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# *A reseach on the Measurement and Trend Forecasting of Digital Economy Development in Cities along the "Belt and Road"*

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***Abstract:*** With the acceleration of global integration, in order to enhance the level of information modernization, optimization of resource allocation and improve the level of high-quality development of China's economy under the new pattern, it is of great significance to measure and forecast the level of digital economy development in the perspective of "One Belt and One Road". Based on this, this paper firstly constructed a digital economy development evaluation index system consisting of five potential factors, including digital economy environment, digital industry development, digital infrastructure, industrial digital development and digital innovation level. Then, considering the information quantity, volatility and relevance of each evaluation index, this paper chose the combination of entropy and CRITIC method to quantify the five potential factors and calculated the digital economy development level based on TOPSIS method. Then, k-means clustering and grey-scale models were used to analyse the spatial and temporal clustering and forecast the development level of the digital economy in each region. The empirical results show that the development trend of digital economy in cities along China's "One Belt, One Road" has been steadily increasing, but the balance of the digital economy development level of each city still needs to be improved. The growth rate of the digital economy is more pronounced in coastal cities than inland cities. Finally, suggestions are made to improve the quality construction of "One Belt, One Road" and the balance of digital economy development in China.

## 1. Introduction

The "One Belt, One Road" initiative has brought tremendous opportunities and challenges for digital economy development and cooperation among cities along the "One Belt, One Road". The rise of the digital economy has become the core driver of digital economy development in cities along the Belt and Road, playing an important role in accelerating economic development, fostering new markets and new growth points for industries, and achieving inclusive and sustainable growth [1]. Therefore, it is imperative to examine the level of digital economy development in cities along the Belt and Road, to build a scientific evaluation system for digital economy development, and to study the development of digital economy in cities along the Belt and Road in China from a new

perspective. Zhang Xueling and Chen Fang[2] selected four secondary indicators to reflect the quality of digital economy development: economic efficiency, social progress, structural optimization and resource and environmental improvement, and used the entropy value method to measure the quality of digital economy development in China in the past ten years. Xu Jianhui[3] constructed a system of indicators for digital economy development in countries along the Belt and Road, measured the current situation of digital economy development in the countries along the Belt and Road with the help of principal component analysis, and conducted a spatial difference analysis using ArcGIS10.2 software. Wang Fang et al[4] established a high-quality development index and early warning model of China's digital economy through expert scoring, entropy value method and grey prediction model, and analyzed its time evolution characteristics. Zheng Ningyu[5] used a three-stage super-efficiency SBM model to effectively solve the radial and angular problems in traditional models, and measured the digital economy efficiency of 51 countries along the "Belt and Road". Qi Junyan[6] used principal component analysis to quantitatively measure the development level of digital economy in 43 countries along the Belt and Road, and found that there are gradations and imbalances in the development level of digital economy in countries along the Belt and Road. This study finds that there are gradations and imbalances in the level of digital economy development in the countries along the Belt and Road. Yang Luming and Liu Jihong[7] constructed an evaluation index system for digital economy development in CEE countries, and used the entropy value method to measure the comprehensive index of digital economy development in 15 CEE countries from 2013 to 2017. The study showed that: in general, the digital economy of CEE countries is well developed, but there are significant gaps in digital economy development between different countries. The existing research on digital economy indicators has insufficient coverage and single evaluation method, and most of them are only analyzed from a single perspective. Moreover, there is a lack of research on the digital economy development of Chinese cities along the Belt and Road. How to scientifically construct an evaluation system for the digital economy is an important proposition in the pursuit of high-quality economic development in the new era, and is particularly important for the sustainable development of China's economy.

The main contribution of this paper is to construct a scientific evaluation system and prediction model for the digital economy of "One Belt, One Road". The comprehensive weight method is adopted, combining the entropy value method with the CRITIC method, and the weights obtained by combining the two as the final comprehensive weights of the indicators, so that the information of the indicators themselves and the relevance of the indicators to their own fluctuations can be taken into account in the process of solving the weights of the indicators. The TOPSIS method is used to measure the digital economy development level of the regions along the route, and the K-means clustering model and gray prediction model are used to cluster and predict the digital economy development of each region, which is an important guiding significance for the in-depth discussion of the development of domestic cities along the route in the context of "One Belt, One Road".

## 2. Theory and Methodology

### 2.1. Indicator system construction

Based on the connotation of digital economy, this paper combs the existing research results of scholars and deeply analyses the White Paper on Digital Economy Index of Chinese Cities (2020), and based on the principles of scientificity, comparability, comprehensiveness and availability, selects the indicators highly related to the development of digital economy. It aims to provide a comprehensive and accurate measurement of the digital economy development level of cities along the "Belt and Road" from different dimensions, and has designed five criteria layers: digital economy environment, digital industry development, digital infrastructure, industrial digital development and

digital innovation level. Each criterion layer is composed of specific indicators and contains a total of 31 secondary indicators, as shown in Table 1.

Table 1: Evaluation Index System of Digital Economy

| Target layer | Criteria layer | Symbols | Indicator layer |
|---|---|---|---|
| "One Belt, One Road" Digital Economy Development (Y) | Digital Economy Environment (F1) | X1 | Gross regional product |
| | | X2 | Gross regional product per capita |
| | | X3 | Gross Regional Product Index |
| | | X4 | Primary GDP Index |
| | | X5 | Secondary GDP Index |
| | | X6 | Tertiary GDP Index |
| | Digital Industry Development (F2) | X7 | Number of enterprises |
| | | X8 | Number of computers in use at the end of the period |
| | | X9 | Computers per 100 persons |
| | | X10 | Number of enterprises with websites |
| | | X11 | Number of websites per 100 enterprises |
| | | X12 | Number of enterprises with e-commerce transactions |
| | | X13 | Share of enterprises with e-commerce trading activities |
| | | X14 | E-commerce sales |
| | | X15 | E-commerce purchases |
| | Digital infrastructure (F3) | X16 | Internet broadband access ports |
| | | X17 | Mobile phone subscribers |
| | | X18 | Fixed-line telephone subscribers |
| | | X19 | Telephone penetration rate |
| | | X20 | Fixed-line penetration rate |
| | | X21 | Mobile Phone Penetration Rate |
| | Industry Digital Development (F4) | X22 | Number of Enterprise Units |
| | | X23 | Total Assets |
| | | X24 | Operating Income |
| | | X25 | Operating Costs |
| | | X26 | Total profit |
| | Level of digital innovation (F5) | X27 | Full-time equivalent of R&D personnel |
| | | X28 | Number of R&D projects |
| | | X29 | R&D project funding |
| | | X30 | Number of invention patent applications |
| | | X31 | Expenditure on digestion and absorption |

## 2.2. TOPSIS evaluation model based on the entropy and CRITIC methods

Entropy method is an objective weighting method. According to the entropy method to determine the weight, it can avoid the interference of human factors, and has more credibility than the subjective weighting method. The specific principle is as follows: it is assumed that the normalized data matrix is:

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

① Calculate the probability distribution values for each indicator:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{1}$$

② Calculating index entropy: Assuming that the entropy of the $jth$ index is defined as $e_j$, the entropy of the $jth$ evaluation index can be defined as:

$$e_j = -\frac{1}{\ln(m)} \sum_{i=1}^{m} p_{ij} \ln(p_{ij}) \tag{2}$$

③ Calculate information entropy redundancy:

$$d_j = 1 - e_j \tag{3}$$

④ Calculate the weight of each index by entropy method:

$$w_j = \frac{d_{ij}}{\sum_{j=1}^{n} d_{ij}} \tag{4}$$

CRITIC weighting method is a kind of objective weighting method, and its main idea is to use two indicators of contrast intensity and conflict to calculate the weight. Among them, the standard deviation is used to represent the contrast strength and the correlation coefficient is used to represent the conflict. If the correlation value between indicators is smaller, the conflict is greater, and the corresponding weight is higher. The specific principle is as follows: First, normalize the data matrix. On the one hand, the standard deviation $\sigma$ is used to express the comparability of $j$ indicators:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} (x_{ij}' - \overline{x_j'})}{m-1}} \tag{5}$$

On the other hand, let the size of the contradiction between indicator $j$ and the remaining indicators be $f_j$:

$$\mathrm{f_j} = \sum_{\mathrm{i=1}}^{\mathrm{m}} (1 - \mathrm{r_{ij}}) \tag{6}$$

Where $r_{ij}$ denotes the correlation coefficient between indicator $i$ and indicator $j$. Next, the information carrying capacity of indicator $j$ is calculated as $C_j$:

$$C_j = \sigma_j * f_j \tag{7}$$

Finally, the information carrying capacity of the indicators is normalized to obtain the CRITIC weights:

$$w_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{8}$$

Index empowerment is an important link in evaluating the development level of digital economy in cities along the Belt and Road. The rationality of weight determination can directly affect the rationality and accuracy of evaluation results [8-9]. Let the index weight vector calculated by the entropy method be $w_1$, and the weight vector calculated by the CRITIC method be $w_2$, the combination weight $w_k$ for the $kth$ indicator is calculated as follows.:

$$w_k = \frac{w_{1k} * w_{2k}}{\sum_{i=1}^{n} w_{1i} * w_{2i}}, i = 1,2,\cdots,n \tag{9}$$

The TOPSIS evaluation process is as follows: firstly, the dimensionless indicator data standardization matrix $B_{mn} = \{b_{ij}\}_{m\times n}$ is multiplied with the combined weight vector $w = [w_1, w_2, \cdots, w_n]$ to obtain the weighted standardization decision matrix $R_{mn} = \{r_{ij}\}_{m\times n}$.

$$r_{ij} = w_j \times b_{ij} \tag{10}$$

Then compute the optimal solution vector $X^+ = (r_1^+, r_2^+, \cdots, r_n^+)$ and the worst solution vector $X^- = (r_1^-, r_2^-, \cdots, r_n^-)$, where $r_j^+ = \max_i\{r_i^+\}$, $r_j^- = \max_i\{r_i^-\}$, And $i = 1,2,\cdots,m, j = 1,2,\cdots,n$. Then the distances $d^+$ and $d^-$ of the normalised decision vectors to the optimal and inferior solutions weighted by the sample assessment metrics were calculated as follows:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(r_j^+ - r_{ij})^2}, d_i^- = \sqrt{\sum_{j=1}^{n}(r_j^- - r_{ij})^2} \tag{11}$$

Finally, the relative closeness degree between the evaluation value vector of each sample indicator and the optimal solution $D_i$ is calculated, which is used as the evaluation comprehensive value $y_i$.

$$D_i = \frac{d_i^-}{d_i^- + d_i^+} = y_i \tag{12}$$

$y_i$ is the comprehensive evaluation score of each evaluation object. The larger the value of $y_i$, the higher the development level of digital economy in the region; Conversely, the lower the level of digital economy development.

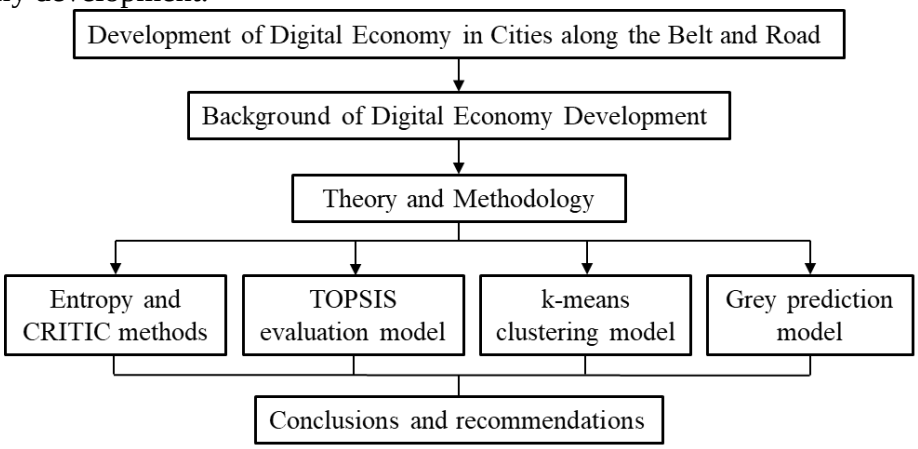


Figure 1: The flow chart

The main content of this study is to evaluate the development level of digital economy in cities along the Belt and Road in China. First of all, the literature method is used to make relevant analysis, sort out and summarize the theory, and analyze the overall situation of the cities along the "one belt and one road". On this basis, the evaluation model of the digital economy development of the cities along the Belt and Road is established, and an empirical study is carried out. Finally, some suggestions are put forward. The specific technical route is shown in Figure 1.

## 3. Evaluation of digital economy development in cities along the Belt and Road

### 3.1. Data source and processing

This paper selected 18 cities along China's "One Belt and One Road" from 2013 to 2020 as the research objects to analyze and predict their digital economic development level. The data collected are directly or indirectly from China Statistical Yearbook (2013-2020), CSMAR, and China Economic and Social Development Statistical Database. The normalization method used is as follows:

For the negative index, make:

$$x_{ij}^{*} = \frac{x_{ij} - \min\{x_{1j},\cdots,x_{mj}\}}{\max\{x_{1j},\cdots,x_{mj}\} - \min\{x_{1j},\cdots,x_{mj}\}} \quad (13)$$

For positive indicators, make:

$$x_{ij}^{*} = \frac{\max\{x_{1j},\cdots,x_{mj}\} - x_{ij}}{\max\{x_{1j},\cdots,x_{mj}\} - \min\{x_{1j},\cdots,x_{mj}\}} \quad (14)$$

### 3.2. The calculation of weight coefficient of digital economy index in each region

After determining the index system for measuring the development level of digital economy, entropy method and critic weight method are used to comprehensively weight all indicators of 18 regions from 2013 to 2020. The specific results are shown in Table 2 and Figure 2:

Table 2: Index weights at all levels

| Indicators | Entropy method | Critic method | Combined weighting | Indicators | Entropy method | Critic method | Combined weighting |
|---|---|---|---|---|---|---|---|
| X1 | 0.020 | 0.028 | 0.019 | X17 | 0.038 | 0.022 | 0.028 |
| X2 | 0.012 | 0.031 | 0.013 | X18 | 0.044 | 0.022 | 0.034 |
| X3 | 0.002 | 0.021 | 0.001 | X19 | 0.117 | 0.025 | 0.100 |
| X4 | 0.001 | 0.023 | 0.001 | X20 | 0.009 | 0.041 | 0.012 |
| X5 | 0.002 | 0.022 | 0.001 | X21 | 0.005 | 0.023 | 0.004 |
| X6 | 0.003 | 0.021 | 0.002 | X22 | 0.032 | 0.038 | 0.040 |
| X7 | 0.027 | 0.030 | 0.028 | X23 | 0.018 | 0.029 | 0.018 |
| X8 | 0.033 | 0.028 | 0.031 | X24 | 0.025 | 0.035 | 0.030 |
| X9 | 0.011 | 0.039 | 0.014 | X25 | 0.002 | 0.098 | 0.008 |
| X10 | 0.033 | 0.032 | 0.035 | X26 | 0.015 | 0.033 | 0.017 |
| X11 | 0.003 | 0.038 | 0.004 | X27 | 0.065 | 0.027 | 0.060 |
| X12 | 0.037 | 0.032 | 0.040 | X28 | 0.056 | 0.022 | 0.042 |
| X13 | 0.007 | 0.052 | 0.013 | X29 | 0.068 | 0.026 | 0.060 |
| X14 | 0.046 | 0.031 | 0.049 | X30 | 0.083 | 0.026 | 0.073 |
| X15 | 0.050 | 0.028 | 0.048 | X31 | 0.066 | 0.024 | 0.053 |
| X16 | 0.071 | 0.051 | 0.122 | -- | -- | -- | -- |

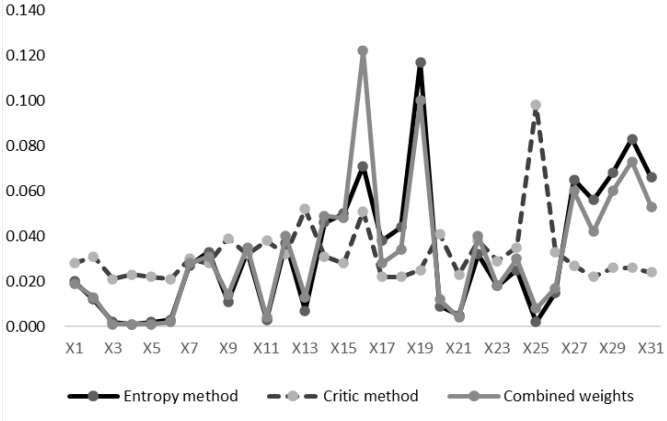


Figure 2: Index weights at all levels

The calculation results in Table 2 show that according to the combined weights, the weights of digital economic environment, digital industry development, digital infrastructure, industrial digital development and digital innovation level are 0.038, 0.263, 0.300, 0.113 and 0.286 respectively.

Digital industry development and digital infrastructure have a greater impact on the level of regional digital economy. Among the second-level indicators, R&D project funds, full-time equivalent of R&D personnel, number of invention patent applications, telephone penetration rate and Internet broadband access port have higher weights, indicating that telephone penetration rate and Internet broadband access port are the main influencing factors of regional digital economy development. At the same time, it is also very important to increase the R&D project funds, the full-time equivalent of R&D personnel and the number of invention patent applications.

### 3.3. Digital economy development level cluster analysis

Based on comprehensive empowerment method to confirm the influence degree of each index of digital economy, using TOPSIS model to determine the ideal solution and negative ideal solution of each index by each region and the ideal solution and negative ideal solution for the Euclidean distance, to determine the relative closeness of regions and the ideal solution, and according to the sort of area, to determine its level of economic development. And the K-means clustering method is used to further explore the regional characteristics of the digital economy development level of cities along the "Belt and Road". Specific classification results are shown in Figure 3.

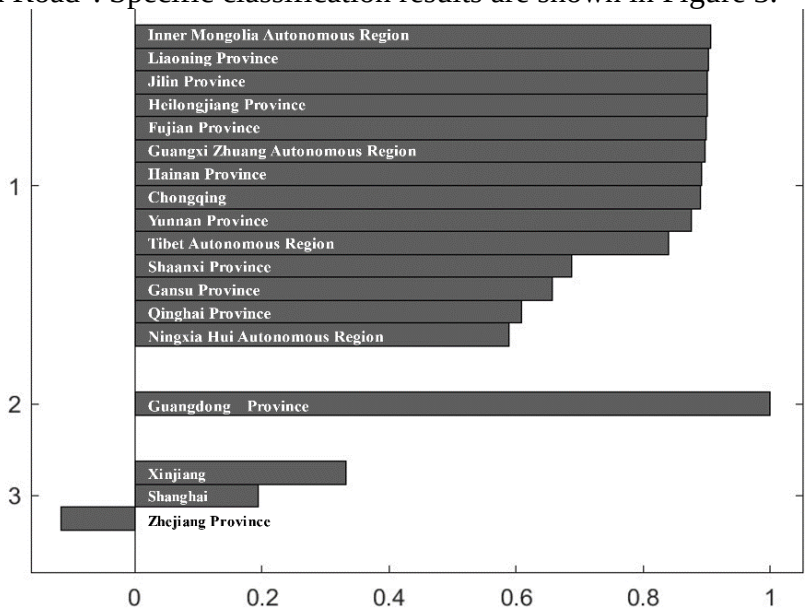


Figure 3: Cluster map of digital economy development levels

According to the clustering results, the 18 regions can be divided into three categories. The first category: cities with a high level of digital economy development. Including Guangdong Province, the economic level of this region is relatively developed. The second category: cities with medium level of digital economy development. Including Shanghai. The third category: cities with a low level of digital economy development, including Fujian Province, Guangxi Zhuang Autonomous Region, Chongqing Municipality, Shaanxi Province, etc. From the perspective of spatial distribution, the digital economy development of cities along the "Belt and Road" shows a certain spatial agglomeration phenomenon. The digital economy level of coastal areas, such as Shanghai, Guangdong and Zhejiang, is higher than the overall average. The digital economy of other cities develops slowly, but their development level is relatively balanced.

### 3.4. Digital economy development level forecast

The GM(1,1) model was used to predict the digital economy level of each city along the route in

2021, and some of the results are shown in Figure 4. The digital economy level in Fujian Province in 2021 predicted by the GM(1,1) model is 0.158, an increase of 8.97% compared to 2020; the digital economy level in Chongqing City in 2021 is 0.098, an increase of 7.69% compared to 2020; the digital economy level in Guangxi in 2021 is 0.063, an increase of 3.17% compared to 2020; Shaanxi Province The digital economy level in 2021 is 0.094, an increase of 8.05% compared to 2020; the digital economy level in Shanghai in 2021 is 0.231, an increase of 0.87% compared to 2020, and the digital economy level in Guangdong Province in 2021 is 0.586, an increase of 11.20% compared to 2020.

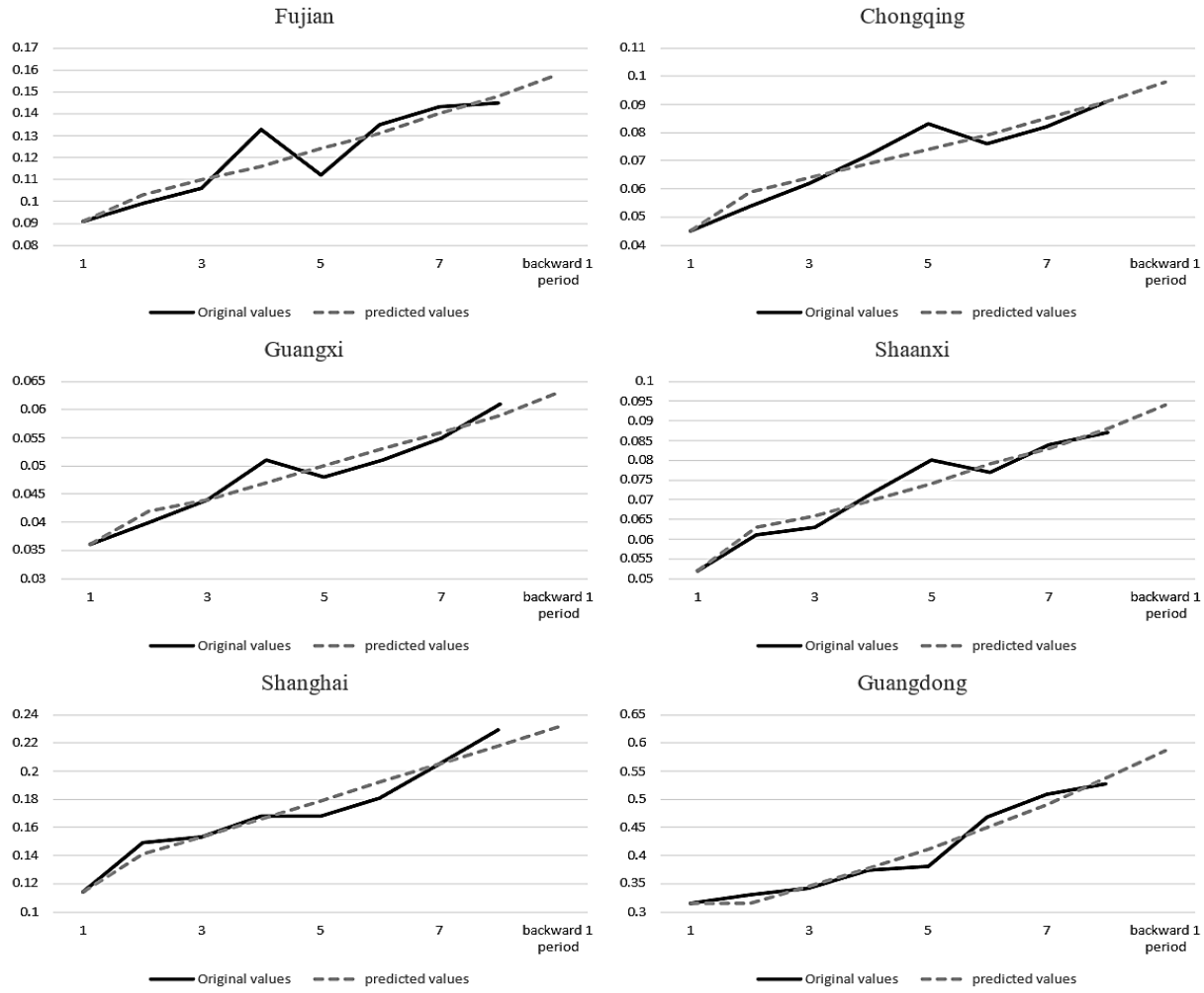


Figure 4: Model fitting and prediction

It reflects that the digital economy of the cities along the "Belt and Road" in China is in the growth stage in 2020. Due to the abundant resources of network infrastructure, innovative talents and communication technology, the digital economy in coastal areas has developed rapidly. The infrastructure and economic environment of digital economy in other regions are relatively slow, which is mainly due to the imbalance of regional development and other reasons.

## 4. Conclusions and Suggestions

In the research of this paper, combined with entropy and CRITIC method, we find that all indicators have significant contributions to the development of digital economy in different regions, among which the development of digital industry, digital infrastructure and digital innovation level

play a relatively important role in the development of digital economy. With the continuous improvement of their attention to the development of digital economy, further vigorously develop the carrier of digital economy, improve the level of digital industry and strengthen the innovation environment of digital economy, make up for the imbalance of regional development, the development of digital economy along the "Belt and Road" cities will have great potential. Based on the above research and analysis, the suggestions for improving the development of digital economy in cities along the Belt and Road are as follows:

(1) Vigorously develop the carrier of digital economy. The carrier of digital economy is the cornerstone of the development of digital industry and the integration of digital industry. Only by vigorously developing the carrier of digital economy can we better promote the development of digital economy, and then improve the depth and breadth of digital economy and industry, and give full play to its role.

(2) Improve the level of digital industry. In order to realize the deep integration of digital economy and industry, it is necessary to further enhance the role of digital economy in high-quality economic development. The coordinated improvement of quantity and quality is the guarantee for the development of digital economy.

(3) Strengthening the environment for innovation in the digital economy. The innovation environment of digital economy is conducive to further expand the application field of digital economy and promote the integration of digital economy and traditional industries. Therefore, it is particularly important to increase the R&D project funds, the full-time equivalent of R&D personnel and the number of invention patent applications.

(4) Coordinating regional development. Regional balanced development is an important link of sustainable development of digital economy. Only by giving full play to the role of diffusion among regions and carrying out extensive cross-regional exchanges of professional talents can we better promote the development of digital economy in various regions and make the development among regions more balanced.

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