China's Energy Demand Prediction for 2019-2035 based on the MPSO-BP Model

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Abstract: Energy demand prediction is of great important to ensure national energy security and maintain steady economic growth. In this paper, a model based on BP neural network is set up to predict energy demand of China from 2019 to 2035 under three different scenarios. To improve the accuracy of the prediction, the modified PSO algorithm is used to optimize BP neural network. To measure the real situation of China's economic operation, we construct Keqiang-new Keqiang index as the descriptive index of economic development. The energy demand is analyzed for the period from 1985 to 2018 based on Keqiang-new Keqiang index, industrialization level, population and urbanization level. The results show that compared with BP neural network, the MPSO-BP model has better simulative and predictive precision and the energy demand of China under different scenarios will be 7.11×10^9, 4.83×10^9 and 6.18×10^9tce, respectively. By analyzing the prediction results, we can conclude that China can achieve the result of slow growth of energy demand or even making it maintain the current level by reducing the energy consumption of the industry while maintaining steady economic growth.

1. Introduction

In recent decades, worldwide energy consumption has been rising continuously due to rapid economic development, improvement of industrialization level, increasing human population, and higher living standards [1].With the acceleration of reforms and opening up, China's economy has kept a rapid and sustaining development mode. The accurate prediction of energy demand is very critical to ensure a more sustainable pattern of economic growth and make rational and scientific energy polices, which can guide the Chinese government to take necessary actions refer to energy supply security, environmental quality and other aspects of energy policy planning [1].The purpose of this paper is to forecast China's energy demands from 2019 to 2035 based on the proposed MPSO-BP model under different scenarios. The rest of this paper is organized as follows: we analyze the factors that influence Chinese energy consumption and screen the indicators for energy demand prediction such as Keqiang-new Keqiang index, industrialization level, population, and urbanization rate. BP neural network based on the MPSO algorithm is designed to estimate the energy demands of China in 2019-2035. The prediction modeling results are analyzed and presented. Then, the MPSO-BP model is applied to forecast the different China's energy demand under the future scenarios set.

2. The BP Neural Network Predicting Model

Because of the complexity and nonlinearity of the energy demand system, it is unrealistic to establish an accurate linear prediction model. As a multi-layer feed forward neural network trained by backward error propagation algorithm, BP neural network has a strong multi-dimensional function mapping ability. In this paper, the BP neural network is used to predict energy demand, and its topology is shown in Figure 1.

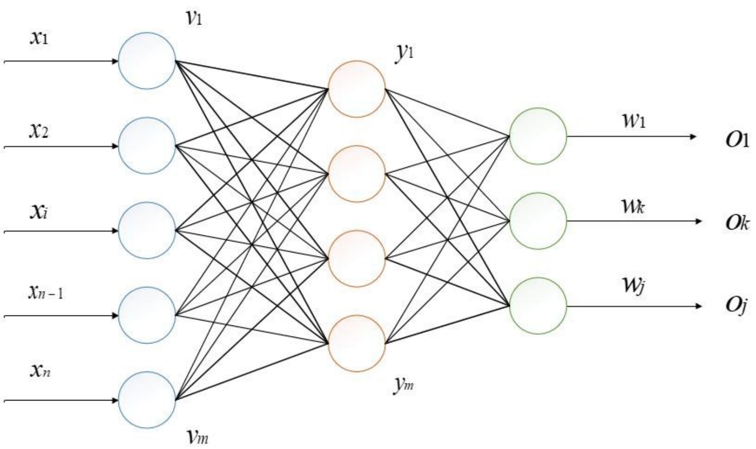

Figure 1. The topology of BP neural network

BP neural network has three layers composed of input layer, hidden layer, and output layer. The training process of BP neural network is divided into two steps. The first step is the forward propagation of the input signal: the input signal of the input layer passes through the hidden layer to the output layer, and the states of neurons in each layer will only affect the state of the next layer. The second step is to adjust the weight and threshold of the BP neural network based on backward error propagation algorithm when the output layer gets an undesirable output, making the error decreasing along the gradient direction.

3. Training results

To highlight the strength of the MPSO-BP model in energy demand prediction, the modeling results and real historical data are shown in Figure 2 and Figure 3 compared with BP neural network model.

It can be obviously seen that the effect of fitting is better by applying the MPSO-BP model. The data processing results show us that the average relative error by using BP neural network prediction is 6.15%, and the average relative error is only 1.18% by using MPSO algorithm, which indicates that the prediction accuracy has been greatly improved. When the descriptive indicators of economic development is selected, the average relative error of prediction is 2.56%, 2.39% and 2.75% respectively. That is to say, the energy demand prediction based on the MPSO-BP model could accurately depict the disciplinarian and relationship between energy demand and its affecting factors, including economic growth, industrialization level, population, and urbanization level. The MPSO algorithm is proved to overcome the shortages of slow convergence speed and local minimum existed in BP neural network, which not only improves prediction efficiency, but also enhances prediction accuracy.

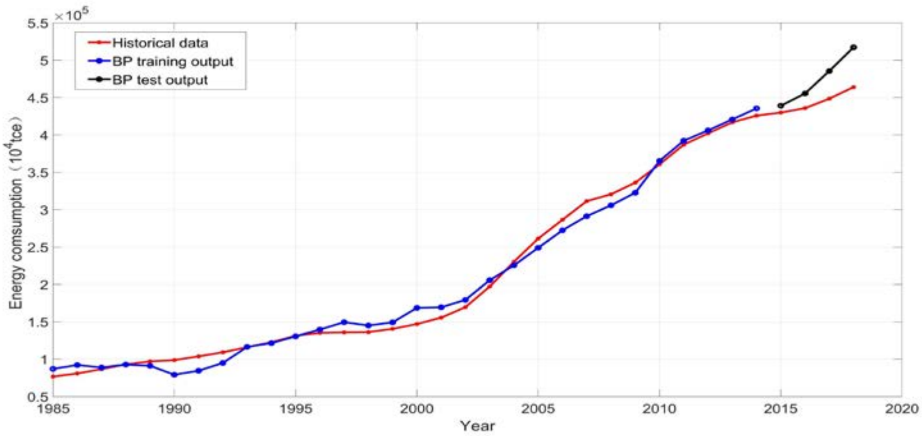

Figure 2. Comparison between the predicted and actual data by BP neural network

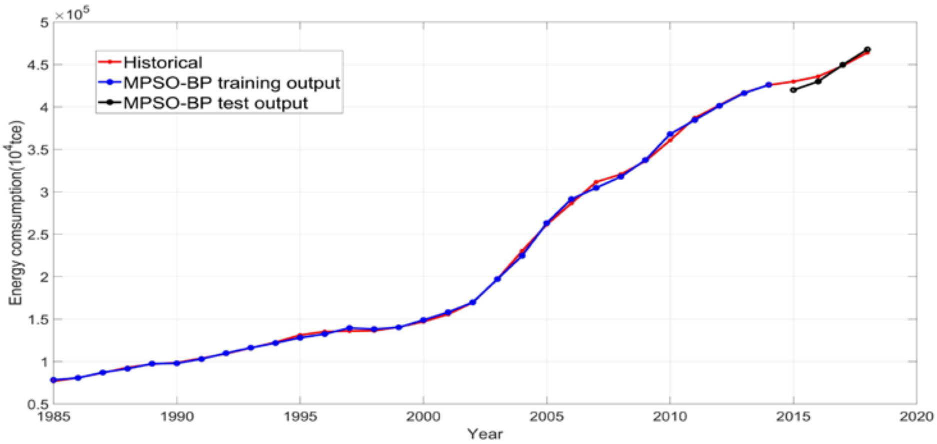

Figure 3. Comparison between the predicted and actual data by the MPSO-BP model

Hence, the MPSO-BP model is used to predict China's total energy demand from 2019 to 2035 to obtain more accurate results and improve the values of prediction in energy planning and policies.

4. Prediction results and discussion

According to the different scenarios set up above, the MPSO-BP model is used to predict China's energy demand in 2019-2035 and the results are shown in Figure 4:

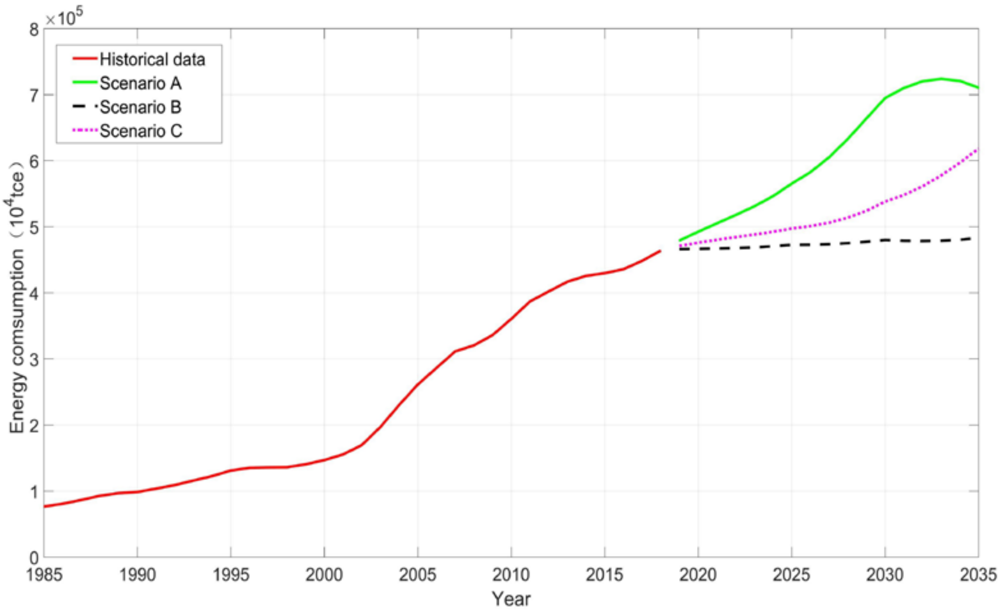

Figure 4. Energy demand predictions under different scenarios (2019-2035)

In scenario A, China's energy demand will reach 5.65×10^9 tce (ton coal equivalent) in 2025, and the average annual growth rate is expected to be 2.79% from 2019 to 2025. By 2030, energy demand will reach 6.95×10^9tce, with an average annual growth rate of 4.21% from 2026 to 2030, which is even faster than the 3.65% average annual growth rate during the period between 2009 and 2018. However, energy demand will show a negative growth after reaching the peak of 7.24×10^9 tce in 2033. China's energy demand is expected to be 7.11×10^9tce in 2035, and the average annual growth rate between 2034 and 2035 is -0.92%. Scenario B assumes that the economic growth will maintain a lower level, environmental protection will be strengthened and many enterprises with high energy consumption and heavy pollution will be closed down, which will lead to upgrading of industrial structure. In scenario B, China's energy demand will hover between 4.66×10^9 and 4.83×10^9tce in 2019-2035, and the annual growth rates of energy demand in 2019-2025 and in

2026-2030 are 0.23% and 0.31%, respectively. The energy demand in 2025 is expected to be 4.73×10^9tce. After reaching 4.80×10^9tce in 2030, energy demand will experience a slight negative growth for two consecutive years, but will increase with an average annual growth rate of 0.31% in the following three years, and it is expected to be 4.83×10^9tce in 2035. In scenario C, China’s energy demand will continue to rise: the annual growth rate of energy demand is 0.91% from 2019 to 2025, 1.59% from 2026 to 2030, and 2.81% from 2031 to 2035, while the projected energy demand of China by 2025, 2030 and 2035 is 4.97×10^9tce, 5.38×10^9tce and 6.18×10^9tce, respectively.

In scenario A, we can find that the energy demand will not increase permanently, but decrease gradually after reaching the peak, which coincides with the research results of Amarawickram and Hunt. The growth of energy demand is the fastest in scenario A (before reaching the peak) while it is the slowest in scenario B. Combined with Table 5, we can find that economic growth maintains a high growth rate and the level of industrialization is basically unchanged in scenario A. In scenario B, the level of industrialization declines significantly, so the energy demand of industry will decrease year by year. Although the economic growth rate is lower than scenario A and C, the level of economic development in scenario B will have a great improvement compared with 2018. Based on the above analysis of the prediction results of energy demand in different situations, we can find that the level of industrialization has the greatest impact on energy demand. When the level of industrialization is basically unchanged, energy demand is positively correlated with economic growth before reaching the peak; when it is showing a relatively high negative growth, even if the level of economic development is constantly improving, population is continually increasing, and urbanization level is constantly rising, energy demand can be still at a relatively low level. Therefore, we can conclude that China can achieve the result of slow growth of energy demand or even making it maintain the current level by reducing the energy consumption of the industry while maintaining steady economic growth.

To improve efficiency and effectiveness of energy use, both the government agencies and enterprises should take necessary actions. Firstly, China should deepen supply-side structural reform further, solve the problem of overcapacity, work hard to put economic development on the path of endogenous growth driven by innovation, accelerate the upgrading of industrial structure, and release the new vitality of China's economic growth. Secondly, China should further step up efforts in environmental protection, reduce industrial firms with high pollution and energy consumption, and support the development of enterprises with better benefits and lower energy consumption. Thirdly, China should accelerate the large-scale development of new energy, and increase the share of new energy in the energy supply so as to ease the dependency on traditional energy and air pollution in China. In addition, it’s necessary to increase investment in research and development for enterprises to release the role of science and technology as the primary productivity and promote the transformation of scientific and technological achievements into actual productivity, which can not only improve the competitiveness of products, but also take environmental protection and reduce energy consumption into account.

5. Conclusions

In this paper, we propose China's energy demand prediction model based on MPSO-BP model, and use it to predict energy demand from 2019 to 2035. The results show that the energy demand prediction model in this paper can depict the disciplinarian and relationship between energy demand and its affecting factors, including economic growth, industrialization level, population, and urbanization level. The following conclusions can be drawn from this study:

(1) Three different scenarios are set up in this paper, and the corresponding energy demand of China in 2035 is 7.11×10^9, 4.83×10^9 and 6.18×10^9tce respectively. Combining the setting of three scenarios and the prediction results, we can draw the conclusion that the level of industrialization has the greatest impact on energy demand and the energy consumption of industry can be reduced by closing some industrial firms with high pollution and energy consumption, improving energy efficiency, etc., so as to reduce the growth rate of energy demand.

(2) It can overcome BP neural network's problems of slow convergence speed and easy to get into a local minimum by using the modified PSO algorithm to optimize it. Compared with BP neural network model, the prediction accuracy of MPSO-BP model is significantly improved, and the prediction results are more close to the real value, which provides an efficient and feasible method for energy demand prediction. In addition, MPSO-BP model has excellent generalization capabilities and can be applied to other.

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