

The Spatiotemporal Evolution and Influencing Factors of Urban Economic Resilience in the Yangtze River Delta Urban Agglomeration

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Abstract: Urban agglomerations are the highest form of spatial organization in the mature stage of urban development, and will be impacted by external risks during the development process. How to enhance the urban economic resilience of urban agglomerations plays an important role in the sustainable development of urban agglomerations. Based on resilience theory and taking the Yangtze River Delta urban agglomeration as the research object, this paper explores the spatiotemporal characteristics, influencing factors and predictions of urban economic resilience in the future. The study found: (1) Based on the kernel density estimation, the economic resilience of the Yangtze River Delta urban agglomeration has significant spatial non-equilibrium characteristics; (2) Based on the correlation analysis, the degree of industrial structure optimization, government financial support, degree of opening to the outside world, innovation investment, Financial development level, urbanization level and ecological level are positively correlated with urban economic resilience; based on principal component analysis, government financial support is a key factor affecting urban economic resilience, with a weight of 17%; (3) Based on the grayscale prediction model, GM(1,1) can better fit the overall urban economic resilience of the Yangtze River Delta urban agglomeration from 2011 to 2020, and the overall urban economic resilience of the Yangtze River Delta urban agglomeration is at a high level from 2021 to 2025, but there is a downward trend. This research has important guiding significance for understanding the urban economic resilience of urban agglomerations and how to improve the urban economic resilience of urban agglomerations and promote regional coordinated development.

Keywords: Yangtze River Delta Urban Agglomeration, Urban Economic Resilience, Kernel Density Estimation, Principal Component Analysis, GM(1,1).

1. Introduction

With the advancement of China's new urbanization process, urban agglomerations have gradually replaced individual cities as complex regional systems of global economic development [1]. They are not only the main spatial carriers of regional social and economic development, but also the main regional units participating in global competition and international division of labor. It will become the most dynamic and potential growth pole for future economic development [2,3]. The urban spatial organization in the urban agglomeration is more compact and the economic connection is closer, which has an important strategic orientation for promoting regional integrated development. The Yangtze River Delta urban agglomeration includes "three provinces and one city" in geographical space. It is an important intersection between the "Belt and Road" and the Yangtze River Economic Belt. It connects the east to the west, connects the south to the north, and is responsible for the rise of the central region and the ecological protection of the Yangtze River Basin. important task. Data show that the Yangtze River Delta urban agglomeration has about a quarter of the country's "double first-class" universities, and the annual R&D expenditure and the number of valid invention patents account for about one-third of the country, accounting for 2.3% of the country's area, but contributing 20%. % of GDP, plays the role of a "pioneer" and "demonstration area" in the national productivity layout. In October 2019, the State Council officially approved the "Overall Plan for the Ecological Green Integrated Development Demonstration Zone in the Yangtze River Delta", emphasizing that the

Yangtze River Delta urban agglomeration should take the lead in exploring the transformation of ecological advantages into economic and social development advantages. In December 2019, the Central Committee of the Communist Party of China and the State Council issued The "Outline of the Yangtze River Delta Regional Integrated Development Plan" takes the common development of the Yangtze River Delta region as a major national strategy, and clarifies the strategic layout of "one pole, three regions and one highland" in the Yangtze River Delta. As one of the most active, open and innovative regions in the country, the Yangtze River Delta urban agglomeration plays a pivotal role in promoting sustainable economic development, but it also faces an imbalance between economic development and environmental quality development [4]. Today, China is facing "big changes unseen in a century". The international balance of power has been profoundly adjusted, the international situation has undergone profound changes, the international environment has become increasingly complex, and various uncertainties and instability have risen significantly. With the advent of the risk society, the construction of resilient cities has increasingly become a topic of common concern in the theoretical and practical circles [5]. The Fifth Plenary Session of the 19th Central Committee of the Communist Party of China put forward the goal of "building a resilient city" for the first time from the height of the national strategy, and incorporated it into the recommendations of the 14th Five-Year Plan and the 2035 vision. Building a resilient city has become a national strategic goal and strategy. direction. Urban economic resilience reflects a city's ability to respond to economic crises,

mitigate external shocks, and resist external risks, and its importance cannot be overstated. Generally speaking, the higher the resilience of a city's economy, the stronger the city's ability to resist external shocks, and the less the city's economic development is affected by external shocks [6]. The urban economic resilience of the Yangtze River Delta urban agglomeration has an important impact on the sustainable economic development of the Yangtze River Delta urban agglomeration and its radiating role. How to achieve self-breakthrough in the uncertain external environment is a new issue for the Yangtze River Delta urban agglomeration in the new era. become a research hotspot.

2. Literature Review and Methods

2.1. Literature Review

At present, the research on the Yangtze River Delta urban agglomeration has achieved relatively rich research results. Scholars have studied the economic growth [7], spatial pattern [8], spatial spillover effect [9], integration boundary effect [10], innovation efficiency [11], and innovation output differences of the Yangtze River Delta urban agglomeration from different perspectives. spatiotemporal evolution [12], spatiotemporal characteristics of carbon emissions [13], etc. Y. Peng, X. Chen (2011), based on the traditional Cobb-Douglas production function, incorporated trade intermediary agglomeration factors into the new production function model, and found that trade intermediary agglomeration has a significant role in promoting economic growth in the Yangtze River Delta region; P.F. Chai, Z.W. Huang (2014) studied the spatial pattern of the Yangtze River Delta urban agglomeration based on the theory of coordinated development, and found that the Yangtze River Delta region is gradually transforming from a single center to a multi-center model; T. Zhou (2015) studied the urban agglomeration in the Yangtze River Delta from an interactive perspective. Spatial spillover effects, the study found that the industrial development of the Yangtze River Delta urban agglomeration has significant spatial correlation, with the characteristics of spatial value chain layout; L. Huang, X.Y. Wang, Y. Xiong (2018) used the Theil index second-order decomposition method and exploratory spatial data. The analysis method and the geographic detector method study the spatial and temporal evolution of the innovation output difference of the Yangtze River Delta urban agglomeration. The study finds that the relative difference of the innovation output of the urban agglomeration has a decreasing trend, and the intra-regional heterogeneity plays a significant role, and the innovation output varies in space. There is an uneven agglomeration distribution in the urban agglomeration; L. Xu (2021) studied the innovation efficiency of the Yangtze River Delta urban agglomeration from the perspective of input and output, and found that the innovation efficiency of the Yangtze River Delta urban agglomeration was positively correlated with the urban R&D investment; Zhou Z.Z. Zhou, L. Xu (2022) By building an economic convergence analysis model and a relative β -convergence model, the study found that the integration of the Yangtze River Delta urban agglomeration has a good development trend, and the integration boundary of the Yangtze River Delta urban agglomeration presents a significant mediating effect; H C.F. Han, F.L. Song, M.M. Teng (2022) used spatial autocorrelation, Kernel density estimation, systematic clustering and other methods are used to study the spatiotemporal characteristics of carbon

emissions in the Yangtze River Delta urban agglomeration. The study found that the carbon emission core density in the Yangtze River Delta region presents an obvious "unipolar" phenomenon, and carbon emissions show a significant positive spatial correlation. The above research has laid an important foundation for the integrated development of the Yangtze River Delta urban agglomeration, but it has not considered the impact of external risks on urban development, that is, the resilience of urban economic development in the Yangtze River Delta urban agglomeration. There is little research. In the face of increasingly complex domestic and foreign environments, a series of external shocks or internal disturbances that may occur will have an impact on the economic system [14]. For example, the new crown epidemic has hindered my country's economic growth, and the heavy rain in Henan has posed a greater threat to the development of cities. External risks have brought a huge impact on urban economic development and social stability. The emergency response capabilities of Chinese cities to deal with risks, disasters and crises are not yet It is very complete, and the urban system is still relatively fragile [5]. Based on this, building a more resilient economy and society is of great significance for enhancing the anti-risk capability of urban agglomerations and further promoting the high-quality development of my country's economy. "Resilient city" has also become an important goal of my country's urban construction. The connotation of "resilience" was first applied to the physical discipline, referring to the ability of the system to return to its original state after being stressed, to Holling (1973) [15] introduced it to the ecological discipline and defined it as engineering resilience, to Reggiani et al. (2002) [16] introduced this concept into the study of economics, considering regional economic resilience as the ability to resist shocks [8]. Wink (2014) [17] introduced the concept of resilience into urban economics for the first time, and he believes that resilience is a kind of ability to avoid, resist, adapt or respond to external shocks. Based on the perspective of evolutionary resilience, Martin R, Sunley P (2015) [18] further defined the connotation of resilience as four aspects: vulnerability, resistance, robustness and resilience. In general, the connotation of resilience has undergone a change in the cognition of "engineering resilience - ecological resilience - social and ecological resilience (evolutionary resilience) - contextual resilience" [19]. The resilience theory lays the foundation for this study. Considering that urban economic resilience is a measure of how urban economic development responds to external risks, this paper focuses on the research on urban economic resilience. Economic resilience can be understood as the ability of a regional economy to actively carry out self-adjustment and structural transformation in response to external shocks [20], and it can also be understood as the ability of an economy (including individuals, households, regions and countries) to cope with external disturbances [21]. In the theoretical study of economic resilience, evolutionary economic geography explores why some regions can "unlock" and realize economic transformation and upgrading, while some regions cannot get rid of "path dependence" and gradually go into recession [21]. Scholars' research on economic resilience using the relevant theories of economic geography mainly focuses on the measurement of economic resilience and its influencing factors. In the measurement of economic resilience: Guillaumont (2009) [22] uses economic vulnerability indicators to measure economic resilience, the smaller the

vulnerability of a country's economy, the stronger the economic resilience; Briguglio L, Cordina G, Farrugia N, et al (2009) [23] constructed an indicator system to measure economic resilience. To measure economic resilience, it includes four indicators: macroeconomic stability, microeconomic market efficiency, governance and social cohesion; Ringwood L, Watson P, Lewin P, et al (2019) [24] use employment indicators to measure regional economic resilience; Y.W. Chen, G.L. Ding (2020) [25] The degree of agglomeration, the level of economic growth, the gap between the rich and the poor, the optimization of the urban industrial structure and the sensitivity of the urban economy construct a comprehensive index of urban economic resilience; R.G. Su, X.L. Zhao (2020) [26] used the employment growth rate index to measure the urban economy toughness. In exploring the influencing factors of economic resilience: Z. Zhang, Z.G. Li, X. Hu (2021) [27] constructed a spatial Durbin model and found that within the dimension of urban agglomeration, local economic resilience is continuously strengthened with the improvement of industrial agglomeration level, and also There are significant spatial spillover effects. Z C.Y. Zhao, S.P. Wang (2021) [28] constructed a panel data model and found that economic agglomeration significantly promoted the improvement of urban economic resilience. R.G. Su, X.L. Zhao (2022) [29] constructed various econometric models such as fixed effect model and quantile model, and found that the upgrading of manufacturing industry significantly promotes urban economic resilience, but the promotion effect shows a downward trend. Industrial upgrading has a positive moderating effect in promoting urban economic resilience, and presents heterogeneity characteristics; G.H. Hua, Y.J. Chen eration has a significant role in promoting urban economic resilience. There is regional heterogeneity in the mediating effect of innovation. The economic development of the urban agglomeration in the Yangtze River Delta has a "pioneering" role in the long-term development of the urban agglomeration in China. However, there are few literatures in the existing research that discuss the urban economic resilience of the urban agglomeration in the Yangtze River Delta, and there is no impact on the economic resilience of the urban agglomeration in the Yangtze River Delta. Factors are systematically sorted out. On the one hand, the research on the urban economic resilience of the Yangtze River Delta urban agglomeration can help to have a better understanding of the resilience of different cities to external shocks, and on the other hand, it can provide some experience for other urban agglomerations to deal with external risks when developing their economies. This paper mainly answers three questions: First, are there regional differences in the economic resilience of the Yangtze River Delta urban agglomeration? Second, what factors can affect the resilience of their cities? Third, what is the future trend of urban economic resilience in the Yangtze River Delta urban agglomeration, and how to improve urban economic resilience? By answering the above three questions, it will help to improve the economic resilience of urban agglomerations and enhance the ability of urban agglomerations to resist external risks. Based on this, the possible marginal contributions of this paper include: evaluating the spatiotemporal characteristics of urban economic resilience in the Yangtze River Delta urban agglomeration through kernel density estimation, exploring which factors can have an important impact on urban economic resilience through correlation analysis and

principal component analysis, and Predict the dynamic trend of urban economic resilience in the Yangtze River Delta urban agglomeration from 2021 to 2025. The research in this paper expands the application of economic resilience in urban agglomerations and provides new empirical evidence for promoting regional integration.

2.2. Research Methods

This paper mainly uses kernel density estimation, correlation analysis and principal component method and grey prediction model GM(1,1). Among them, kernel density estimation is used to intuitively and vividly reveal the spatial and temporal distribution characteristics of urban economic resilience in the Yangtze River Delta urban agglomeration. Correlation analysis and principal components method test which factors can affect urban economic resilience and determine the weight of each factor. GM (1,1) is used to predict the changes in the overall economic resilience of the Yangtze River Delta urban agglomeration from 2021 to 2025.

2.2.1. Kernel Density Estimation

As a non-parametric estimation method, kernel density estimation can describe the distribution shape of random variables with a continuous density curve. By approximating the probability density of the variables, the kernel density estimation results reflect the location, shape and ductility of the variable distribution information [31]. Due to its weak dependence on the model and good statistical properties, this method has been widely used in the study of spatial distribution differences. Calculated as follows:

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \quad (1)$$

$$f(x) = \frac{1}{n_h} \sum_{i=1}^n K\left(\frac{X_i - x}{h}\right) \quad (2)$$

Among them: n_h is the number of observations, X_i is the observation point value, x is the average value, h is the bandwidth, and $K(\cdot)$ is the kernel function.

2.2.2. Correlation Analysis and Principal Component Analysis

This paper studies the influencing factors of urban economic resilience through correlation analysis. In order to visually show which factors have an important impact on urban economic resilience, this paper analyzes by drawing scatter plots of core variables and influencing factors and fitting curves. After obtaining which factors will affect the urban economic resilience, the principal component analysis method is used to calculate the weight of each influencing factor [32,33], and then the key factors affecting the urban economic resilience are obtained.

2.2.3. Grey forecast- GM(1,1)

Grey forecasting system refers to a forecasting system in which part of the information is known and part of the information is unknown. The basic idea is to accumulate the original data sequence once to generate a new sequence, thereby weakening the randomness of the original data and making it show more obvious characteristic rules [31]. The main task of the theory is to fully mine the known information, seek the mathematical laws of system operation, and make quantitative predictions of future changes. In grey system research, GM forecasting model is the basic model of grey

forecasting theory, and GM(1,1) model, as the core and basis of it, has become the most researched because of its low sample size, simple structure and simple calculation. The most widespread and widely used predictive model [34, 35]. The basic principle is as follows: If the original sequence is:

$$X^{(0)} = \{X^{(0)}(1), X^{(0)}(2), \dots, X^{(0)}(n)\} \quad (3)$$

Accumulate (4) once to get:

$$X^{(1)} = [X^{(1)}(1), X^{(1)}(2), \dots, X^{(1)}(n)] = \left[X^{(0)}(1), \sum_{t=1}^2 X^{(0)}(t), \dots, \sum_{t=1}^n X^{(0)}(t) \right] \quad (4)$$

Then the corresponding first-order differential equation of the GM(1,1) model:

$$\frac{dx^{(1)}}{dt} + ax^{(1)}(t) = \mu(2) \quad (5)$$

Among them: a is the development gray number, μ is the endogenous control gray number.
remember:

$$B = \begin{bmatrix} -\frac{1}{2}[X^{(1)}(1) + X^{(1)}(2)] & 1 \\ -\frac{1}{2}[X^{(1)}(2) + X^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[X^{(1)}(n-1) + X^{(1)}(n)] & 1 \end{bmatrix} \quad (6)$$

$$Y_n = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{bmatrix} \quad (7)$$

Construct the immediate-mean-generating sequence $Z^{(1)}$

$$Z^{(1)}(k) = -\frac{1}{2}(X^{(1)}(k-1) + X^{(1)}(k)) \quad (8)$$

But

$$B = \begin{bmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -Z^{(1)}(n) & 1 \end{bmatrix} \quad (9)$$

Make

$$\hat{\alpha} = \begin{bmatrix} a \\ \mu \end{bmatrix} \quad (10)$$

Then (9) can be expressed as:

$$Y = B\hat{\alpha} \quad (11)$$

Solve using the least squares method:

$$\hat{\alpha} = (B^T B)^{-1} B^T Y_n \quad (12)$$

Therefore, the prediction model can be obtained, namely:

$$\hat{X}^{(1)}(k+1) = \left(X^{(0)}(1) - \frac{\mu}{\alpha} \right) e^{-ak} + \frac{\mu}{\alpha} \quad (13)$$

3. Research Design

3.1. Data Sources

This paper takes the Yangtze River Delta urban agglomeration as the research object, and discusses the temporal and spatial change characteristics of the urban economic resilience of the Yangtze River Delta urban agglomeration from 2011 to 2020, the influencing factors and its prediction on the future economic resilience of the Yangtze River Delta urban agglomeration. The data source is the "China Urban Statistical Yearbook" and the "Statistical Yearbook" of cities in the Yangtze River Delta. Since Ma'anshan and Anqing have many missing values, these two cities are excluded.

3.2. Variable Design

3.2.1. Urban Economic Resilience

As the core variable of this study, urban economic resilience is based on the research methods of Martin R, Sunley P (2016) [18] and Z. Zhang, Z.G. Li, X. Hu. (2021) [27], and the change in GDP is used to measure urban economic resilience. The calculation method is as follows:

$$resi_{it} = \frac{G_{r,t}}{G_{r,t-1}} \bigg/ \frac{G_{n,t}}{G_{n,t-1}} \quad (14)$$

Among them: $G_{r,t}$ represents the annual growth rate of real GDP in region r in period t , and $G_{n,t}$ represents the annual growth rate of real GDP in the whole country in period t .

3.2.2. Influencing Factors

The factors affecting urban economic resilience are complex. This paper draws on the research results of literature [11-14, 25-30], and selects the following factors to study the influencing factors of urban economic resilience: (1) Select the degree of industrial structure optimization (iso), use the first Measured by the proportion of the added value of the tertiary industry in GDP, optimizing the industrial structure can resist a certain degree of external risks; (2) Select government financial support (gfs) and use fixed asset investment (excluding farmers) to measure, the government as the urban infrastructure Important builders, whose financial expenditure can affect the city's economic resilience; (3) Select the degree of openness (open), measured by the number of newly established foreign-invested enterprises, to enhance the level of the city's opening to the outside world, which can attract more foreign-funded enterprises and provide the city Construction lays an important foundation; (4) Select innovation investment (innovation), measured by scientific and technological expenditure, innovation capability is the core competitiveness of a city's sustainable development, and enhancing the level of urban innovation can affect urban economic resilience; (5) Select financial The development level (financial) is measured by the balance of various RMB deposits in financial institutions. Financial development reflects the capital level of the city and provides financial support for urban economic construction; Measured by numbers, the level of urbanization has contributed to the talent pool for urban economic construction, which is conducive to enhancing the resilience of the urban economy;

(7) Select the ecological level (ecology), which is measured by the area of green space. The ecological level reflects the degree of urban green development. Ecological protection and economic development will enable the healthy development of the city, thereby enhancing the urban economic resilience.

4. Empirical Results Analysis

4.1. Dynamic Characteristics of Urban Economic Resilience in the Yangtze River Delta Urban Agglomeration

Figure 1 reflects the overall urban economic resilience of the Yangtze River Delta urban agglomeration from 2011 to 2020. It can be found from the figure that the urban economic resilience of the Yangtze River Delta urban agglomeration can be roughly divided into four stages: from 2011 to 2013, the urban economic resilience was in the rising stage, from 2011 to 2012, it was in the stage of climbing over the hurdles, and from 2012 to 2013, the urban economic resilience With a great increase, it reached its peak in 2013; the urban economic resilience declined significantly from 2013 to 2014; the urban economic resilience was stable from 2014 to 2019, and the urban economic resilience level was at an average level; 2019- Urban economic resilience is on a downward trend in 2020. Overall, the urban economic resilience of the Yangtze River Delta urban agglomeration has not yet formed a stable state, and the overall urban economic resilience still has a large room for growth.

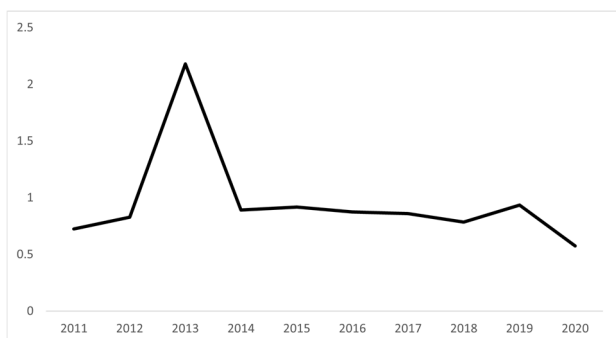


Figure 1. 2011-2020 Urban Economic Resilience Trend Chart

Figure 2 reflects the kernel density estimation results, that is, the spatiotemporal characteristics of urban economic resilience in the Yangtze River Delta urban agglomeration. It can be found from the figure that the urban economic resilience of the Yangtze River Delta urban agglomeration from 2011 to 2020 presents a "single peak" phenomenon. The center of nuclear density showed a changing trend: the center of nuclear density moved to the right in 2011-2014, and the center of nuclear density moved to the left in 2014-2020. Among them, the peak in 2011 was the highest, the lowest in 2014, and the peak gradually recovered after the trough in

2014. The width of the crest from 2011 to 2014 gradually became longer, the width of the crest from 2014 to 2017 decreased again, and the width of the crest from 2017 to 2020 increased, and the width of the crest reached its peak in 2014. The above analysis shows that the economic resilience of the Yangtze River Delta urban agglomeration has significant spatial and temporal disequilibrium characteristics.

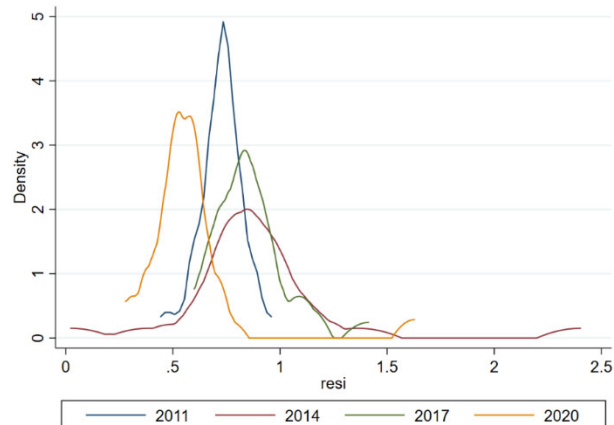


Figure 2. The spatiotemporal characteristics of urban economic resilience

4.2. Analysis of Influencing Factors

From the above empirical results, it can be seen that the level of economic resilience of each city in the Yangtze River Delta urban agglomeration is different, which is not conducive to the development of regional integration. Therefore, we should explore the influencing factors of urban economic resilience, and then find a corresponding path for improving urban economic resilience and provide a good solution. The solution lays the foundation. In this part, the scatter plot in the correlation analysis is used to explore the relationship of each variable on the urban economic resilience, and the weight of each variable is determined by principal component analysis, and then the key factors affecting the urban economic resilience are obtained. Considering the large differences in the data, standardize each influencing variable:

$$X^* = \frac{X - \mu}{\sigma} \quad (15)$$

Among them: X^* is the standardized data, X is the original data, μ and σ are the mean and standard deviation of the original data, respectively. After processing by Equation (15), the data falls in a standard normal distribution with a mean of 0 and a variance of 1, thereby eliminating the difference in the magnitude of the data and ensuring the robustness of the analysis results. Figure 3 is a scatter plot of urban economic resilience and various influencing factors. From the scatter plot, it can be found that each variable has a certain positive correlation with urban economic resilience.

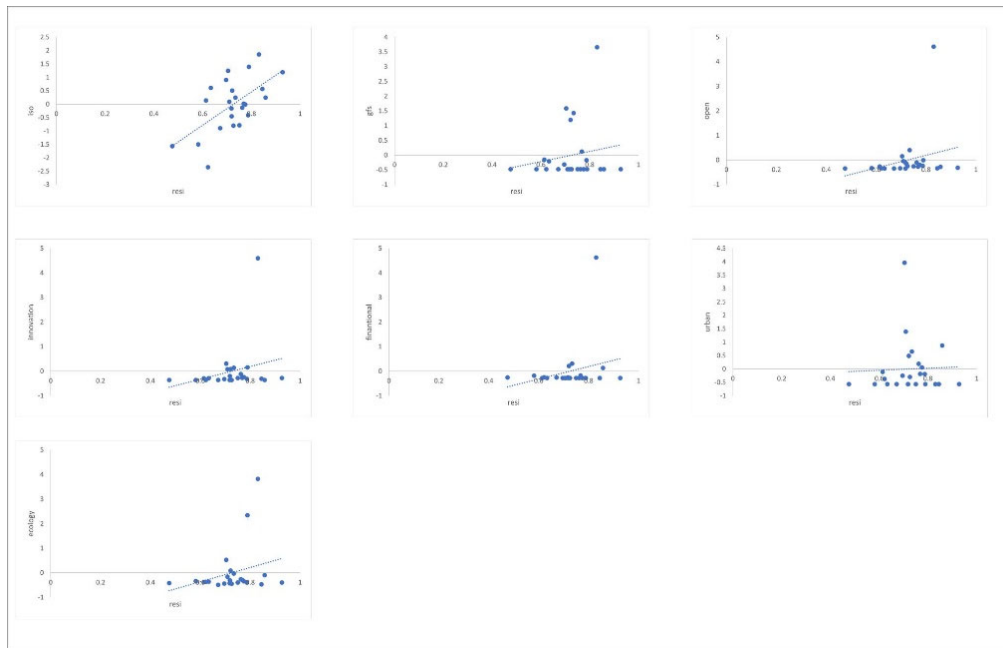


Figure 3. Scatter plot of urban economic resilience and influencing factors

In order to quantify the impact of each indicator on urban economic resilience, this paper uses principal component analysis to calculate the weight of each indicator. The larger the weight value, the greater the impact on urban economic resilience, and vice versa. First, perform exploratory analysis on the data: KMO and Bartlett coefficients are 0.803, greater than 0.75, and the significance level is 0.00, so the data can be subjected to principal component analysis. Second, determine the number of common factors: two common factors are extracted according to the principle that the eigenvalue is greater than 1, and the variance contribution rate of the common factors is 86.701%, indicating that the extracted common factors can better express the characteristics of the data and reduce the number of data loss of information. Third, the calculation of the weight: the "total variance explanation" and "component matrix" obtained by the principal component analysis are used to calculate the weight of each influencing factor. Table 2 reports the weight of each influencing factor. The weights of each influencing factor are 14%, 17%, 15%, 15%, 14%, 10% and 15% in order, and the top four are government financial support, degree of opening to the outside world, innovation investment and ecological environment. From the results, if the economic resilience of the Yangtze River Delta urban agglomeration is to achieve long-term sustainable improvement, it is necessary to continuously strengthen the construction of the above-mentioned influencing factors, especially when developing the economy, the ecological environment cannot be ignored. Any economic growth at the expense of the environment will be unsustainable. The concept of urban development that lucid waters and lush mountains are invaluable assets has been empirically tested.

4.3. Grey Forecast

Figure 1 shows the dynamic trend of the overall urban economic resilience of the Yangtze River Delta urban agglomeration from 2011 to 2020. Although it can be roughly summarized from Figure 1 that urban economic resilience can be divided into four stages, its changing law is difficult to highlight, especially the dynamic characteristics of urban economic resilience in the future. In order to deeply explore

the economic resilience of the Yangtze River Delta urban agglomeration in the future, this paper uses GM(1,1) to make gray predictions. Figure 4 shows the overall urban economic resilience of the Yangtze River Delta urban agglomeration, the data fitted by GM(1,1), and the errors of the two.

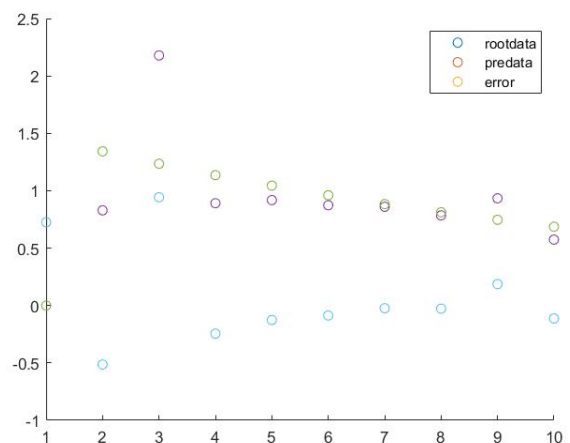


Figure 4. GM(1,1) fitting and error diagram

It can be seen from the figure that the original data and the forecast data show a coincident trend after 2013, and most of the errors between the two are in the range of -0.3 to 0.3, indicating that the model is used to fit the economic resilience of the Yangtze River Delta urban agglomeration. It has a good effect, so this paper continues to use the model to predict the urban economic resilience of the Yangtze River Delta urban agglomeration from 2021 to 2025. Table 3 reports the predicted value of the urban economic resilience of the Yangtze River Delta urban agglomeration from 2021 to 2025. On the whole, the economic resilience of the Yangtze River Delta urban agglomeration in the next five years will have a high level, indicating that the Yangtze River Delta urban agglomeration will have a good "resistance" to the impact of external risks in the future. However, it cannot be ignored that, from the forecast results, the future urban economic resilience of the Yangtze River Delta urban agglomeration will show a downward trend. Therefore, in the future, the Yangtze River

Delta needs to be based on factors such as government financial support, degree of openness, innovation investment and ecological environment to improve the long-term growth rate. The overall urban economic resilience of the triangular urban agglomeration.

Table 1. GM(1,1) forecast result

year	2021	2022	2023	2024	2025
resi	1.397	1.285	1.181	1.086	0.999

5. Conclusions and Policy Recommendations

Ecological level are positively correlated with urban economic resilience. The ecological environment ranks among the top four influencing factors, and government financial support is a key factor affecting urban economic resilience. (3) GM(1,1) can better fit the urban economic resilience of the Yangtze River Delta urban agglomeration, and the forecast results of GM(1,1) show that the economic resilience of the Yangtze River Delta urban agglomeration is at a high level from 2021 to 2025. But there is a downward trend. Based on the above conclusions, this paper puts forward the following policy recommendations: First, government financial support plays a pivotal role in improving urban economic resilience. The government should enhance the construction of urban infrastructure, including traditional infrastructure and "new economy" infrastructure. On the one hand, improve the comprehensive transportation system in the region, focus on the development of innovative capacity building in transportation, enhance the accessibility of urban agglomeration transportation, promote efficient division of labor and cooperation within urban clusters, and promote the rational and efficient flow of production factors; infrastructure, such as optical fibers, base stations, etc., use the Internet to enhance the informatization capabilities of urban agglomerations, enhance the digital economy level of urban agglomerations, and use modern technologies to resist external risks, thereby enhancing urban economic resilience. Second, continue to expand the level of opening to the outside world. As General Secretary Xi Jinping mentioned on many occasions, "China's door to opening will never be closed, it will only open wider and wider." By expanding the level of opening to the outside world, integrating domestic and foreign excellent management experience and technical capabilities, forming management ideas with Chinese characteristics, and continuously improving the core competitiveness of urban agglomerations, thereby enhancing the urban economic resilience of urban agglomerations. Third, increase investment in innovation. Combined with their own resource endowments, urban agglomerations develop information technologies such as big data, the Internet, cloud computing, artificial intelligence, and blockchain, and increase the investment of innovative resources in high-tech industries such as biomedicine, new energy vehicles, and smart logistics, as well as related The policy is tilted towards high-tech industries, gradually forming regional industrial advantages, and promoting the resilient development of the regional economy. Fourth, strengthen ecological awareness and fully consider the carrying capacity of ecological resources. The ecological environment is positively correlated with urban economic resilience. Therefore, to improve urban economic resilience, it is necessary to protect ecological space and not relax

regulations on urban environmental pollution. Ecological and environmental problems have external characteristics. The government should actively establish an effective ecological compensation mechanism, an open and transparent environmental governance supervision and public participation mechanism, and vigorously develop ecological industries, so that economic development and environmental protection can develop in harmony, thereby enhancing urban economic resilience. In addition, the optimization of industrial structure, the level of financial development, and the level of urbanization will also affect urban economic resilience. Optimize the industrial structure, continuously enhance the position of the tertiary industry in the regional economy, promote the transformation and upgrading of the industrial structure of urban agglomerations, enhance the resilience of the urban economy, and reduce the impact of external risks on economic development; financial development provides financial support for regional construction and innovation, It is conducive to improving the resilience of urban economy; the improvement of urbanization level provides human capital for urban construction and lays a foundation for economic construction, so it is conducive to the enhancement of urban economic resilience.

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