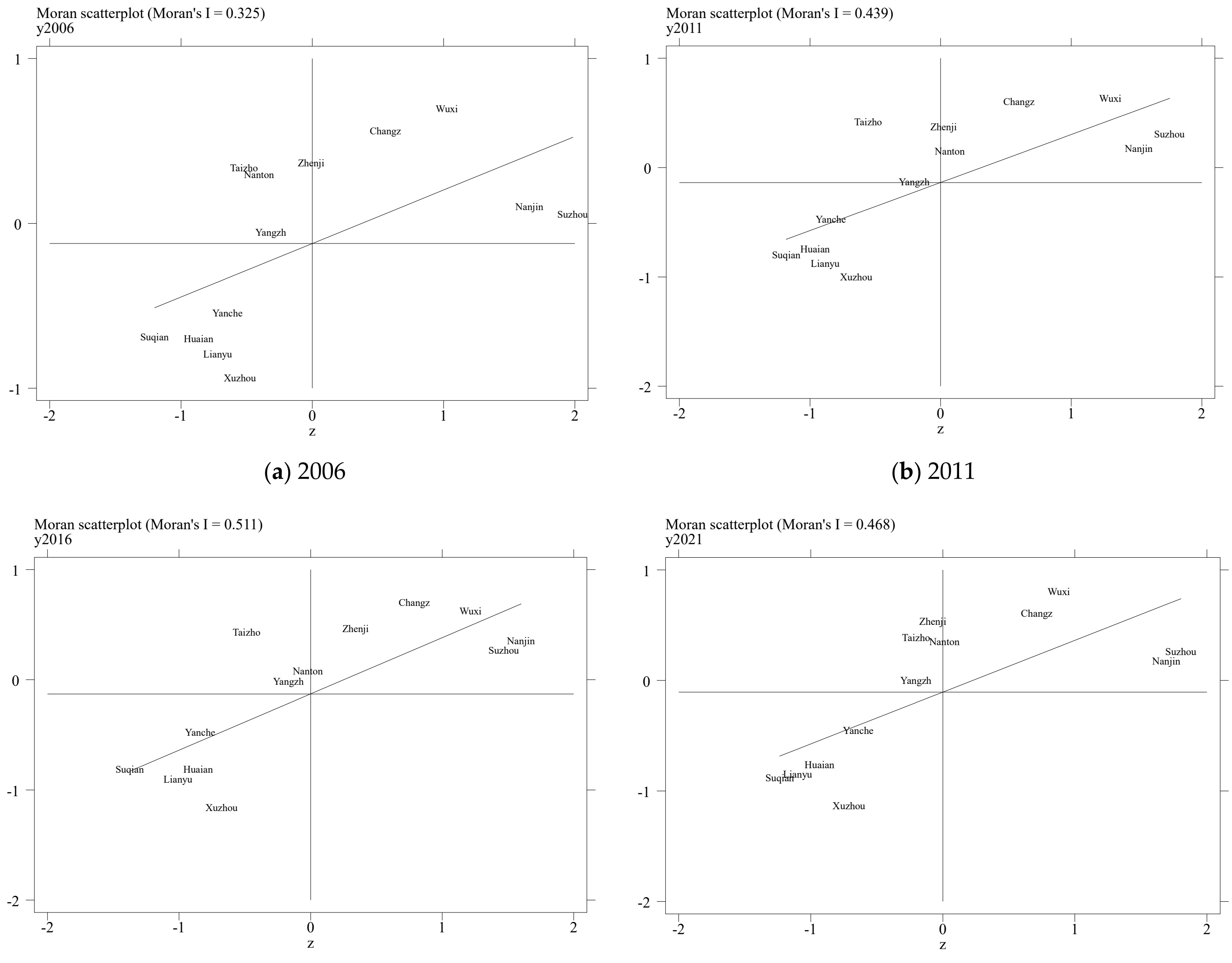
From the further decomposition results of intra-regional differences, from 2006 to 2021, the Thiel index in Southern Jiangsu showed a downward trend and then an upward trend, the Thiel index in Central Jiangsu was relatively stable and showed a downward trend in general, and the Thiel index in Northern Jiangsu showed an increasing and then decreasing trend. Among the three regional cities, the difference and contribution rates of Southern Jiangsu were the largest, followed by Northern Jiangsu, and those of Central Jiangsu were the smallest.

3.3. Spatial Convergence Analysis

3.3.1. Spatial Correlation Tests

In this paper, global spatial correlation was employed to test the Moran's I index of urban economic resilience. The outcome of the test is shown in Table 5. In 2006–2021, the Moran's I index values of urban economic resilience in Jiangsu Province were all positive, and all passed the spatial autocorrelation test at the 1% significance level, showing that the urban economic resilience displayed a positive spatial correlation, so its spatial convergence could be analyzed.

Results of the local spatial autocorrelation test are shown in Figure 6. The Moran's I scatter chart of urban economic resilience in Jiangsu Province was mainly located in quadrants one and three, showing that there was a positive spatial correlation between urban economic resilience. In terms of time, the change of cities in each quadrant was steady. In 2006, Changzhou, Wuxi, Nanjing, and Suzhou were all in the high–high agglomeration area. Nantong, Taizhou, and Yangzhou were all in the high–low agglomeration area. Yancheng, Suqian, Huaian, Lianyungang, and Xuzhou were all in the low–low agglomeration area. Between 2011 and 2021, the cities of Zhenjiang and Nantong moved around the first and second quadrants.



(**a**) 2006 (**b**) 2011

(**c**) 2016 (**d**) 2021

Figure 6. Moran's I scatter plots of urban economic resilience in Jiangsu Province.

Table 5. Values of Moran's I index of urban economic resilience in Jiangsu Province.

Year	Moran's I	Z	*p*	Year	Moran's I	Z	*p*
2006	0.325	2.393	0.008	2014	0.486	3.223	0.001
2007	0.328	2.420	0.008	2015	0.485	3.212	0.001
2008	0.370	2.637	0.004	2016	0.511	3.354	0.000
2009	0.359	2.563	0.005	2017	0.495	3.282	0.001
2010	0.417	2.865	0.002	2018	0.487	3.241	0.001
2011	0.439	2.980	0.001	2019	0.464	3.132	0.001
2012	0.465	3.118	0.001	2020	0.463	3.168	0.001
2013	0.471	3.139	0.001	2021	0.468	3.190	0.001

3.3.2. Convergence Analysis

With reference to the existing studies [57,58], this paper selected the level of economic development, market scale, innovation level, urban vitality, and transportation convenience as the control variables. Among them, the level of economic development was expressed by the average GDP of land. The market scale was expressed as population density, and the innovation level was expressed by the ratio of technical personnel to the total number of employees, multiplied by 100. The urban vitality was expressed by multiplying the ratio of non-state-owned enterprise employees to total employees by 100. The degree of transportation convenience was expressed by highway density. The descriptive statistics of the relevant variables are presented in Table 6.

Table 6. Statistical description of variables.

Variable	Name	Mean	SD	Max.	Min.	Sample Size
Economic resilience	res	0.359	0.144	0.782	0.108	208
Economic development	GDP	7344.846	6357.050	30,264.190	561.613	208
Market scale	mar	848.680	322.197	1616.490	396.350	208
Innovation level	inn	9.116	5.076	43.095	1.314	208
Urban vitality	vir	67.951	15.236	99.175	27.466	208
Transportation convenience	tra	117.764	40.415	261.530	51.810	208

Based on a series of tests, a comprehensive judgment concluded that the double-fixed SEM model was closer to reality. The results of model selection are provided in Table 7.

Table 7. Results of the model test.

Test Method	Test Statistic	Spatial Absolute Convergence		Spatial Conditional Convergence	
		Statistics	*p*	Statistics	*p*
LM test	LM-error	46.342	0.000	45.611	0.000
	LM-lag	16.677	0.000	21.209	0.000
Robust LM test	Robust LM-error	29.795	0.000	24.631	0.000
	Robust LM-lag	0.131	0.717	0.229	0.632
Hausman test	Hausman	9.980	0.002	33.410	0.000
LR test	Spatial fixed effect	78.850	0.000	81.810	0.000
	Time fixed effect	19.490	0.000	34.800	0.000

For the purpose of ensuring the robustness of the test results, this research constructed SDM, SAR, and SEM models, respectively, to explore the convergence of urban economic resilience in Jiangsu Province. According to Table 8, the SEM model should be selected for convergence analysis with reference to the statistical values of Log-L and R^2, which is consistent with the conclusions above and confirms the reliability of the model.

Table 8. Convergence results of urban economic resilience in Jiangsu Province.

Variable	Classical Absolute Convergence	Spatial Absolute β Convergence			Classical Conditional Convergence	Spatial Conditional β Convergence		
		SDM	SAR	SEM		SDM	SAR	SEM
β	−0.063 *** (0.006)	−0.129 *** (0.032)	−0.125 *** (0.032)	−0.130 *** (0.032)	−0.315 *** (0.041)	−0.306 *** (0.044)	−0.301 *** (0.043)	−0.305 *** (0.042)
ln(gdp)					0.176 *** (0.029)	0.146 *** (0.029)	0.123 *** (0.025)	0.131 *** (0.026)
ln(mar)					−0.101 *** (0.038)	−0.083 *** (0.029)	−0.076 *** (0.029)	−0.079 *** (0.006)
ln(inn)					−0.004 (0.006)	0.001 (0.029)	0.001 (0.006)	0.001 (0.006)
ln(vit)					−0.029 ** (0.014)	0.006 (0.013)	−0.000 (0.013)	−0.001 (0.012)
ln(tra)					0.035 (0.036)	0.090 *** (0.031)	0.089 *** (0.029)	0.087 *** (0.028)

Table 8. *Cont.*

Variable	Classical Absolute Convergence	Spatial Absolute β Convergence			Classical Conditional Convergence	Spatial Conditional β Convergence		
		SDM	SAR	SEM		SDM	SAR	SEM
ρ/λ		−0.193 * (0.104)	−0.152 (0.101)	−0.188 * (0.104)		−0.203 * (0.105)	−0.135 (0.097)	−0.195 * (0.105)
θ		−0.128 * (0.071)				−0.103 (0.087)		
Log-L		493.639	492.040	492.544		512.133	509.502	510.284
R^2	0.2985	0.337	0.277	0.299	0.321	0.029	0.285	0.312
Time effect	Y	Y	Y	Y	Y	Y	Y	Y
Spatial effect	Y	Y	Y	Y	Y	Y	Y	Y
N	195	195	195	195	195	195	195	195
s	0.004	0.009	0.008	0.009	0.024	0.023	0.022	0.023
p	170.153	80.166	83.197	79.375	29.280	30.337	30.920	30.505

Note: *, **, and *** indicate the significance levels of 10%, 5%, and 1%, respectively, and the standard error of the parameters to be estimated is in square brackets.

The absolute convergence trend toward the urban economic resilience was obvious, and the convergence coefficients, β, were all negative, which was significant at the level of 1%, indicating that the growth of economic resilience of various cities will gradually converge to the same stable level with the passage of time, without considering the control variables, and the differences between regions had a decreasing trend. For the spatial coefficient, λ, of the error term, λ was significantly negative, which indicates that there was a competitive relationship between cities, and the "siphon effect" of a city, although it can enhance the local economic resilience, could have negative impacts on the neighboring cities. In other words, it has a negative spatial spillover effect.

The absolute convergence rate was lower than the conditional convergence rate. The conditional convergence rate of 0.024 was 6 times that of the classical absolute convergence rate of 0.004. The spatial conditional β convergence speed of SDM, SAR, and SEM models was over twice as fast as the absolute convergence speed. The fundamental reason is that the conditional convergence model integrated the heterogeneous characteristics between different regions, which greatly shortened the convergence period and improved the accuracy of the urban economic resilience convergence test. The classical convergence rate was lower than the spatial convergence rate. The spatial β converged at a rate of 0.009, which was significantly higher than the classical absolute convergence rate of 0.004, and the speed of conditional β convergence was close to the absolute conditional convergence speed; that is, the addition of spatial factors reflected the geographical characteristics of economic resilience, and the economic resilience of neighboring cities radiated each other, accelerating the improvement of overall economic resilience levels. The spatial spillover of urban economic resilience was intensified, the economic resilience between regions showed convergence characteristics, and the spatial differences were further reduced.

Under the condition of convergence, the coefficients of control variables between the classical convergence and the spatial β convergence were not much different, but there was a slight difference in the significance level and influence degree. The estimated coefficients of economic development and transportation convenience were significantly positive, which had a positive impact on economic resilience. The degree of economic development is the basis for the region to withstand shocks and recover after shocks. The higher the level of the economy, the more resistant it is to risk. In the areas with high traffic accessibility, for one, it can promote the investment in infrastructure construction. Second, it can promote the transportation efficiency, and then produce positive benefits to the economy. The influence coefficient of market scale was negative, which could restrain the increase in economic toughness. Although population density increases, to a certain extent, promote the expansion of market size and resource utilization, the cost of congestion may exceed the benefits, which is not beneficial to the level of economic resilience. Therefore, it is necessary to undertake reasonable planning for the spatial distribution of urban populations.

4. Discussion

4.1. Theoretical Contributions

In recent years, floods, earthquakes, COVID-19, and other types of emergencies have occurred frequently, constantly challenging the city's ability to withstand risks. Constructing the resilient city and increasing the level of economic resilience of the city have become the key themes of the current sustainable development of cities. This paper comprehensively evaluated the economic resilience levels of cities in Jiangsu Province and discussed its dynamic evolution trend. To a certain extent, it has enriched the research related to urban economic resilience and expanded its theoretical framework and scope of application.

First, by measuring the cities' levels of economic resilience, this research found that state-adapted resilience and response–recovery resilience are keys in determining the overall economic resilience. This further validates the findings of Das et al. (2020) [59] and Oprea et al. (2020) [60], who concluded that the economic development level and social innovation ability are important factors affecting urban resilience. A city with a stronger economic scale and learning ability has stronger adaptability and innovation ability when confronted with shocks, and thus has a higher level of economic resilience. However, for cities with a weak economic level and learning ability, the original economic structure is easily destroyed after the disturbance occurs, and it is difficult to recover at short notice, so the level of economic resilience is relatively low.

Second, the temporal and spatial evolution characteristics of urban economic resilience in Jiangsu Province were studied. It was discovered that there was a large gap among the economic resilience levels of the cities in the study region, and a significant "siphon effect" existed in some cities. Liu et al. (2021) [61] also confirmed this finding. When there are large differences in the size of cities between localities, resources will flow from smaller to larger cities, such as social investment, human capital, and so on, which will restrain the development of the economic resilience of smaller cities. Meanwhile, the paper also proved this point again when analyzing the overall economic resilience of Jiangsu Province. This research found that inter-regional differences were the major cause of imbalances in economic resilience within the province.

Third, by examining the convergence characteristics of a city's economic resilience within the region, it was found that there was a strong spatial correlation between cities. The urban economic resilience of Jiangsu Province has experienced many "centralization–dispersion" evolution trends, although it finally showed a trend of agglomeration, but the agglomeration trend was weakened on the whole. The spatial correlation between cities was strongest in 2016. The heterogeneity factor among cities had a significant contribution to the convergence rate of economic resilience. This research of Chacon et al. (2020) [62] also discussed this point and found that cities with high transportation accessibility have advantages in the construction of urban economic resilience. Tan et al. (2017) [29] also suggested that differentiated approaches ought to be developed to enhance the resilience of the economy in different cities.

4.2. Development Proposals

First, it is important to improve the innovation capacity to maintain economic vitality. The strength of urban innovation capacity, as an important link in response–recovery resilience, affects whether cities can create new growth paths after the impact and influences the level of economic resilience. To this end, it requires governments at all levels to increase public financial expenditures in the fields of science and technology and education, especially to increase financial support for the less developed cities in the Northern Jiangsu, stimulate the innovation vitality of enterprises, and deepen the mechanism of cooperation between industry, academia, and research and the transformation of scientific and technological achievements.

Second, it should give full play to the agglomeration effect and boost the resilience. The cities with high economic resilience in Jiangsu Province are mainly concentrated in Southern Jiangsu, which has a significant correlation and agglomeration effect in space.

Therefore, we should give full play to the radiating role of these cities with high economic elasticity to the surrounding cities with low economic elasticity. It is possible to improve the transport and road networks and information and communication networks between different cities to ensure the smoothness of communication between different cities and improve the transmission efficiency of energy, capital, information, and other factors.

Third, it is essential to narrow the regional gap and achieve synergistic development. The economic resilience of cities in Jiangsu Province presents an uneven spatial distribution of "high in the south and low in the north", and the contribution of inter-regional differences to the overall differences is as high as 80%. Therefore, in the process of coordinating and improving the economic resilience of cities in Jiangsu Province in the future, it is necessary to focus on inter-regional differences. Specifically, when the government formulates relevant economic development policies, it should have a certain policy tilt toward regions with relatively weaker economic levels, offset its own inherent location disadvantages by virtue of policy advantages, strengthen dynamic cooperation between cities, and reduce the negative spatial spillover effects between regions.

5. Conclusions

By measuring the economic resilience of cities in Jiangsu Province, this study analyzed in depth the resilience development of 13 prefecture-level cities in Jiangsu Province during the period of 2006–2021, and clarified their development trends, spatial differences, and convergence characteristics. The main conclusions of the study included the following: First, all 13 cities increased their economic resilience, which showed a tendency to evolve from a low to high level of resilience. Second, the economic resilience of cities in this study region exhibited significant spatial variability, and inter-regional differences were the dominant sources of overall resilience differences. Third, there were obvious spatial correlations within the region's cities, which were mainly presented as "H-H" and "L-L" agglomerations. Fourth, there was a convergence in the economic resilience of cities in this study area, and their economic resilience gap will gradually narrow with the passage of time. Fifth, the heterogeneity among different cities had an evident effect on the convergence rate of urban economic resilience.

The study had certain references to improve the level of urban economic resilience in Jiangsu Province, and it is useful for the development of economic resilience level in other provinces or regions. However, due to various constraints, the following aspects need to be improved in future research: First, the discussion of urban economic resilience in this article it is still in a preliminary stage, and the scientific meaning and framework structure of urban economic resilience should be explored in the future from the perspective of diversification and comprehensiveness. Second, regarding the index system construction, urban economic resilience involves a number of aspects. This paper lacks quantitative indicators for policy, culture, and other aspects, and because of data limitations, the choice of indicators was based on national published data. Third, only Jiangsu Province was chosen as the research region to study the development status of urban economic resilience levels, which can be expanded and made more representative in the future.

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