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Model Prediction and Empirical Analysis of China's Higher Education

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Abstract

The level of development of higher education determines the comprehensive strength of a country and is related to all aspects of society. The establishment of the higher education system depends on the country's economic development. In order to in-depth study of China's future education development level and constraints, this article first extracted 14 data indicators from three aspects of education input, education output and education process, and established a multi-dimensional higher education evaluation system. We choose China for in-depth analysis, including a time series model based on the Holt_Winter exponential smoothing method, forecasting the development of higher education in China in the next 15 years, and establishing a BP neural network model to evaluate policy effects. Finally, we found that the application of the model is very common, but it is actually difficult to reform.

Keywords

Holt_Winter's exponential smoothing method; BP neural network model; Higher education system.

1. Introduction

With the development and progress of science and technology in the world and the continuous improvement of human culture, people gradually realize that the higher education system plays a vital role in the development of the national economy and even the development of the whole society. With the advent of the era of universal higher education, strengthening the quality assurance of higher education has become the core of the development policy of higher education in all countries (regions). The establishment of a universal teaching quality model as an important part of higher education quality assurance is the focus of global higher education reform [1]. Western developed countries, such as the United States, are leading the world in higher education. There are abundant researches on the evaluation of the development quality of higher education. Through continuous exploration, higher education quality evaluation standards and testing systems have been established one after another. In the United States, the "National Student Participation Survey" method of education quality evaluation is proposed to evaluate the teaching quality standards of universities [2].

2. Basic Assumptions

In order to simplify the problem and solve the problem better, we put forward reasonable assumptions. Each of our assumptions is true and consistent with the basic facts: (i) assume that only to study the current situation of higher education, excluding population factors, primary education and other effects on higher education; (ii) assume that the obtained data can outline the overall situation of the country and provide scientific and accurate data; (iii) assume that the model does not consider the influence of personal factors such as educational preferences on higher education; (iv) assume that the model does not consider the impact of

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wars and plagues on higher education; (v) assume that the future economy of the country where the model is applied will grow steadily in order to ensure uninterrupted implementation of reform policies;

3. Time Series Model Based on Holt-Winter Exponential Smoothing Method.

3.1. Analysis Approach

Holt-Winter exponential smoothing method, also known as Holt linear trend method, is a function model that takes independent variable and dependent variable as time[3-4]. The Holt-Winter exponential smoothing method is composed of exponential weighted average, with high calculation accuracy and convenience, and is mainly used for trend prediction decomposition model of linear time series data [9]. In this paper, the exponential smoothing method is mainly used to establish the relevant time series model. Since the historical data are not seasonal, the non-seasonal Holt exponential smoothing method is used.

3.2. Model Building

Firstly, we establish the basic formula of Holt - Winter exponential smoothing.

$$T_t = \alpha x_t + (1-\alpha)(T_{t-1} + b_{t-1}) \tag{1}$$

$$b_t = \beta(T_t - T_{t-1}) + (1-\beta)b_{t-1} \tag{2}$$

Among them, x_t is the estimated value of cycle t benchmark calculated from the current cycle. T_{t-1} is the trend value of the previous estimation and $T_{t-1} + b_{t-1}$ is the benchmark estimated value of cycle t based on the previous data.

From the data, the increment of smoothing benchmark from period t-1 to period t is obtained and the trend is estimated from the current period. The prediction formula is as follows:

$$E_{t+k} = T_t + kb_t \tag{3}$$

Where, $k \geq 1$, t is the current period. k is the prediction step. α and β are the smoothing constants, and $0 < \alpha, \beta < 1$. T_t is the estimation of the trend of period t using the data of period t. b_t, b_{t-1} is the estimation of trend increment b using the data of previous t period or previous t-1 period. x_t is the actual observation value of phase t and E_{t+k} is the predicted value of phase $t+k$ using the data of previous phase t.

3.3. Results and Analysis

We used SPSS software to process the data and established a time series model through Holt-Winter index smoothing method to predict the changes of the health degree of China's higher education system in the next 15 years. The predicted results are as follows:

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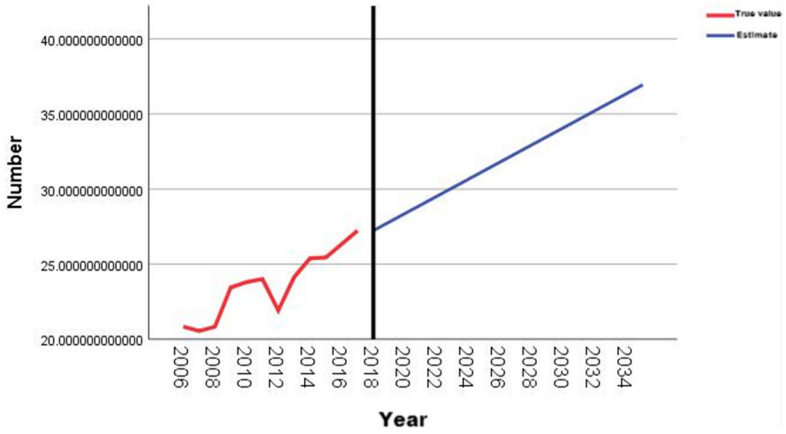

Figure 1. Time series prediction of Holt-Winter exponential smoothing method

As can be seen from the above figure, the overall score of China's higher education system has been on the rise from 2006 to 2018, with some fluctuations. According to the model, the score of China's higher education system will increase year by year in the future. China's higher education system will be healthier and healthier if the current policies and conditions of higher education are maintained.

Based on the time series model of Holt-Winter index smoothing method, we predict the grading of China's higher education system in the next 15 years or so. Among them, the score of China's higher education system is likely to be 29.5197 in 2022, 30.0903 in 2023, and 36.9388 in 2035, which is likely to reach the development height of the higher education system of developed countries. However, the current higher education system in China is in a less healthy state, so targeted policies are needed to promote the development of higher education in China.

From the time series forecast chart, we can see that from 2006 to the middle of 2017, the score of China's higher education system rose slowly at first, but there was a significant decline in 2012, and then it rose rapidly again. We find that in the seventh year of its development, China's higher education system may encounter a bottleneck. That is, around 2024, current policies will no longer meet the needs of China's higher education development. Therefore, before 2024, the Chinese government needs to optimize the current higher education system and issue new policies and regulations to promote the sustainable and healthy development of the higher education system.

4. Evaluation of Policy Effects Based on BP Neural Network Model

4.1. BP Neural Network Model

4.1.1. Analysis Approach

BP neural network is a kind of multi-layer feedforward neural network, including input layer, output layer and hidden layer [5-6]. The basic principle is to use gradient descent method to adjust weights and thresholds, so as to minimize the mean square error of actual output and expected output. The objective function is defined as:

$$J = \frac{1}{2}\sum_{p=1}^{N}\sum_{k=1}^{m}\left(y_k^p - O_k^p\right)^2 \tag{4}$$

Among them, O_k^p is the output of the output node under the action of the sample. y_k^p is the target value of the output node under the action of the sample. m is the dimension of the output variable and N is the number of training samples.

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4.1.2. Model Building

Firstly, the network input node number n, hidden layer node number l, output layer node number m, connection weights ω_{ij}, $\omega_{jk}^{'}$ between input layer and hidden layer, hidden layer and output layer neurons are determined. The threshold value of hidden layer is $a=[a_1,a_2,\cdots,a_l]$, and that of output layer is $b=[b_1,b_2,\cdots,b_m]$. Then, the hidden layer output h_j is calculated:

$$h_j = f\left(\sum_{i=1}^{n}\omega_{ij}x_i - a_j\right), \qquad j=1,2,\cdots,l \tag{5}$$

Among them, f is the excitation function of the hidden layer and x_i is the variable of the $i-$th input node.

Calculation output layer o_k:

$$o_k = \sum_{j=1}^{l} h_j\omega_{jk}^{'} - b_k, \qquad k=1,2,\cdots,l \tag{6}$$

Weight update:

$$w_{ij}(t+1) = \omega_{ij}(t) + \eta[(1-\beta)D(t) + \beta D(t-1)], \qquad i=1,2,\cdots,n \tag{7}$$

$$w_{jk}^{'}(t+1) = w_{jk}^{'}(t) + \eta[(1-\beta)D^{'}(t) + \beta D^{'}(t-1)] \tag{8}$$

Among them, η is the learning rate, $\eta>0$, $D(t)=-\partial J/\partial\omega_{ij}(t)$, $D^{'}(t)=-\partial J/\partial\omega_{jk}^{'}(t)$. β is the momentum factor, $0\le\beta<1$.

a_j and b_k are updated according to the error between network output o_k and expected output y_k.

$$a_j(t+1) = a_j(t) + \eta h_j(1-h_j)\sum_{k=1}^{m}\omega_{jk}^{'}(y_k - O_k) \tag{9}$$

$$b_k(t+1) = b_k(t) + (y_k - O_k) \tag{10}$$

Judge whether the algorithm has finished the iteration, if not, return the iteration.

4.1.3. Model Results

The data of 14 indicators in China from 2006 to 2017 are selected to test the comprehensive evaluation scores obtained from the above principal component analysis to verify the effectiveness of the model. The data from 2006 to 2010 are taken as the training set and the data from 2016 to 2017 as the test set. The training times are set as 5000 times, the learning rate is 0.01, and the parameters are constantly adjusted. Finally, 2 input nodes, 5 hidden layer nodes and 1 output node of the model are obtained. MATLAB software is used to establish BP neural network model and the obtained test results are shown in the figure below:

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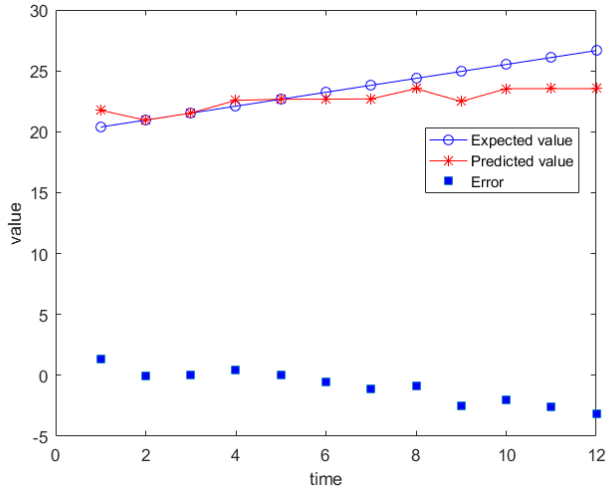

Figure 2. BP neural network network model error diagram

As can be seen from the above figure, the difference between the predicted value and the real value of the model is small. The overall error is small, too. So, the test effect is good.

4.2. The Impact of Policy Implementation and the Difficulty of Change

According to the time series model of the Holt-Winter index smoothing method ,2023-2024 is the transition period of policy implementation and after 2024 is the final stage. Higher education is related to the national economy and people's livelihood, and determines the comprehensive national strength of a country. The implementation of the policy will have a huge effect on the following:

China is a big country in higher education, but it has not yet become a powerful country in higher education. At present, there are still some problems in China, such as imperfect education structure, insufficient investment in education, little achievements in discipline construction, weak international competitiveness and so on. The contradiction in the development of China's higher education lies in the contradiction between the people's desire for high-quality higher education and their unbalanced, inadequate and incomplete development [7]. The training system of China's higher education still needs to be constantly improved, the policies keep pace with the times, there is still room for progress, and the road of education reform is still far away.

5. Conclusions

Since by selecting the specific data of the above 14 indicators from 2006 to 2017 in China and using principal component analysis method, the comprehensive evaluation score of each year is obtained, which shows that the situation of China's higher education system fluctuates slightly from 2006 to 2017, but the overall higher education system is constantly improving.According to the score of principal component analysis, the Holt-Winter index smoothing time series model is used to make the fitting prediction of the data from 2006 to 2017 and the development trend of China's higher education system in the next 15 years is obtained [8]. The conclusion is that China will continue to improve its higher education system in the future and continue to narrow the gap with countries with top higher education systems. In consideration of China's special national conditions, we analyze the population, economy, government and other aspects, and propose reasonable policies to reduce the obstacles on the road to improve China's higher education system [9].

In order to test the effectiveness of the above policy proposals, we used BP neural network to verify the data of China from 2006 to 2017. The verification results showed that the average

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absolute error was only 0.048944, indicating that the training results of the model were good, so the principal component analysis score was reliable and the reasonable policy proposed was effective [10]. In the future, China should increase the investment of higher education funds, promote the improvement of higher education quality, train the new generation of talents and form a healthy and sustainable higher education system.

6. Data Availability

The data in this paper come from Question F of the 2021 American College Students Mathematical Modeling Competition and the statistics of the World Bank.

7. Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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