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Prediction of Aging Degree Based on Holt Linear Trend and BP Neural Network

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ABSTRACT. *The change of population age structure is related to all aspects of the development of social production in China. It is beneficial to the adjustment of industrial structure and the construction of social security system by predicting the development of aging population in China. In order to predict the change of aging degree in China, based on the data of population aging in China from 1990 to 2018, using SPSS, MATLAB, Excel and other software, the paper forecasts the population aging degree from 2019 to 2023 by constructing Holt linear trend and BP neural network model. The model established by the model is tested, and the error analysis of the prediction results shows that the reliability of the prediction is high. Finally, according to the prediction of aging changes, the paper puts forward corresponding suggestions for the adjustment of industrial structure and the construction of social security system.*

KEYWORDS: *Holt linear trend; BP neural network; Population aging; Age structure*

1. Introduction

The age structure of population is one of the factors that affect the adjustment of industrial structure, and it is also the main basis for the construction of social security system. Since 2000, the proportion of 65 year old population in the age structure of population in China has exceeded 7% of the total population, reaching the standard of population aging. The aging degree of China's population still keeps increasing. Until 2018, the aging degree of China's population reached 11.9%. The advantage of "population dividend" has been gradually disappearing. At the same time, with the increasing of the aging population, it brings great challenges to the adjustment of industrial structure and the construction of social security system. Therefore, by predicting the trend of population aging in the future, it has a profound guiding significance for the direction of industrial structure adjustment and the scale of social security system construction in the future.

Since China entered the aging society, many scholars in China have studied the degree of aging in China: Zhou Maojun (2018) used the combination of logistic

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model and grey Markov model to predict the trend of aging in Anhui Province, and predicted the degree of aging in the future through comparative analysis [1]. Yang meng-ran (2019) used GM (1:1) model to predict the trend of population aging in Shanghai, and according to the predicted results, gave corresponding suggestions [2]. Chen Tai-chang (2019) analyzed the challenges and opportunities brought by aging to China's development by using the prediction data of the United Nations on population aging, and put forward countermeasures in combination with the goal of socialist construction [3]. Huqian (2019) empirically analyzed the supply effect of population aging in China based on the provincial panel data, and further found the impact of population aging on China's social development [4]. From the existing research literature, most of the prediction models for the trend of population aging have large errors or lack of comparative research, and the impact of population aging is not specifically combined with the data of their own prediction, which has a certain subjectivity. Therefore, this paper combined with the actual aging index data to predict the future trend of population aging in China, and made corresponding suggestions on the impact of aging.

2. Index establishment and current situation analysis

In order to study the development and change of the aging population in China, this paper obtains the data of the proportion of the population over 65 years old in the total population from the wind database in 1990-2018 as the index data to measure the development and change of the aging population. The change of the aging degree of China's population every year is shown in Figure 1. It can be seen from the figure that the aging degree of China's population shows a linear trend of increasing year by year, which also reflects that China's population structure is undergoing a huge change, and the aging situation is constantly increasing. China is in the stage of population aging, and the degree of aging is deepening, which has a huge impact on the future social development and the construction of the pension industry. As the country with the largest population in the world, the change of population age structure is related to all aspects of economic and social development. It is of great significance for China's economic development to build a reasonable index of population age structure and predict the change of population age structure in the next few years through the study of China's historical population data. At the same time, the prediction of population age structure and the degree of aging in China is also of great significance for the direction of industrial structure adjustment.

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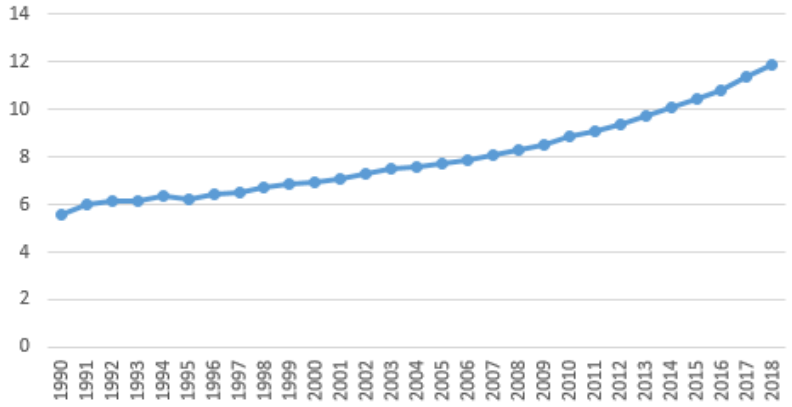

Figure 1. Changes of population aging

3. Prediction of aging degree based on Holt linear trend

3.1. Research ideas

In order to predict the change of the aging degree of population in China in the future. It can be seen from the change data of China's population aging that, because the degree of China's population aging presents linear change and there is no seasonal non-stationary change, it is more appropriate to use Holt linear trend model of exponential smoothing method for prediction in this paper. In this paper, SPSS software is used for descriptive analysis of the data, and then the exponential smoothing prediction formula is constructed. Finally, according to the linear characteristics of the data, the data is substituted into the prediction formula, and the change of the aging degree of the population in the next few years is obtained through the software.

3.2. Research methods

The Holt linear trend model of exponential smoothing method is applicable to the time series data with obvious linear trend but without seasonal component by predicting the change situation after the change trend of the original data [5]. The model is composed of forecasting formula and smoothing formula, in which smoothing formula reflects the linear smoothing information and the changing trend after smoothing. The specific formula is as follows:

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$$\hat{Y}_{t-k} = F_t + hb_t \quad (1)$$

$$F_t = aY_t + (1-a)(F_{t-1} + b_{t-1}) \quad (2)$$

$$b_t = \beta(F_t - F_{t-1}) + (1-\beta)b_{t-1} \quad (3)$$

Among them, formula 1 is the prediction formula, formula 2 and formula 3 are the linear smoothing and incremental smoothing formulas respectively, which are the smoothing coefficients when the mean square error between the predicted value and the observed value is the smallest and the value is between 0 and 1.

3.3. result analysis

3.3.1 significance test of the model

Before using the prediction structure of the exponential smooth Holt linear trend model for analysis, the prediction model needs to be tested. The model test results are obtained by solving the model with spss.23 software, as shown in Table 1. It can be found from the table that the R-square of the model in terms of goodness of fit is 0.995, and the fitting effect is good. In terms of autocorrelation test of model residual, Q statistic is 8.786, P value is 0.922, which rejects the original hypothesis, so it can be determined that there is no autocorrelation of model residual, and it also shows that the model is effective.

Table 1. Statistics of Holt linear model

Model	Number of forecast variables	Model fit statistics		Yang boks Q(18)			Outliers
		Stationary R party	R party	Statistics	DF	Saliency	
Holt linear trend	0	0.404	0.995	8.786	16	0.922	0

3.3.2 prediction results of the model

After checking the established model, it is proved that the established model is effective, and then it can be predicted according to the established model. Using SPSS software, the results of forecasting the degree of population aging in 2019-2023 are 12.41%, 12.94%, 13.47%, 14%, 14.53% respectively. The specific model fitting prediction effect is shown in Figure 2. It can be seen from the figure that the fitting effect of the observed value and the predicted value of the model is good, and the fitted values fall within the prediction interval of two dashed lines, indicating that the fitted predicted value is more accurate. According to the

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prediction results, the trend of population aging in China is showing a linear change with a rapid growth rate [6]. From the long-term change results, the aging degree of China's population deepened from the initial 6.25% to 14.53% in the next few years. The degree of aging has been deepening with the passage of time. Due to the population base effect, the speed of population aging in recent years is obviously faster than that in previous years.

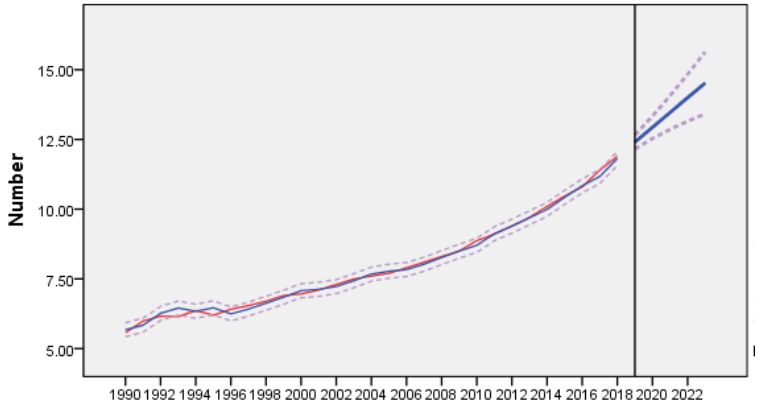

Figure 2. model prediction effect fitting diagram

4. Prediction of aging degree based on BP neural network

4.1. research ideas

Firstly, the aging degree data obtained in wind database is normalized, and the lag order set by the model is determined by difference. In order to avoid over fitting and dividing training, the proportion of test and validation data is 70%, 15% and 15%, respectively. Take 70% of the data as input variables and 15% as output variables. According to the calculation formula of hidden layer neurons and the principle of minimum mean square deviation, the number of hidden layer neurons is set, and the parameter form of the model is determined by continuous training. Then MATLAB is used to solve the problem, and the validity of the model is tested according to the autocorrelation of the model error and the fitting effect, then the reliability of the prediction result is determined.

4.2. research methods

BP neural network model includes three layers: input layer, hidden layer and output layer. The specific model structure is shown in Figure 3. The basic idea of the model operation is to train according to the tutor learning mode, so as to provide a learning mode to the network. The activation value of the neuron is then transmitted

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through the input layer and the hidden layer to the output layer, and then the response value is output. At the same time, in order to reduce the error between the expected output and the actual output, the model will continuously modify the weights of each hidden layer to improve the accuracy of the model output results [7]. Suppose the input sample of aging degree is x, the output sample data is y, the input of hidden layer is k, the weight between input layer and hidden layer is p, the weight between hidden layer and output layer is w, the output matrix is Q, and the excitation function of the model is sigmoid function

$$S(n) = \frac{1}{1+e^{-n}}$$

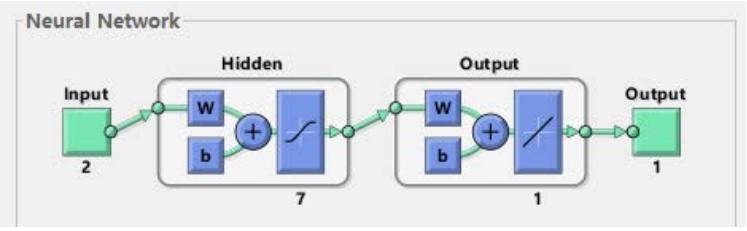

Figure 3. structure of the model

4.3. prediction process analysis

4.3.1. model structure and parameter setting

In this paper, there are two neurons in the input layer and one in the output layer. The solution formula for the number of hidden neurons is as follows:

$$Q = \sqrt{n+m} + a$$

Where n is the number of neurons in the input layer, M is the number of neurons in the output layer, which is a constant between 1 and 10 [8]. According to the limited range, by changing the number of hidden neurons and training repeatedly, according to the principle of minimum error, it is found that when the number of hidden neurons is 8, the relative error of the model is the minimum. The specific training effect is shown in Figure 4. According to the toolbox training results of neural network, when epoch = 8, the minimum mean square error is achieved, and the prediction effect of neural network is also optimized.

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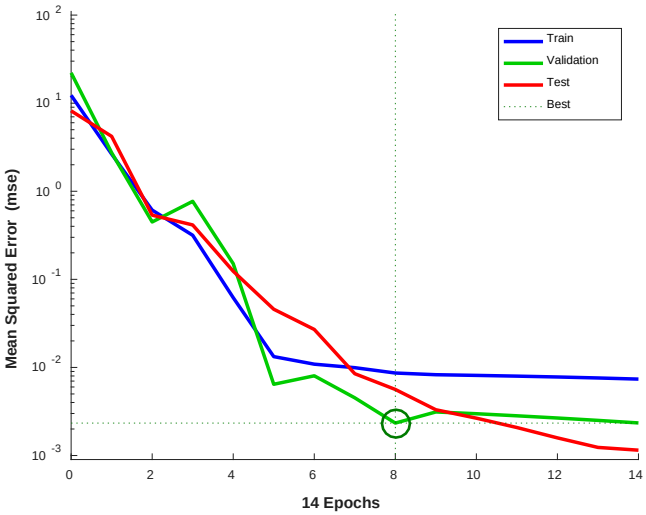

Fig. 4. mean square error

4.3.2. model inspection

The fitting effect of training data, validation data and test data of the model is shown in Figure 5. From the fitting effect chart, it can be seen that the fitting effect of the model is good [9]. The value of training data is 0.99872, and the value of verification data and test data are greater than 0.99. It shows that the model can be used to predict the change and development of aging degree in China in the future. At the same time, the fitting effect of the model is better for the general large amount of historical data. Through repeated training and Simulation of a large number of aging data in China, the model can accurately fit the change of aging degree in China in the next few years.

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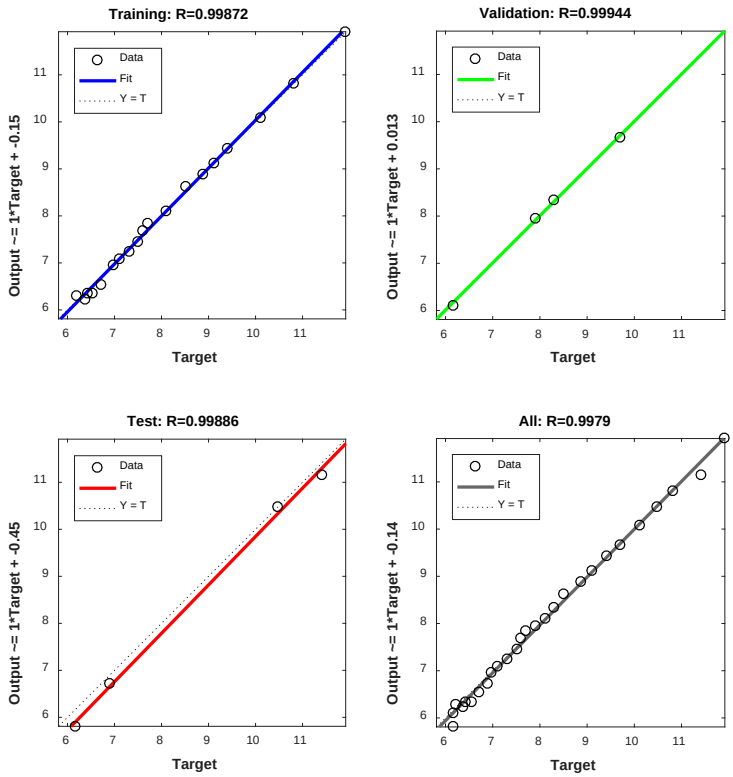

Figure 5. fitting effect of the model

4.4 predicted results

By setting the parameters of the model and checking the model, we can find that the prediction effect of the model is better. The relative error of model prediction is shown in Table 2. It can be seen from the relative error table that the maximum relative error between the real value of the model and the predicted value is 0.02097, and the average relative error is 0.0062. Based on the model, the degree of population aging in 2019-2023 is predicted to be 12.46%, 13.20%, 13.97%, 14.27% and 14.42%. It can be found that in the next five years, the degree of population aging will be further deepened, and there will be a further deepening trend in the future. Therefore, in the future, our country should adjust the industrial policy according to the change of population aging, take measures to deal with the problems of aging society in time, raise the corresponding wage level to deal with the current situation of effective labor population reduction, reduce the dependence on a large number of labor force and improve the degree of machine replacing population by increasing the innovation of industrial technology. China should give

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full play to the advantages of artificial intelligence industry and use it in all aspects of our life.

Table 2 relative error of model prediction

Particular year	True value%	Neural network prediction value%	relative error
2001	7.1	7.0981	0.000267606
2002	7.3	7.2418	0.007972603
2003	7.5	7.4621	0.005053333
2004	7.6	7.688	0.011578947
2005	7.7	7.8461	0.018974026
2006	7.9	7.9542	0.006860759
2007	8.1	8.1085	0.001049383
2008	8.3	8.3463	0.005578313
2009	8.5	8.6192	0.014023529
2010	8.87	8.8969	0.003032694
2011	9.1	9.1302	0.003318681
2012	9.4	9.4481	0.005117021
2013	9.7	9.6616	0.003958763
2014	10.1	10.0928	0.000712871
2015	10.47	10.4737	0.000353391
2016	10.8	10.8218	0.002018519
2017	11.4	11.1609	0.020973684
2018	11.9	11.9176	0.001478992

5. Conclusions and suggestions

According to the prediction results of the index smooth Holt linear trend model and BP neural network model, we can see that the prediction results of the two models are similar, and the degree of aging in China will be further intensified in the next five years. From the prediction accuracy of BP neural network, it can be seen that the prediction accuracy of the model increases with the time trend, and the prediction reliability is high. According to the prediction results of the model, the following suggestions and countermeasures are put forward for China to deal with the challenges of aging in the future.

1. Optimize industrial structure, accelerate technological progress and reduce labor-intensive industries. As the trend of population aging is increasing, and the cycle is longer. Therefore, the industrial structure of our country also needs to be adjusted accordingly. For the labor-intensive industry, we need to upgrade the industry, introduce new and high technology, improve the production efficiency and labor efficiency, and less rely on the labor force excessively.

2. Adjust the scale of the pension system according to the change of the aging degree. With the increasing of aging, the pension system needs to be improved.

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Therefore, the coverage and the scale of social endowment insurance need to be further expanded. At the same time, we need to establish and improve the nursing security system for some empty nesters, and give full play to the role of the government and social assistance. In response to the further aggravation of the aging society, we need to establish and improve the pension industry, and form a complete pension industry service security system.

3. Timely adjust the trend of population aging and optimize social welfare policies. On the one hand, we need the government to actively issue corresponding policies, introduce incentive surplus policies, and provide basic guarantee for the families of children from the aspects of medical treatment and education. On the other hand, enterprises need to provide sufficient lactation period and corresponding economic subsidies for employees. Only by adjusting both the government and the society can we effectively alleviate the problem of the aging population. By promoting the increase of new population, social production can be continued and innovation and development vitality can be shown.

4. To strengthen the construction of industrial facilities for the elderly, the current aging level in China will not be alleviated in a short time. Facing a large number of elderly population, the demand for pension products and facilities is huge. China should increase investment in the pension industry. If we can not meet the needs of our country's pension in time, it will cause huge social chaos. At the same time, we should further improve our pension model, establish and improve our pension insurance and medical insurance, so that our aging population can get effective care and nursing.

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