Forecast of China’s average annual economic growth rate based on BP neural network

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Abstract. With the continuous development of China’s economy, the influence of financial factors on China’s economy continues to deepen. In recent years, economic development has been more stable, and the average annual growth rate has slowed down. However, the impact of financial factors of China is mostly qualitative analysis, and only few reasonable mathematical models are used in this field. This paper uses BP neural network to establish a nonlinear model of China’s annual economic growth rate and financial factors to analyze the current average annual economic growth rate, which provides effective guidance for China’s future development strategy.

1. Introduction
Finance is an economic activity with the purpose of using currency as a symbol and to increase the value of money through currency integration. It includes indirect investment and financing centered on banks and direct investment and financing centered on investment banks. The rapid development of the financial industry maintains a close relationship with the growth of the economy. For China, there is a bidirectional causal relationship between the development of finance and the growth of the economy [1].

According to the "A series of reports on China's economic and social development achievements during the 70th anniversary of the founding of New China" issued by the National Bureau of Statistics, from 1979 to 2018, the average annual growth rate of China's economy reached 9.4%. From 2017 to 2019, the average annual growth rate is 6.9%, 8.1%, and 6.1%, which are lower than the high-speed growth period of 1978-2008 (the average growth rate is 9.8%). In 1996, Wang Guangqian proposed the development of finance to the modern economy: The role of finance in the increase in the input of factors (labor and capital), the role of finance in the increase in factor productivity, and the role of changes in the proportion of the financial industry's own output value in the total economy. Qualitative analysis of the overall contribution of finance to economic growth from the above three aspects [2]. In 2015, Zhou Decai proposed to define and empirically measure the connotation and financial factors of China’s economic development, and pointed out that the backwardness of the structure and efficiency of China’s financial development is disproportionate to China’s economic development and that China’s financial development and economic growth are mutually influential [3]. In 2018, He Hui, Gao Qi, and Hou Jiarong established the relationship between financial development, industrial structure upgrade, and economic growth through a time series model, pointing out that China’s economic growth is still at an extensive growth stage. The change of industrial structure is still the main factor of China's economic growth, but it also affirmed the positive effect of financial
development level on economic growth [4]. However, at present, the impact and contribution of finance on China's economic development are both qualitative analysis and moderate reasoning, and there is no suitable mathematical model to discuss the relationship between them. This article aims to establish a reasonable mathematical model to more accurately analyze the impact and contribution of different financial factors on China's economic development, and further analyze its economic principles to provide an application reference for better realization of the quality development of China's economy.

2. Principles and algorithms
In the prediction of neural networks, this paper selects a typical BP neural network. It includes the number of neurons, the number of hidden layers, and the connection between neurons.

The s-type transfer function is:

$$y = \log \frac{1}{1 + e^{-x}}$$

Where, y states sigmoid output, x states input.

The loss function is:

$$C = \frac{1}{N} \sum_{i=1}^{N} [y(i) \times \log(a(i)) + (1 - y(i)) \times \log(1 - a(i)) ]$$

Where, N refers to the number of sample categories, y(i) refers to the label of sample i, positive class is 1, negative class is 0, a(i) refers to the probability that sample i is predicted to be positive.

In general, according to the Occam's razor principle in machine learning, if a simple neural network structure can be used to meet the requirements, a simple network structure should be used as much as possible, therefore, single hidden layer neural network structure is adopted (see figure 1).

![Six-dimensional multilayer feed-forward neural network structure](image)

Figure 1. Six-dimensional multilayer feed-forward neural network structure

Suppose the number of hidden layer neurons is n, and the BP neural network uses small batch stochastic gradient descent during training. The parameters that affect its prediction result are the learning rate, the size of the Batch value, the number of iterations, and the hidden layer neurons.
Number etc. The neural network needs to have a suitable learning rate. The learning rate determines the range of weight updating in each iteration. If the model learning rate is too large, the model learning may be unstable; but if the learning rate is too small, it will increase the number of model iterations, affecting the model training efficiency. The Batch value determines the number of samples that the network operates at a time during each training. From the perspective of model operation efficiency and convergence efficiency, a small batch of data sets is optimal. The neural network is generally the best advantage to find the loss function, when the sample size is too large, the gradient estimation should be more stable and accurate. It is easy to make the neural network converge to the poor local best, so the Batch value should be set Moderate. In addition, when training neural networks, the number of hidden layer neurons is different, which will have a greater impact on the accuracy and performance of model prediction. When the number of neurons in the hidden layer is too small, the model cannot extract more representative features, resulting in under-fitting of the network, making it difficult for the network to accurately describe the relationship between input and output, and ultimately reducing the prediction performance. On the contrary, when the number of neurons in the hidden layer is too large, on the one hand, it will increase the number of iterations, making the model fitting time too long, and the training efficiency is too low, on the other hand, the model is also easy to fall into the state of overfitting [5].

3. Experimental results and discussion

3.1. Experimental design

This paper collects the average annual growth rate of China's economy from 2007 to 2016 as an output neuron vector, which is used to evaluate the development of China's modern economy. At the same time, the role and contribution of finance in factor input (Capital input: average savings rate and interest rate in developing countries; labor input: employed labor), the role and contribution of finance in the improvement of factor productivity (Degree of economic financialization, proportion of external financing of enterprises—The increase in the proportion of external financing of enterprises can be measured by the rate of change in the proportion of average outstanding loans to GDP), the role of finance in directly increasing the economic aggregate (Financial industry's share of GDP), and other financial factors that may have an impact on China’s economic growth as the input layer neural vector. The input neuron vector and output neuron vector data are shown in Table 1.

Table 1. BP neural network training samples of economic annual growth rate.

| Year | Annual average economic growth rate (%) | China's average savings rate (%) | Interest rate(%) | Employment labor force(ten-thousand people) | Degree of economic financialization | Proportion of external financing of enterprises (%) | Financial industry's share of GDP (%) |
|------|----------------------------------------|----------------------------------|-----------------|-------------------------------------------|-------------------------------------|---------------------------------------------|-------------------------------------|
| 2007 | 14.23                                  | 49.9                             | 7.47            | 75321                                     | 0.543806647                        | 19.32                                       | 5.62                                |
| 2008 | 9.65                                   | 50                               | 5.31            | 75564                                     | 0.585365854                        | 16.687                                      | 5.73                                |
| 2009 | 9.4                                    | 49.79                            | 5.31            | 75828                                     | 0.530612245                        | 17.284                                      | 6.24                                |
| 2010 | 10.64                                  | 50.65                            | 5.81            | 76105                                     | 0.544827586                        | 16.39                                       | 6.22                                |
| 2011 | 9.55                                   | 49.44                            | 6.56            | 76420                                     | 0.557522124                        | 14.765                                      | 6.27                                |
| 2012 | 7.86                                   | 48.9                             | 6               | 76704                                     | 0.526841448                        | 14.402                                      | 6.51                                |
| 2013 | 7.77                                   | 48.57                            | 6               | 76977                                     | 0.504896627                        | 14.629                                      | 6.92                                |
| 2014 | 7.3                                    | 47.71                            | 5.6             | 77253                                     | 0.499511241                        | 14.863                                      | 7.25                                |
| 2015 | 6.91                                   | 46.26                            | 4.6             | 77451                                     | 0.473732179                        | 15.475                                      | 8.4                                 |
| 2016 | 6.74                                   | 44.98                            | 4.35            | 77603                                     | 0.446996466                        | 16.086                                      | 8.22                                |

In Table 1, the interest rate is the one-year loan interest rate, subject to the last adjustment in each year. Economic financialization is a universal problem in the world economy in the past three decades. Specifically, the so-called economic financialization refers to the rising proportion of a broad range of financial industries, including currencies, banks, securities, trusts, futures, and insurance, in an economy, and has a profound impact on the economy and politics of the economy. Economic
financialization generally takes a financially relevant rate, that is expressed as the ratio of total financial assets/gross national product. Economic and financialization is actually a process in which the financial system is gradually improved and complicated with the continuous development of commodity economy, technology and system, becoming a diversified: multi-modal, multi-level, multi-functional interconnected, balanced financial system, financial structure or architecture process. The growth of the proportion of external financing of enterprises can be measured by the rate of change of the proportion of average outstanding loans to GDP, which is the ratio of Chinese government debt to GDP. The forecasting data is selected from 2017 to 2019 (see table 2).

**Table 2.** BP Neural Network Forecasting Sample of Annual Economic Growth Rate.

| Year | Annual average economic growth rate (%) | China's average savings rate (%) | Interest rate(%) | Employment labor force(ten-thousand people) | Degree of economic financialization | Proportion of external financing of enterprises (%) | China's average savings rate (%) |
|------|----------------------------------------|----------------------------------|------------------|--------------------------------------------|-----------------------------------|---------------------------------------------|----------------------------------|
| 2017 | 6.76                                   | 44.93                            | 4.35             | 77640                                      | 0.47122602                        | 16.198                          | 7.95 |
| 2018 | 6.57                                   | 44.73                            | 4.35             | 77586                                      | 0.47723824                        | 16.274                          | 7.68 |
| 2019 | 6.1                                    | 44.57                            | 4.35             | 77471                                      | 0.47935411*                        | 16.955                          | 7.8  |

*As China's total savings and GDP data for 2019 is not officially given, the values in the forecast sample are the fitted values of the least square method.

Figure 2 shows the relationship between each influencing factor and the output vector. It can be seen that between 2007 and 2011, the interest rate is consistent with the annual growth rate, and the proportion of financing is also the same. The latter is that the savings rate and interest rate are in good agreement with the annual growth rate. It can be seen from the comprehensive comparison that the interest rate has the highest consistency with the annual growth rate, while the proportion of finance in GDP is inversely related to the annual growth rate. There is also a certain relationship with other factors, such as the degree of economic financialization and economic growth showing a good positive correlation, although the impact is weak, but there is a certain contribution.

Figure 2. Relationship between various influencing factors and annual economic growth rate.

### 3.2. Results and discussion

The results (see table 3) show that the prediction effect of the BP neural network is generally good, and the prediction deviation in individual years is relatively large, with a maximum not exceeding 8.27%. It can be explained that since there is no real data on the degree of economic and financialization in 2019, the forecast for the annual growth rate for the year is affected, making the predicted value lower than the true value.

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Table 3. 2017-2019 China's annual economic growth rate and BP neural forecast value comparison.

| Year | Annual economic growth rate | Actual value | Predictive value | Relative error |
|------|-----------------------------|--------------|------------------|----------------|
| 2017 |                             | 6.76         | 6.726132         | 0.005035       |
| 2018 |                             | 6.57         | 6.975369         | -0.05811       |
| 2019 |                             | 6.1          | 5.633775         | 0.082755       |

At the same time, in order to compare the accuracy of the predicted data horizontally, multiple linear regression models are used to analyze the same data. It can be seen from the previous data that the annual economic growth rate is obviously linearly related to some influencing factors and is affected by multiple independent variables. At the same time, there are some weak correlations that will change the prediction results to some extent. Therefore, each variable in the model is independent, so establish a system of equations:

\[
\begin{align*}
    y_1 &= a_1x_{11} + a_2x_{12} + a_3x_{13} + a_4x_{14} + a_5x_{15} + a_6x_{16} \\
    y_2 &= a_1x_{21} + a_2x_{22} + a_3x_{23} + a_4x_{24} + a_5x_{25} + a_6x_{26} \\
    y_3 &= a_1x_{31} + a_2x_{32} + a_3x_{33} + a_4x_{34} + a_5x_{35} + a_6x_{36} \\
    y_4 &= a_1x_{41} + a_2x_{42} + a_3x_{43} + a_4x_{44} + a_5x_{45} + a_6x_{46} \\
    y_5 &= a_1x_{51} + a_2x_{52} + a_3x_{53} + a_4x_{54} + a_5x_{55} + a_6x_{56} \\
    y_6 &= a_1x_{61} + a_2x_{62} + a_3x_{63} + a_4x_{64} + a_5x_{65} + a_6x_{66}
\end{align*}
\]

After solving each parameter using least squares, the data of the relevant influencing factors in 2017, 2018 and 2019 are calculated to calculate the three-year online travel market transaction volume, and the data are 6.923, 7.114 and 6.245, respectively. Compared with the prediction results of BP neural network and the actual average annual growth rate as shown in Figure 3, it is obvious that the accuracy of the prediction results of BP neural network is more accurate than that of multiple linear regression model.

![Figure 3](image_url)
This article trains the BP neural network based on the data of China’s annual economic growth rate and its six influencing factors from 2007 to 2016. The BP model is used for predicting and analyzing the economic growth rate from 2017 to 2019, the results are compared with the calculation of multiple linear regression analysis model. It shows that the prediction effect of the BP neural network is mostly good, which provides an application reference for the adjustment of China's annual economic growth rate (adjusting the interest rate of bank loans to achieve steady economic development or rectify the scale of the financial industry to increase the annual growth rate). In addition, BP neural network is similar with multiple linear regression analysis that the accuracy of prediction depends on the quantity and quality of data. Further research and improvement is needed in the selection and processing of variable data.

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