Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 23, No. 1, 2026

Spatial and Temporal Evolution of Urban Economic Resilience in Urban Agglomerations of the Central Plains

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Abstract: Taking 30 prefecture-level cities in urban agglomeration of the Central Plains as the research object, this paper defines urban economic resilience as the ability of economic system to maintain stability under external shocks, recover quickly after damage, and achieve higher quality development. The entropy method is used to measure the level of urban economic resilience from 2007 to 2022, and the global Moran index, local Moran index and spatial classification method are combined to analyze the evolution characteristics of urban economic resilience in time and space. The results show that: 1. The mean value of the comprehensive economic resilience of urban agglomerations in the Central Plains fluctuated slightly around 0.25 for a long time, reaching a peak of 0.284 in 2011, and falling to the lowest value of 0.225 in 2019 due to the impact of COVID-19. Among the four sub-dimensions, the mean value of economic resilience is the highest, while the economic resilience is relatively weak. 2. In terms of time series evolution, the overall economic resilience of all cities shows a trend of stability while declining. Zhengzhou is significantly ahead in resilience level, while Luoyang is firmly in the second place. The years 2009 and 2019 are the key years for resilience fluctuations. 3.In terms of spatial pattern, the economic resilience of urban agglomerations has a significant positive spatial correlation, which is mainly characterized by high-high agglomeration and low-low agglomeration. Zhengzhou, Luoyang and other central and western core cities form high-value agglomeration areas, while eastern Henan, southern Henan and some cities in northern Anhui form contiguous low-value agglomeration areas. The overall distribution pattern is leading in the central region, high in the west and low in the east, high in the north and low in the south, and Zhengzhou as the center of the outward gradient decline, the resilience gap between the core and peripheral cities exists for a long time. This paper reveals the spatial-temporal evolution of economic resilience of urban agglomerations in the Central Plains, which can provide data support and theoretical reference for improving economic resilience and promoting coordinated development in the region.

Keywords: Urban agglomeration in the Central Plains, Urban economic resilience, Temporal and spatial evolution, Moran Index.

1. Introduction

Reform and opening up and economic globalization have accelerated the process of urbanization and industrialization in China, and the urban economy has realized leapfrog development. As the core support of urban operation, the stability of urban economy is directly related to the quality of regional development. However, affected by multiple external shocks such as the global financial crisis, trade frictions, geopolitical changes and COVID-19, urban economic development has shown significant fluctuations. Different cities differ significantly in their ability to cope with shocks and recover growth, which is defined as urban economic resilience by economic geography scholars. Under the dual background of the transition of China's economic development stage and the intensification of external uncertainty, it is of great theoretical value and practical significance to systematically identify the spatio-temporal evolution characteristics of urban economic resilience and analyze its influencing factors for improving the city's ability to resist risks and promote high-quality development. The Central Plains urban agglomeration is a national urban agglomeration with Henan Province as the main body and covering 30 prefecture-level cities in five provinces of Henan, Shanxi, Hebei, Shandong and Anhui. Since the Central Plains Urban Agglomeration Development Plan was approved and implemented in 2016, the economic strength of the region has significantly improved. Exploring the spatial-temporal pattern and evolution law of urban economic resilience is not only helpful to grasp the regional development trend, but also provides scientific basis for enhancing the overall economic stability of urban agglomerations.

2. The Meaning of Economic Resilience and Its Measurement Methods

2.1. Establishment of an Indicator System for Economic Resilience

Based on relevant literature, this paper defines economic resilience as the ability of an urban economic system to maintain stability under external shocks, or to recover quickly after damage and achieve a higher level of development. Based on the adaptability theory, Martin (2012) [10]divided the process of economic resilience into four stages: the ability to resist shocks, the ability to recover after shocks, the ability to restructure and reorganize structures, and the ability to achieve sustainable development through innovation and transformation. At present, there is no unified evaluation system for urban economic resilience in the world. Based on the existing research, this paper summarizes the evaluation dimensions as follows: economic resistance capacity, economic recovery capacity, economic adjustment capacity

and economic innovation capacity. For details, see Table 1:

Table 1. Rating system of urban economic resilience

Target layer	Sub-target layer	Indicator layer	Indicator
Urban economic resilience	Economic resistance capacity	GDP per capita (Yuan)	+
		Share of Primary industry in GDP (%)	-
		Urbanization rate (%)	+
		Registered urban unemployment rate (%)	-
		Foreign trade dependency (%)	-
	Economic recovery capacity	Per capita disposable income of urban residents (Yuan)	+
		Fiscal self-sufficiency rate (%)	+
		City Engel coefficient (%)	-
	Economic adjustment capacity	Ratio of total social fixed asset investment to GDP (%)	+
		Share of tertiary industry in GDP (%)	+
		Ratio of actual Utilized foreign capital to GDP (%)	+
	Economic innovation capacity	R&D expenditure (Yuan)	+
		Number of patents granted (pieces)	+
		Number of students in higher education	+

2.2. Data Sources

In order to meet a series of requirements such as scientific, accurate, available and operable data, the data in this paper are all from the statistical yearbooks (2008-2023) published by the statistical bureau of various provinces and cities to study the spatial-temporal evolution of economic resilience of 30 cities in the urban agglomeration of the Central Plains, and each city is taken as a separate variable to obtain the evaluation index data of each city.

2.3. Data Processing

Set the number of cities to n, set the number of index items to m, and establish a section data matrix: X=$\{x_{ij}\}$, The detailed data processing steps are as follows:

If the j-th evaluation index is positive, then:

$$T_{ij} = \frac{x_{ij} - min(x_{ij})}{max(x_{ij}) - min(x_{ij})} + 0.0001 \quad (1)$$

If the j-th evaluation index is negative, then:

$$T_{ij} = \frac{max(x_{ij}) - x_{ij}}{max(x_{ij}) - min(x_{ij})} + 0.0001 \quad (2)$$

T_{ij} is the data of the j-th index of the ith city after standardized processing. The purpose of adding 0.0001 is to avoid that the standardized data is 0 and cannot be calculated.

Calculate the ratio of the sum of individual index values:

$$p_{ij} = \frac{T_{ij}}{\sum_{i=1}^{n} T_{ij}} \quad (3)$$

Calculate the entropy value of a single evaluation index:

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

Determine the weight coefficient of each evaluation index, and the specific formula is as follows:

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j},\ g_j = 1 - e_j \quad (5)$$

The measurement values of the sub-objectives are obtained by weighted average of the quantitative standard values of the evaluation indicators in each part:

$$y_k = \sum_{j=1}^{z} T_{ij} w_j \quad (6)$$

The value of comprehensive economic resilience is equal to the sum of the measurement values of each sub-objective:

$$Y = \sum_{k=1}^{4} y_k \quad (7)$$

After data processing, the economic resilience values of each city at each time point are shown in Table 2.

Table 2. Urban economic resilience from 2007 to 2022

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zhengzhou	0.905	0.919	0.967	0.925	0.946	0.933	0.923	0.947	0.944	0.952	0.910	0.909	0.854	0.907	0.902	0.874
Kaifeng	0.173	0.169	0.172	0.171	0.203	0.218	0.240	0.217	0.221	0.219	0.216	0.221	0.177	0.211	0.220	0.177
Luoyang	0.460	0.455	0.518	0.502	0.487	0.487	0.450	0.436	0.434	0.427	0.437	0.431	0.384	0.452	0.434	0.385
Pingdingshan	0.277	0.291	0.287	0.275	0.314	0.307	0.290	0.263	0.255	0.251	0.257	0.253	0.224	0.232	0.274	0.233
Anyang	0.256	0.250	0.230	0.237	0.280	0.248	0.252	0.249	0.232	0.235	0.242	0.237	0.189	0.221	0.217	0.203
Hebi	0.239	0.243	0.284	0.276	0.271	0.307	0.284	0.263	0.287	0.284	0.300	0.288	0.246	0.273	0.257	0.202
Xinxiang	0.343	0.344	0.351	0.335	0.332	0.339	0.332	0.315	0.331	0.309	0.306	0.306	0.263	0.293	0.300	0.282
Jiaozuo	0.338	0.290	0.315	0.307	0.324	0.323	0.306	0.299	0.297	0.303	0.326	0.311	0.277	0.283	0.299	0.287
Puyang	0.202	0.191	0.208	0.195	0.218	0.196	0.212	0.197	0.201	0.205	0.212	0.195	0.161	0.181	0.202	0.163
Xuchang	0.252	0.277	0.278	0.279	0.315	0.311	0.305	0.296	0.306	0.311	0.311	0.316	0.267	0.288	0.297	0.247
Luohe	0.235	0.258	0.243	0.262	0.266	0.258	0.250	0.247	0.251	0.243	0.266	0.260	0.244	0.255	0.267	0.225
Sanmenxia	0.290	0.291	0.304	0.322	0.335	0.325	0.306	0.281	0.271	0.266	0.287	0.269	0.246	0.295	0.288	0.226
Nanyang	0.229	0.217	0.213	0.211	0.237	0.229	0.232	0.211	0.230	0.226	0.244	0.220	0.187	0.206	0.229	0.212
Shangqiu	0.149	0.157	0.142	0.136	0.156	0.158	0.155	0.137	0.140	0.140	0.152	0.168	0.158	0.154	0.161	0.135
Xinyang	0.145	0.171	0.147	0.166	0.197	0.152	0.172	0.139	0.147	0.148	0.163	0.157	0.131	0.145	0.163	0.130
Zhoukou	0.111	0.100	0.088	0.086	0.103	0.099	0.099	0.086	0.112	0.092	0.093	0.101	0.085	0.104	0.122	0.091
Zhumadian	0.135	0.133	0.123	0.121	0.134	0.129	0.136	0.116	0.124	0.120	0.133	0.138	0.122	0.135	0.153	0.131
Jiyuan	0.320	0.309	0.318	0.297	0.326	0.335	0.328	0.310	0.304	0.316	0.317	0.311	0.279	0.317	0.305	0.293
Changzhi	0.281	0.350	0.310	0.319	0.389	0.348	0.342	0.296	0.281	0.277	0.255	0.236	0.196	0.214	0.246	0.236
Jincheng	0.347	0.343	0.339	0.316	0.390	0.372	0.360	0.322	0.294	0.283	0.265	0.265	0.227	0.234	0.252	0.300
Yuncheng	0.208	0.262	0.210	0.209	0.263	0.224	0.241	0.177	0.169	0.161	0.144	0.143	0.129	0.145	0.144	0.124
Liaocheng	0.288	0.292	0.286	0.274	0.314	0.295	0.327	0.303	0.267	0.272	0.253	0.224	0.249	0.201	0.218	0.336
Heze	0.173	0.165	0.162	0.181	0.226	0.229	0.243	0.215	0.204	0.210	0.177	0.181	0.141	0.178	0.191	0.291
Handan	0.318	0.270	0.291	0.283	0.285	0.271	0.265	0.237	0.247	0.236	0.253	0.254	0.210	0.259	0.264	0.235
Xingtai	0.190	0.182	0.202	0.211	0.193	0.192	0.202	0.175	0.192	0.189	0.200	0.197	0.156	0.186	0.178	0.179
Bengbu	0.239	0.215	0.267	0.283	0.316	0.345	0.331	0.312	0.310	0.327	0.317	0.302	0.265	0.277	0.260	0.193
Huaibei	0.224	0.218	0.271	0.281	0.285	0.292	0.278	0.259	0.257	0.256	0.284	0.251	0.218	0.260	0.254	0.228
Fuyang	0.113	0.101	0.086	0.111	0.147	0.139	0.177	0.142	0.140	0.138	0.148	0.172	0.155	0.167	0.169	0.173
Suzhou	0.093	0.087	0.100	0.105	0.124	0.141	0.143	0.137	0.157	0.173	0.158	0.167	0.140	0.162	0.166	0.129
Bozhou	0.153	0.156	0.145	0.165	0.154	0.146	0.137	0.131	0.132	0.153	0.152	0.160	0.140	0.151	0.152	0.118

3. Analysis of Time Series Evolution of Urban Economic Resilience

3.1. Time Evolution Analysis of Overall Economic Resilience of Cities

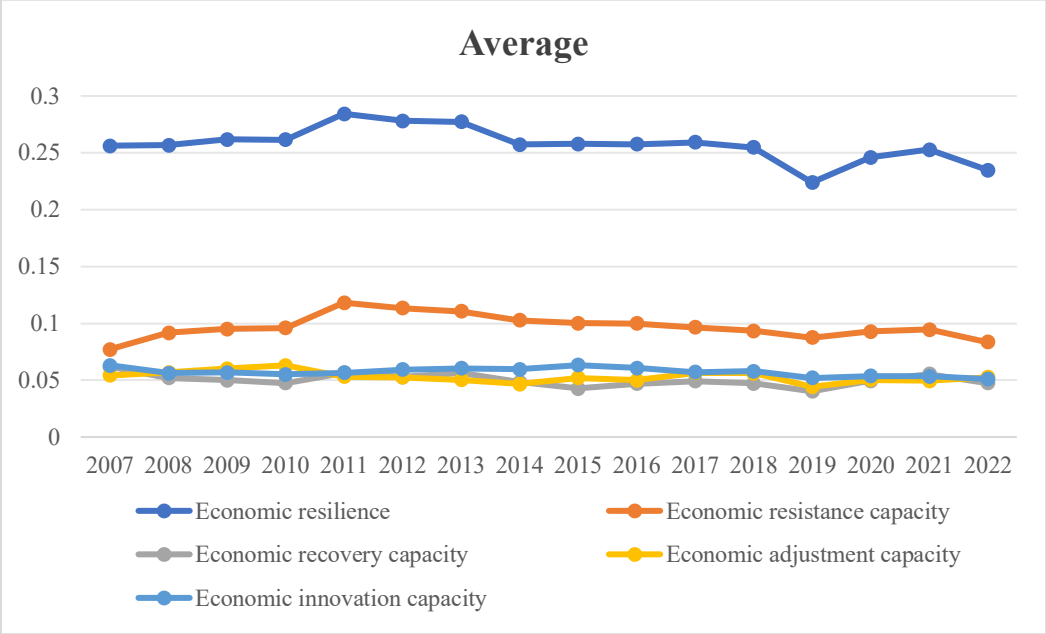


Figure 1. Overall changes in the economic resilience of cities

The overall changes in the economic resilience of cities in the Central Plains Urban cluster from 2007 to 2022 are shown in Figure 1. During the study period, the mean value of urban comprehensive economic resilience fluctuated slightly around 0.25 in most years, increased significantly from 2011 to 2013, and reached a peak of 0.284 in 2011. From 2019 to 2022, the fluctuation intensified and dropped to the lowest value of 0.225 in 2019. On the whole, the economic resilience of urban agglomerations has been relatively stable in the past 16 years. However, it declined significantly in 2019 due to the

impact of COVID-19. Although it rebounded the following year, it has not recovered to the pre-epidemic level. From the perspective of each dimension, the mean value of each subsystem changed slightly from 2007 to 2022, showing a trend of first rising and then falling, and remaining relatively stable at the original level. In order of mean value, they are economic resilience, economic innovation, economic adjustment and economic recovery. To sum up, enhancing economic innovation capacity is the key path to enhance the comprehensive economic resilience of urban agglomerations in the Central Plains. While improving the overall resilience, we should pay attention to the balanced development among cities, narrow the regional gap, and promote coordinated and common progress. Economic resilience needs to be steadily improved, as maintaining the current level is not conducive to high-quality regional development. Therefore, we should continue to optimize the economic structure, strengthen scientific and technological innovation, promote industrial upgrading, and enhance the resilience of urban economy from multiple dimensions.

3.2. Analysis on the Time Series Evolution of Urban Economic Resilience

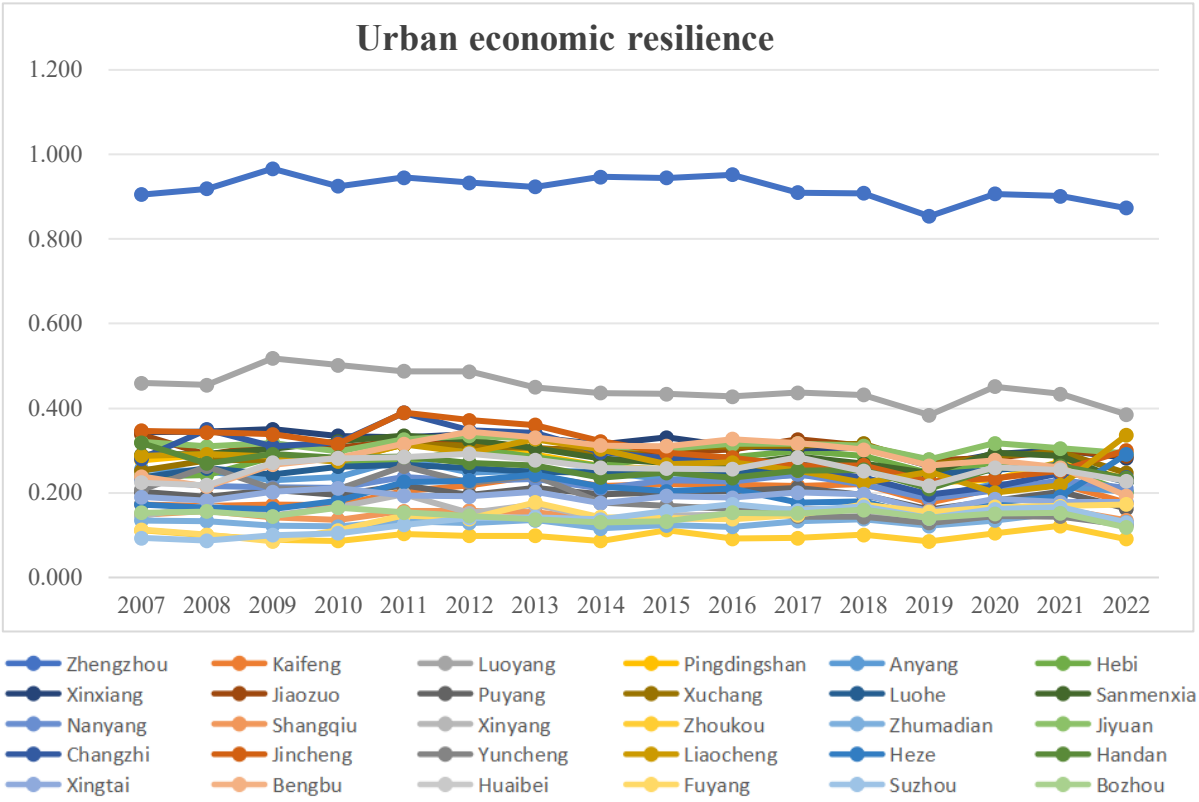


Figure 2. Line chart of economic resilience of each city from 2007 to 2022

The time series evolution characteristics of economic resilience of each city in the Central Plains urban agglomeration from 2007 to 2022 are shown in Figure 2. Study period, the city's economic resilience is exist local fluctuations, but the overall basic stable and slightly lower, reflects a group of most cities are in the ongoing consolidation in risk against and response capabilities, to maintain the stability of the city's economic development. The resilience level of urban clusters shows significant hierarchical differences: Zhengzhou, as the only provincial capital city, is significantly ahead of other cities in resilience level, while Luoyang takes the second place and maintains obvious advantages. The leading positions of the two cities have been stable in the 14 years. The resilience levels of Jincheng, Xinxiang, Jiyuan and Jiaozuo are in the middle and upper reaches of urban clusters, but their resilience levels show differentiated fluctuations with the year, and the annual ranking changes dynamically. Among them, the resilience of Xinxiang and Jiaozuo declined steadily, Jincheng had a similar trend but significantly recovered in 2022, and Jiyuan showed a significant decline in 2019. The resilience levels of Zhoukou, Fuyang, Suzhou, Shangqiu and Xinyang have been in the lower reaches for a long time. The resilience of Zhoukou in most periods is significantly low, and the index in most years is lower than 0.1, reflecting its lagging economic development and slow growth. Shangqiu and Xinyang showed a positive "U" -shaped feature of rising first and then declining. The improvement effect of resilience in the early stage decreased in the later stage, while Fuyang and Suzhou showed an overall upward trend, reflecting the positive effect of resilience improvement. From the point of time fluctuations, toughness of sharp fluctuations in the cities are mainly concentrated in 2009 and 2019, more than 2009 is on the rise, is given priority to with decline in 2019. In the context of The Times, the global economy recovered rapidly after the financial crisis in 2009, which led to the simultaneous improvement of the resilience of all cities in urban clusters. The sudden spread of COVID-19 in 2019 has had a severe impact on the global economy. Due to other negative factors, the resilience of cities in the cluster has decreased significantly.

4. Analysis on the Spatial Evolution of Urban Economic Resilience

4.1. Spatial Correlation Analysis

To investigate the spatial correlation of the economic resilience of the cities in the Central Plains urban

agglomeration, observe the degree of economic agglomeration and dispersion of each city, so as to better understand the spatial differences and connections of the economic development of the cities in the Central Plains urban agglomeration. If the global autocorrelation appears, then the local autocorrelation is done [19].

4.1.1. Global autocorrelation

Global autocorrelation is to judge the spatial agglomeration degree of urban economic resilience in the whole system. The global index tells us whether there is spatial agglomeration or outlier.The calculation formula is as follows:

$$Moran'I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(x_i-\bar{x})(x_j-\bar{x})w_{ij}}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}} \quad (8)$$

x_i and x_j respectively represent the economic resilience values of the i-th and j-th cities; $\bar{x}$ represents the average economic resilience of each city, S^2 represents the variance of economic resilience of each city, and w_{ij} represents the spatial weight matrix.Stata software is used to obtain the global Moran index, as shown in Table 3.

Table 3. Global Moran Index from 2007 to 2022

Years	Moran's I	E(I)	sd(I)	z	p-value*
2007	0.306	-0.034	0.083	4.127	0.000
2008	0.299	-0.034	0.082	4.063	0.000
2009	0.298	-0.034	0.084	3.980	0.000
2010	0.274	-0.034	0.083	3.712	0.000
2011	0.281	-0.034	0.084	3.760	0.000
2012	0.285	-0.034	0.085	3.775	0.000
2013	0.255	-0.034	0.080	3.596	0.000
2014	0.240	-0.034	0.077	3.548	0.000
2015	0.239	-0.034	0.075	3.663	0.000
2016	0.228	-0.034	0.074	3.548	0.000
2017	0.242	-0.034	0.078	3.558	0.000
2018	0.232	-0.034	0.074	3.593	0.000
2019	0.201	-0.034	0.072	3.274	0.001
2020	0.210	-0.034	0.074	3.277	0.001
2021	0.232	-0.034	0.072	3.691	0.000
2022	0.173	-0.034	0.076	2.732	0.003

It can be observed that from 2007 to 2022, the global Moran's index of economic resilience of all cities in the Central Plains urban agglomeration is greater than 0, the z score is greater than +1.65, and the p value is less than 0.1. Therefore, it can be seen that the economic resilience of all cities in the Central Plains urban agglomeration has been spatially clustered over the years. In the process of urban development, there may be coordinated progress due to the geographical connection. Moreover, all cities in the Central Plains urban cluster are located in the Central Plains and have similar history, culture and development concepts.

4.1.2. Local Autocorrelation

Local Moran index will tell us where there are outliers or where there are clusters. The calculation formula is as follows:

$$LocalMoran'I = \frac{(x_i-\bar{x})\sum_{j\neq1}^{n}w_{ij}(x_j-\bar{x})}{S^2} \quad (9)$$

Moran scatter plots in 2008, 2009, 2011, 2015, 2019 and 2022 are selected in Figure 3 in the Appendix, and the analysis is as follows: There is a significant spatial agglomeration of urban economic resilience in the Central Plains urban agglomeration. Most cities are concentrated in the first quadrant (high-high agglomeration, H-H) and the third quadrant (low-low agglomeration, L-L), showing obvious high-value or low-value spatial agglomeration. A few cities were located in the second quadrant (low-high agglomeration, L-H), with spatial polarization. The number of cities in the fourth quadrant (high-low agglomeration, H-L) was very small, showing sporadic spatial island effect. From the perspective of time series evolution, Zhengzhou, Luoyang, Xinxiang, Jiaozuo, Xuchang, Jiyuan and Jincheng are stable in the H-H quadrant for a long time, and their economic resilience remains high. Pingdingshan, Sanmenxia and Changzhi have shifted from H-H to L-H, among which Pingdingshan and Sanmenxia have a small decline, while the resilience of Changzhi itself and its surrounding cities has declined significantly. Kaifeng, Xingtai and Yuncheng have always been located in the L-H quadrant, with low resilience and insufficient radiation to the surrounding high-value cities. Hebi and Puyang were in the L-H quadrant in most years, with only a brief change in 2019, reflecting the differentiated impact of the epidemic on the resilience of the two cities. Nanyang and Anyang changed from L-H to L-L after 2019, and their resilience decreased synchronously with that of their surrounding cities. Xinyang, Zhoukou, Zhumadian, Shangqiu, Fuyang, Suzhou, and Bozhou have been stable in the L-L quadrant for a long time, forming a continuous low-value agglomeration area. Huaibei, Luohe and Handan fluctuated at the boundary between L-L and H-L, with low resilience and insufficient stability on the whole. Liaocheng has been in the H-L quadrant for a long time, with high resilience but limited radiation driving effect on surrounding areas. Heze changed from L-L to H-L in 2022, and its resilience was significantly improved and surpassed that of surrounding cities in that year. Bengbu fluctuated repeatedly between L-L and H-L, and its resilience improvement lacked continuity, and finally fell back to the low level.

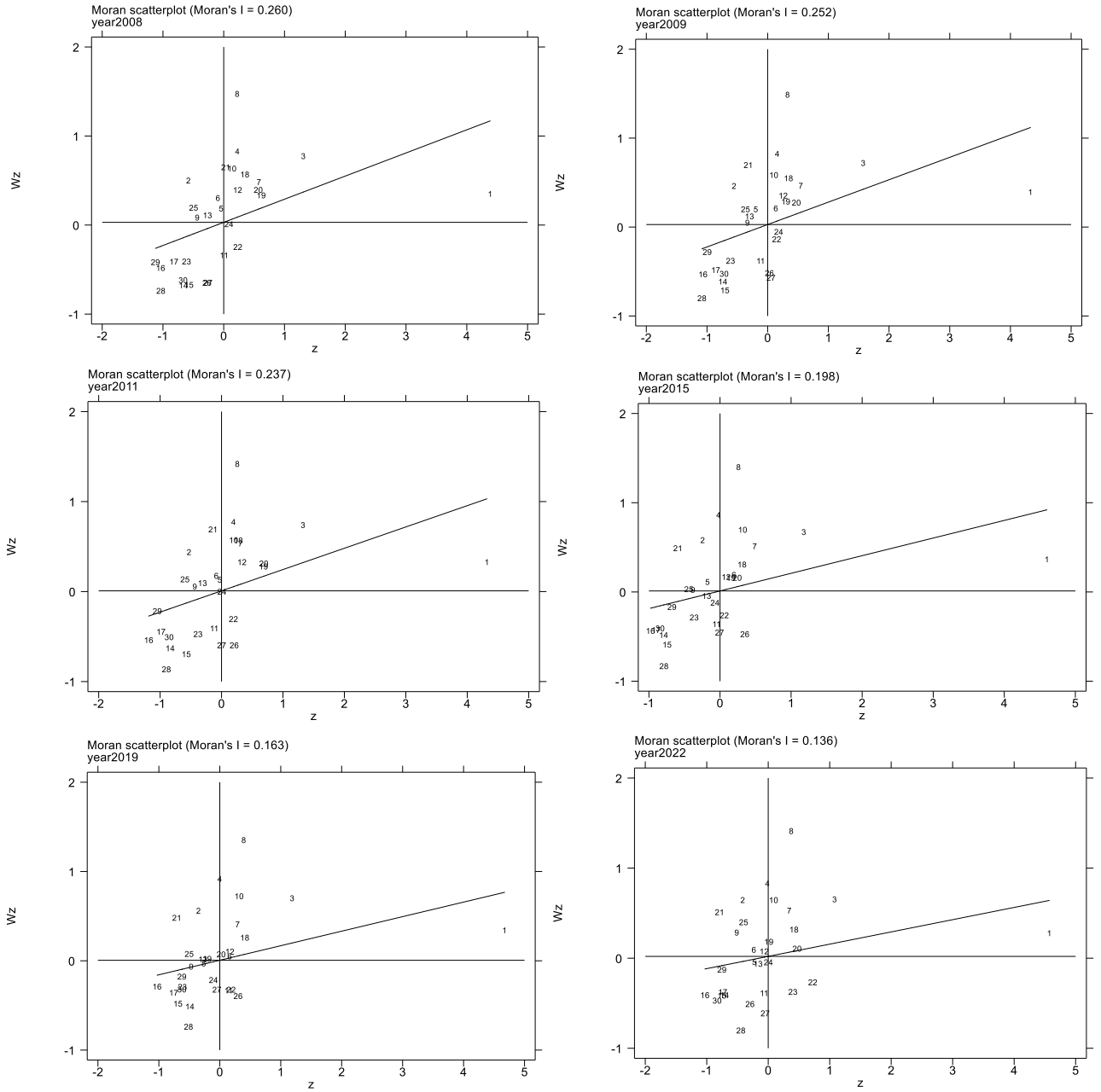


Figure 3. Moran Scatter Plot of 2008, 2009, 2011, 2015, 2019 and 2022

4.2. Analysis on Spatial Evolution of Urban Economic Resilience

Referring to the time points with obvious fluctuations in the time series analysis, this paper selects the data of 2008, 2009, 2011, 2015, 2019 and 2022, and uses Jenks method with Arcgis software to divide the economic resilience of the cities in the Central Plains urban agglomeration into four levels: high level, higher level, lower level and low level. [21] The classification results are shown in Table 4. It can be seen that Zhengzhou's economic resilience level has always ranked first, and most of its surrounding cities have also maintained a higher level, which together constitute the economic core of the Central Plains urban agglomeration and play a key leading role in regional economic development. The overall urban economic resilience is decreasing in a network outward gradient with Zhengzhou as the center, and the economic resilience of border cities is generally low. From the spatio-temporal evolution characteristics, during the study period, cities with high economic resilience concentrated in the central and western regions, southwest and northwest regions at the initial stage, and gradually converged to the core areas of the central and western regions. The number of cities with high and higher level of economic resilience showed a decreasing trend, while the number of cities with low and lower level of economic resilience gradually increased and the distribution scope continued to expand. Among them, the economic resilience of Bengbu in the southeast and Liaocheng in the northeast is significantly higher than that of the surrounding cities, showing local heterogeneity. In the long run, Zhengzhou has always been in a high economic resilience gradient, and most of the cities in the west and northwest adjacent to Zhengzhou are stable at a higher level. Cities with lower economic resilience are mainly distributed in the southwest and northeast. Cities in the east and south have been in the low level range for a long time, and the improvement trend is not obvious, which has become the weak area of economic resilience of urban agglomeration in the Central Plains. On the whole, the spatial pattern of economic resilience of urban agglomeration in the Central Plains shows the distribution characteristics of leading in the central region, high in the west and low in the east, high in the

north and low in the south, and shows an overall downward trend over time. The economic resilience of cities in the region varies significantly and the distribution is unbalanced. The gap between core and edge cities exists for a long time. The level of regional coordinated development needs to be improved, and the economic resilience still needs to be further enhanced.

Table 4. Spatial distribution of urban economic resilience

	Low level	Lower level	Higher level	High level
2008	Zhoukou, Zhumadian, Fuyang and Suzhou	Kaifeng, Hebi, Puyang, Shangqiu, Xinyang, Nanyang, Xingtai, Heze, Huaibei, Bengbu, Haozhou	Luoyang, Pingdingshan, Xuchang, Luohe, Sanmenxia, Anyang, Xinxiang, Jiaozuo, Jiyuan, Changzhi, Jincheng, Yuncheng, Handan, Liaocheng	Zhengzhou
2009	Xinyang, Zhumadian, Zhoukou, Shangqiu, Heze, Suzhou, Haozhou, Fuyang	Kaifeng, Nanyang, Luohe, Anyang, Puyang, Xingtai, Yuncheng	Luoyang, Pingdingshan, Xuchang, Sanmenxia, Xinxiang, Jiaozuo, Jiyuan, Changzhi, Jincheng, Handan, Liaocheng, Huaibei, Bengbu	Zhengzhou
2011	Shangqiu, Zhoukou, Zhumadian, Fuyang, Suzhou, Haozhou	Kaifeng, Nanyang, Luohe, Anyang, Puyang, Hebi, Xinyang, Xingtai, Handan, Heze, Huaibei, Yuncheng	Luoyang, Pingdingshan, Xuchang, Sanmenxia, Xinxiang, Jiaozuo, Jiyuan, Changzhi, Jincheng, Liaocheng, Bengbu	Zhengzhou
2015	Shangqiu, Zhoukou, Xinyang, Zhumadian, Yuncheng, Fuyang, Haozhou, Suzhou	Kaifeng, Pingdingshan, Anyang, Luohe, Sanmenxia, Puyang, Nanyang, Handan, Xingtai, Liaocheng, Heze, Huaibei	Luoyang, Xuchang, Jiyuan, Jiaozuo, Xinxiang, Hebi, Changzhi, Jincheng, Bengbu	Zhengzhou
2019	Puyang, Shangqiu, Zhoukou, Xinyang, Zhumadian, Yuncheng, Xingtai, Heze, Fuyang, Haozhou, Suzhou	Kaifeng, Pingdingshan, Anyang, Nanyang, Changzhi, Jincheng, Handan, Huaibei	Luoyang, Xuchang, Luohe, Sanmenxia, Xinxiang, Hebi, Jiaozuo, Jiyuan, Liaocheng, Bengbu	Zhengzhou
2022	Puyang, Shangqiu, Zhoukou, Xinyang, Zhumadian, Yuncheng, Haozhou, Suzhou	Kaifeng, Xuchang, Pingdingshan, Nanyang, Sanmenxia, Luohe, Hebi, Anyang Changzhi, Handan, Xingtai, Fuyang, Huaibei, Bengbu	Luoyang, Jiaozuo, Xinxiang, Jiyuan, Jincheng, Heze, Liaocheng	Zhengzhou

5. Conclusion

5.1. Research Summary

This paper systematically analyzes the spatial-temporal pattern evolution characteristics of economic resilience of 30 prefecture-level cities in the Central Plains urban agglomeration from 2007 to 2022: (1) The overall resilience showed a steady rise at first and then a fluctuating decline. It was significantly affected by external shocks such as the global financial crisis and the COVID-19 pandemic, which reached the peak in 2011 and fell to the bottom in 2019. (2) The level of urban resilience is significantly differentiated, with Zhengzhou and Luoyang forming a dual-core leading pattern and always being in the first echelon; Jincheng, Xinxiang, Jiyuan and other cities are in the middle and upper reaches, but there are obvious differences in annual fluctuations. Zhoukou, Fuyang, Suzhou and other cities have been in the downstream for a long time, with lagging economic development and weak risk response ability. Although some downstream cities have a trend of improvement, the effect is limited. (3) The global Moran index continues to be positive. The high-value agglomeration is concentrated in the central and western regions with Zhengzhou and Luoyang as the core, and the low-value agglomeration is distributed in the eastern, southern and northern Anhui. The resilience of the border cities is generally low, the gap between the core and the edge cities exists for a long time, and the level of regional coordinated development is insufficient. (4) External shocks are the key cause of resilience fluctuations. In 2009, the resilience of all cities was generally increased due to the global economic recovery, but in 2019, the resilience of the whole region decreased significantly due to the impact of COVID-19, reflecting the urgent need to improve the ability of some cities in urban clusters to cope with sudden external risks.

5.2. Development Suggestions

(1) Strengthen dual-core driving and classified policies to promote differentiated improvement of urban resilience: accelerate the construction of Zhengzhou national central city and Luoyang sub-central city, and strengthen the dual-core leading and gradient radiation role. Targeted policies will be implemented for cities with different levels of resilience: low-value agglomeration cities will consolidate their industrial foundation and enhance their resilience; Promote industrial transformation and structural optimization for cities with declining resilience; To strengthen regional cooperation for low and high agglomeration cities, enhance radiation undertaking capacity, and gradually reduce the development gap within urban clusters.

(2) Focusing on prominent problems such as weak economic resilience and lack of innovation-driven development, we will, on the one hand, improve the system for ensuring people's livelihood and providing fiscal support to enhance economic resilience. On the other hand, we will increase investment in scientific and technological innovation, improve research and development intensity and talent support, take innovation as the core focus, and comprehensively enhance the ability of the economic system to adapt, adjust and transform.

(3) Deepen regional coordination and risk prevention and control, optimize the spatial equilibrium pattern of resilience: break administrative barriers, establish a cross-provincial collaborative development mechanism, promote the free flow of factors and cross-regional industrial cooperation, and focus on supporting the development of low-value regions in the eastern and southern regions. At the same time, we will

establish a linkage mechanism for economic risk monitoring and early warning and cross-regional emergency response, improve the ability to respond to external shocks, optimize the spatial layout by relying on the advantages of transportation hubs, and gradually form a balanced, coordinated and sustainable pattern of resilient development.

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