Prediction of Carbon Tax Levied in China and Its Effects Based on BP Neural Network

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Abstract. Historical data of crude oil, coal and natural gas in China are used to calculate the carbon emission and carbon tax in recent years. It is proved that the nonlinear model, BP Neural Network, is more suitable for the calculation of carbon tax under the influence of various energy factors. Then BP Neural Network and GM (1, 1) have a good learning ability to forecast the carbon tax revenue from 2020 to 2030. BP Neural Network, however, has less error and shows that Per capita disposable income, GDP and Per capita GDP play a decisive role in the development of carbon tax and environmental protection. Based on the assumption that the carbon tax will be imposed and increased, the carbon emission intensity of each province and the carbon tax acceptance of urban residents will be within the ideal range in the next decade. All evaluation indicators of models and data analysis show that the carbon tax has a good policy guidance for energy saving and emission reduction. This study about carbon tax provides a new solution for domestic environmental protection.

Keywords: Carbon Tax, Prediction and Analysis, BP Neural Network, GM (1,1).

1. Introduction

Carbon emissions and energy consumption continue to affect human beings' life and activites with the rapid development of economy in the world. Excessive carbon emissions have become a widely discussed topic in the world today. Greenhouse gases cased by excessive carbon emissions absorbs infrared radiation and lead to a huge rise in the Earth's temperature [1]. When the Earth gets too hot, it can lead to a range of environmental problems, such as glacier and permafrost melting in the Arctic Pole. In 2015, 178 countries at the Paris Climate Conference signed the agreement to respond to the world's climate change problems [2-4].

Carbon tax as a powerful economic policy instrument has been widely recognized by countries around the world. It can effectively promote the development of low-carbon economy and reduce the emission of carbon dioxide. This paper examines the changes in economic indicators such as GDP and urban per capita disposable income based on BP Neural Network model, after selecting the important economic indicators. The model is used to predict the carbon tax and give the necessary policy recommendations.

2. Previous work

In general, the long-term implementation of carbon tax policies can reduce the consumption of fossil energy and improve the ecological environment. At the same time, it increases the market demand for clean energy and transforms the energy structure. However, the implementation of carbon tax in the short term is likely to have a negative impact on various subsystems of the macro econom.

At present, there are few studies that combine the carbon tax system and machine learning methods in the theoretical community [5-8]. In general, because China has not yet introduced a carbon tax, the problem of biased information makes the carbon tax collection questionable. It will distort the neutral nature of the tax to a certain extent and affect the economic and social development. The prediction of carbon tax in this paper can improve the management, monitoring and service level of carbon tax and make up for the lack of research on carbon tax information management in China.

3. Calculation of carbon tax in China

There are three ways to calculate carbon tax according to carbon emissions. The first is to calculate the carbon dioxide emissions of energy consumption based on the carbon content. However, it is not easy to achieve in reality and is adopted in some European countries. The second method is to set a carbon tax value for each energy source according to the carbon content of different energy types. The taxation of energy consumption in production activities is also due to different energy quality, but the fairness of taxation is insufficient. The last one is the heat taxes that is levied according to the heat released by the energy. It is now adopted in Britain. The advantage is that heat is used instead of carbon dioxide as the tax basis. Although it may not reflect the reduction of pollutant emissions due to technological progress, making manufacturers slack in the research and development of energy efficiency.

Considering the international situation in China, this paper adopts the third method to calculate the total amount of carbon tax in China, and makes a prediction and analysis of China's carbon tax based on different models.

Table 1. Carbon tax rate of different types of energy

Tax collection items	Tax rate
Crude oil (Y_1)	19, 000 yuan/one thousand tons
Gasoline (Y_2)	
Kerosene (Y_3)	
Diesel (Y_4)	
Fuel oil (Y_5)	
Natural gas (Y_6)	648, 000 yuan/cubic meter
Coal (Y_7)	4, 200 yuan /one thousand tons
Coke (Y_8)	

Source: www.chinatax.gov.cn

The formula for carbon tax in China is shown as follows:

$Y=a_1Y_1+ a_2Y_2+...+ a_nY_n \quad (n=8)$

where Y represents the carbon tax amount, Y_1, Y_2 ... Y_n represent the consumption of energy shown in Table 1. a_1, a_2... a_n represent the corresponding tax rate, respectively.

The total energy consumption from 2004 to 2021 can be found in the National Bureau of Statistics of China (www.chinatax.gov.cn). Carbon tax related factors include urban per capita disposable income, GDP, per capita GDP, total population, urbanization rate, per capita energy consumption, per capita coal consumption, per capita oil consumption, etc. Fianlly we obtain the results of carbon tax and various factor indicators from 2004 to 2022 as shown in Figure 1.

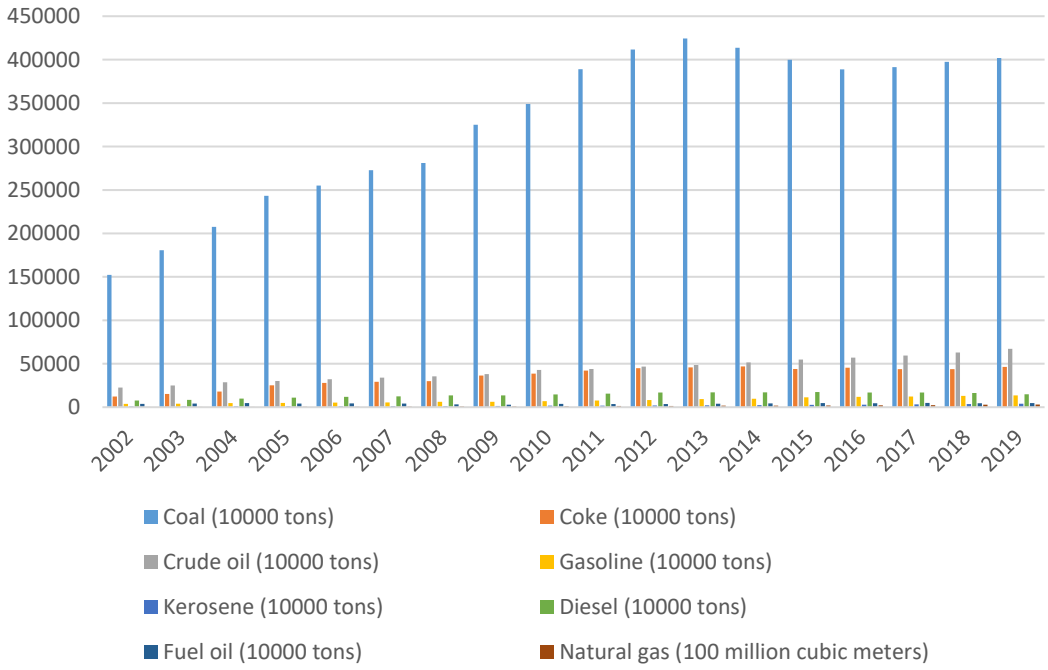


Figure 1. Consumption of different types of energy

Coal has always been the most used energy source, and the consumption of coal has increased from 2002 to 2013, while the consumption of coal has declined after 2013. It is due to the impact of national carbon neutrality and related environmental protection policies on the consumption structure of coal. The use of oil is second only to coal, but the use of these two energy sources has been increasing compared to coal. The use of coke has always been in the third place, and its dosage trend is basically the same as that of coal. In addition to these three energy sources, the rest of the energy use has basically not increased or decreased significantly.

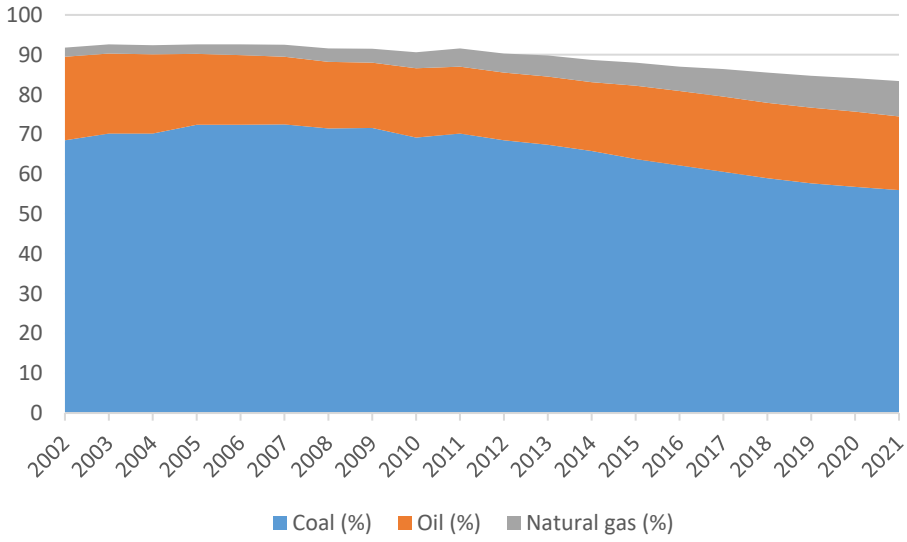


Figure 2. Proportion of carbon energy from 2002 and 2021

Figure 2 shows that the proportion of coal, oil, and natural gas has declined from 2002 to 2021. The decline of coal is the most obvious, and the downward trend of natural gas is the lowest. It can show that China has adopted more other energy situations to consume, by inhibiting the use of these three energy sources to reduce carbon emissions. The use of coal is from nearly 70% to 60%. 10% decline for environmental improvement effect can not be underestimated.

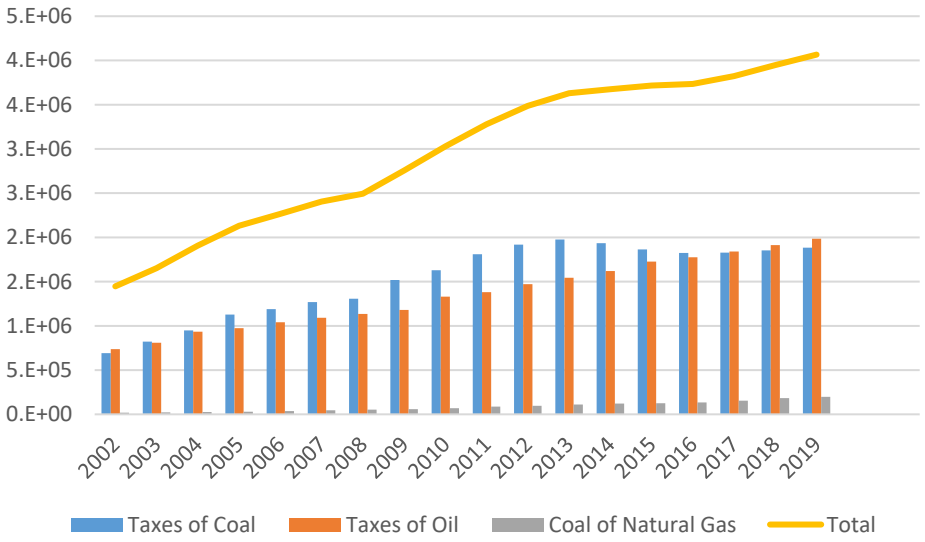


Figure 3. Calculation results of China's carbon tax

Figure 3 calculates the carbon tax result from the above formula from 2002 to 2019. The carbon tax is proportional to the emission of coal, and the amount of coal used is also based on 2013 as a node, but the carbon tax on oil is rising. It is different from the proportion of oil use, and the carbon tax brought by natural gas is also growing. It also shows that China's current control of carbon is focused on coal. The total amount of carbon tax fraom 2002 to 2021 continues to grow, although the growth trend is sometimes slightly slower. It also shows that the national carbon reduction plan and the goal of achieving carbon neutrality are in an orderly manner.

It shows the historical data of factors that related to carbon tax and represents the statistics of various factors. The we carried out different models to predict carbon tax from 2020 to 2030. The model prediction process is mainly completed in Python software and the detailed programming process is shown in Appendix 1.

We can effectively remove invalid data dimension information through penalty items. In linear model, the penalty term alleviates the overfitting effect of the model best. In the selection, the penalty coefficients of lasso and ridge models are 0.2 and 0.3, while R^2 results are 0.895 and 0.896 respectively in Figure 4, which indicates that ridge model is the most suitable in linear models.

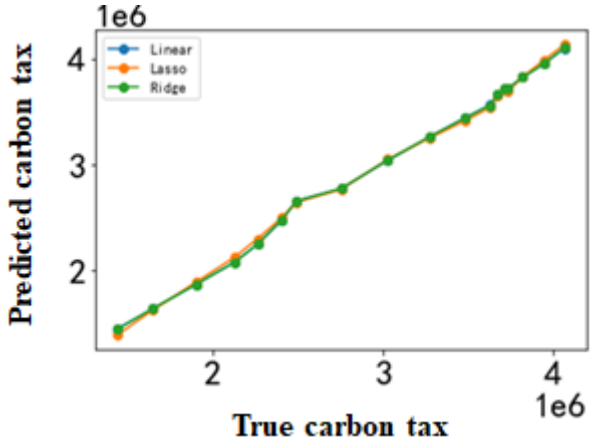


Figure 4. Predicted carbon tax by linear model

In BP Neural Network, easonable selection of the number of neurons and hidden layers effectively improves the accuracy of prediction and obtains the most correct model operation results. Finally, on the premise of reasonable parameter adjustment, 5 neurons and 3 hidden layers is selected as the operating parameters of the Neural Network to show the best prediction effect. Besides, “relu” is used as the activation function. The fitting results of BP Neural Network are shown in Figure 5 with 0.988

R^2. Neural Network is better and more suitable for analyzing the relationship between carbon tax and factors, which can further help predict carbon tax.

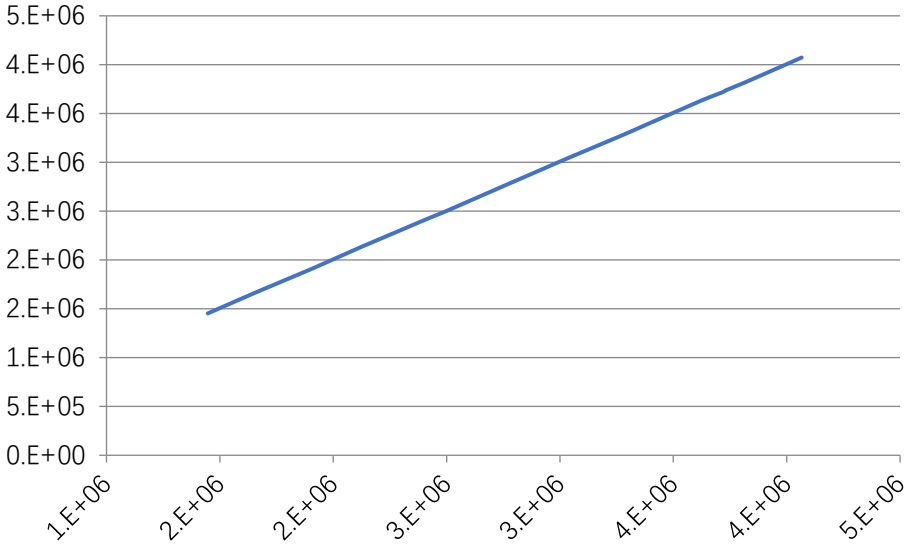


Figure 5. Analysis of fitting results by BP Neural Network

4. Prediction of carbon tax

Grey model does not need a large number of samples while Neural Network model has high fault tolerance. So we can make use of the advantages of the two to make reasonable prediction and calculation of China's carbon emissions in the future while keeping the error within a small range.

After constructing the model, we could get the differential equation of carbon tax from 2002 to 2019:

$$x(k) = 42.37\, e(0.047\,(k-1)) - 40.93$$

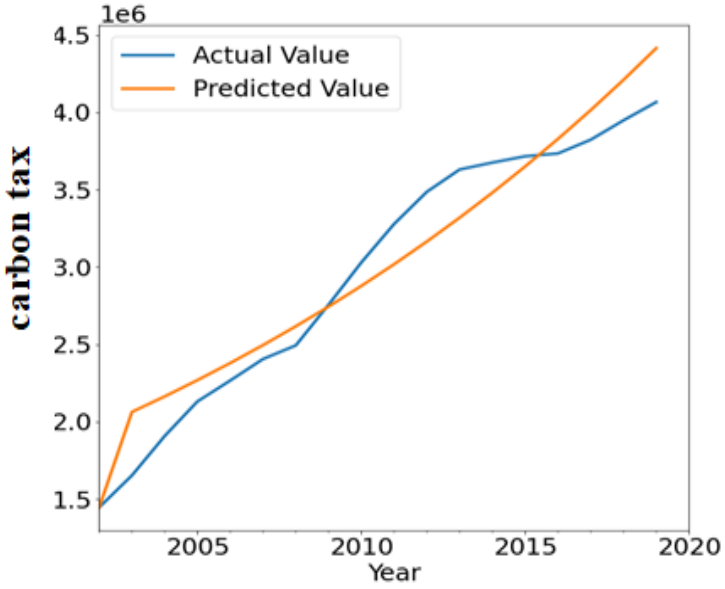


Figure 6. Predicted value of carbon tax from 2002 to 2019 by GM(1,1)

According to the Grey Model, we can calculate and analyze the carbon emission change curve from 2002 to 2019, which is basically consistent with the actual carbon emission change curve (Actual value) in these years, and both continued upward trend. After bringing the precise data into Table 2 and calculating, although there are special cases with large errors such as 2003 and 2004, the errors can be ignored in most cases. For example, in 2009, 2015, and 2016, the data reached with the

second-level precision, the actual carbon emission data can be simulated with the calculation data. We can further find that the carbon emission will continue to rise in the next ten years.

Table 2. Carbon emissions in the next ten years

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Emissions	4.63	4.85	5.09	5.34	5.60	5.87	6.16	6.46	6.77	7.10	7.45

We consider the role of factors, analyze and forecast carbon emissions based on Neural Network models according to the carbon tax data obtained from 2002 to 2019. The overall error of predicted carbon tax is smaller than that of Grey Model. Increasing factor information can improve the accuracy of carbon tax prediction. Using the carbon tax prediction model established above, the carbon tax revenue from 2020 to 2030 is fitted and predicted in Figure 7. Through horizontal comparison,

By considering a variety of factors, we have predicted the carbon tax from 2020 to 2030. Through the model, we can more accurately analyze and predict carbon emissions and the reasonable collection of carbon tax.

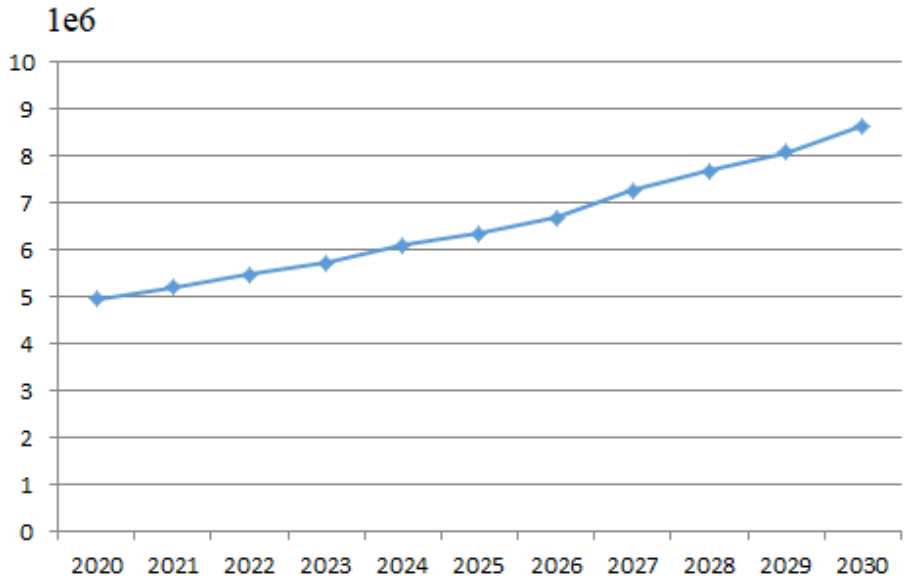


Figure 7. Carbon tax predicted by BP Neural Network from 2020 to 2030

5. Conclusion

This paper focuses on the new methods of prediction and analysis of carbon tax. First, we used linear model and BP Neural Network model to calculate the carbon tax that should be collected. Then, we added multiple factors, including but not limited to the emissions and trends of the three major fossil energies. Through the consideration of multiple factors and the selection of models, our prediction results are also more accurate. Carbon tax is essential for environmental development. China's carbon tax collection should take into account both short-term and long-term economic development and formulate a reasonable carbon tax.

If China starts to levy carbon tax on fuels, the energy consumption level of China's economy is much higher than that of ordinary energy consuming countries due to its high dependence on energy and resources. However, the carbon tax has little impact on GDP and disposable income of urban residents and effectively controls environmental pollution and further improve the concept of environmental protection. Therefore, the formulation of carbon tax should be analyzed from the implementation effect of other countries, and a carbon tax formulation scheme suitable for China should be studied and implemented as soon as possible. However, the number of original samples is small. Because it is difficult to collect provincial carbon tax data, only national data and indicator panel data from 2000 to 2019 are available for algorithm analysis. Both the geographical scope and the indicator data are obviously lacking and thin. In addition, our study does not reflect the dynamic

carbon tax rate. The energy use structure of the whole country is different every year, but a unified carbon tax rate is adopted for each fossil energy in the process of carbon tax prediction. So it fails to reflect the marginal regulation of carbon tax on energy conservation.

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