World Scientific Research Journal (WSRJ) ISSN: 2472-3703
www.wsr-j.org

Forecast of Carbon Dioxide Emissions of All the Industries in China Based on Gray Model

Jun Dong, Shiyan Xie[a, *], Xihao Dou, Shanlei Lv

School of Economics and Management, North China Electric Power University, Beijing 102206, China

[a]609653526@qq.com

Abstract: Controlling carbon emissions has moved high up on the government's agendas in China. The 13th Five-year Plan clearly stated that we need to strengthen the management of high energy-consuming industries which include electricity, chemicals, construction and metal industries. Under this situation, this paper chooses to use the grey model (1,1) to predict carbon emissions based on the data from World Input-output Database of 35 sectors in China. In the end, the paper put forward some suggestions for the carbon emission reduction.

Keywords: carbon dioxide emission, grey model

---

1. INTRODUCTION

The world's carbon dioxide emissions have risen sharply since the Industrial Revolution, leading to such chain reactions as greenhouse effect, extreme weather, ocean acidification, sea level rise and species extinction. The global climate change caused by human social activities has threatened human existence and has become the consensus of the world. According to World Bank statistics, the global carbon dioxide emissions have risen from 9396705 kilotons in 1960 to 33.472376 kilotons in 2010 while China's carbon dioxide emissions have risen sharply from 2.697 metric tons per capita to 7.544 metric tons between 2000 and 2014.

Since the reform and opening up, economy of China has a rapid development, but the rapid GDP growth has brought a lot of greenhouse gas emissions. For a long time, the United States has always been the biggest emitter of greenhouse gas emissions. However, some foreign experts and scholars recently think that from the perspective of China's economic growth, it is very likely that China will surpass the United States as the world's largest emitter of greenhouse gas emissions. According to data from the World Resources Institute (WRI), China accumulates about 151 billion tons of greenhouse gas emissions between 1990 and 2016 and might replace the United States, which will emit a total of 147 billion tons next year, the number one emitter. Since China has not yet completed industrialization and urbanization and is still in a stage of development, the total amount of greenhouse gas emissions will still be on the rise in the coming period. At the same time, China is now in a period of economic restructuring and its economic growth is slowing down. In order to promote sustainable economic development, the government strongly supports the development of renewable energy and rectifies high-energy-consumption and high-emission enterprises. Therefore, although the total emissions are on the rise, In the future, China's emissions per unit of GDP are likely to decline.

Faced with enormous pressure on emissions reduction, China actively develops a low-carbon economy to control its greenhouse gas emissions. In 2009, the Chinese government formally proposed a plan to reduce greenhouse gas emissions: it promised to reduce its greenhouse gas emissions per unit of GDP by 40% to 45% based on 2005 levels by 2020. In 2011, the government explicitly proposed to reduce 17% of carbon emissions per unit of GDP during the 12th FYP period, which means that the national carbon dioxide emissions per unit of GDP should be 17% lower than that in the year 2010. In 2014, China and the United States signed a bilateral agreement, promising that the carbon dioxide emissions will reach the peak in 2030 and then the emission will drop off. In the past 20 years, China has made tremendous contributions to delaying the growth of global greenhouse gases. Under the environment of promoting energy-saving emission reduction, predicting and analyzing carbon dioxide emissions in various sectors and clarifying the characteristics of carbon dioxide emissions changes in various industries are of great importance for effective implementation of energy-saving emission reduction in China.

At present, many scholars at home and abroad have made various studies on carbon emission prediction and put forward some more practical methods [1-9]. Du Qiang and Loehman. A[1-2] proposed a Logistic prediction model for carbon emissions growth. Zhao Xi [3] proposed a discrete second-order difference equation prediction model. Song Jiekun and Bangzhu Z [4-5] proposed a carbon emission forecasting model for support vector regression; Ji Jianyue [6] drew lessons from the idea of IPAT model and put forward STIRFDT model for marine transportation carbon emissions. Hsiao-Tien Pao [7] used gray prediction method to predict Brazil's carbon dioxide emissions, energy consumption and economic growth for five years. Peter J. Marcotullio et al. [8] used regression analysis to predict the future transport carbon emissions of the Asia-Pacific Region; According to the historical data of China's transportation sector Liu Jian Cui [9] used linear regression method to predict the transport sector's energy consumption and carbon emissions.

In the current literature analysis, there are many literatures about the prediction and analysis of the total amount of carbon emissions, while there are relatively few literatures on the prediction of carbon emissions in various industries. At the same time, due to the different perspectives of analysis and the complicated and diverse factors that affect the carbon emission, the impact on the carbon dioxide emission forecast is also different. Based on the gray forecasting theory and the EU input-output database (WIOD), this paper chooses the data of carbon dioxide emissions of 35 departments in China from 1995 to 2009 and used GM (1,1) model to forecast the carbon dioxide emissions in various industries from 2010-2018. In the end, the paper put forward some suggestions to the emission reduction implementation in China.

2. METHODOLOGY

The grey theory think that all the system can be divided into three types including white, black and grey. The information in white system is completely known, and in black system is completely unknown. While in the grey system means part of the information is known, or the information is not complete.

Using GM (1, 1) model to predict mainly includes the following steps:

(1) Collect and organize the original data sequences which need to be analyzed:

$$x^{(0)} = [x^0(1), x^0(2), x^0(3) \ldots \ldots x^0(n)] \tag{1}$$

(2) Accumulate the original data sequences with 1-AGO and get the new data sequences:

$$x^{(1)} = [x^1(1), x^1(2), x^1(3) \ldots \ldots x^1(n)] \tag{2}$$

In which

$$x^{(1)}(k) = \sum_{i-1}^{k} x^{(0)}(i) \quad (k = 1,2,3, \ldots \ldots, n) \tag{3}$$

(3) Since the sequences$x^{(1)}(k)$ has an exponential growth rule, so does the solution of the first-order differential equation, therefore, we can consider that the sequence $x^{(1)}$ satisfies the following first-order linear differential equation:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u \tag{4}$$

According to the definition of derivatives, for the discrete functions, there is:

$$\frac{\Delta x^{(1)}}{\Delta t} = \frac{x^{(1)}(k+1) - x^{(1)}(k)}{k+1-k} = x^{(1)}(k+1) - x^{(1)}(k) = \alpha^{(1)}\left[x^{(1)}(k+1)\right] = x^{(0)}(k+1) \tag{5}$$

In which $x^{(1)}$ can only take the mean of k and k+1, that is:

$$\frac{1}{2}[x^{(1)}(k+1) + x^{(1)}(k)] \tag{6}$$

Take it in:

$$\mathrm{k} = \mathrm{n} - 1, x^{(0)}(n) + \frac{1}{2}\left[x^{(1)}(n) + x^{(1)}(n-1)\right] = \mathrm{u} \tag{7}$$

$$\begin{bmatrix} x_1^{(0)}(2) \\ x_1^{(0)}(3) \\ x_1^{(0)}(4) \\ \cdot \\ \cdot \\ \cdot \\ x_1^{(0)}(n) \end{bmatrix} = \begin{bmatrix} -\frac{1}{2}\left[x^{(1)}(1) + x^{(1)}(2)\right] & 1 \\ -\frac{1}{2}\left[x^{(1)}(2) + x^{(1)}(3)\right] & 1 \\ -\frac{1}{2}\left[x^{(1)}(3) + x^{(1)}(4)\right] & 1 \\ \cdot & \\ \cdot & \\ \cdot & \\ -\frac{1}{2}\left[x^{(1)}(n-1) + x^{(1)}(n)\right] & 1 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \tag{8}$$

Briefly written as:

$$Y_n = BA \tag{9}$$

(4) Using the least square method can get the approximate solution:

$$Y_n = B\hat{A} - E \tag{10}$$

In which E is the error term. Ignore the error temporarily, we can get:

$$\hat{A} = (B^T \mathrm{B})^{-1} B^T Y_n = \begin{bmatrix} \hat{a} \\ \hat{u} \end{bmatrix} \tag{11}$$

Solve the differential equations:

$$x^{(1)}(t+1) = \left[x^{(1)}(1) - \frac{\hat{u}}{\hat{a}}\right] e^{-\hat{a}t} + \frac{\hat{u}}{\hat{a}} \tag{12}$$

Write in discrete form:

$$x^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{\hat{u}}{\hat{a}}\right] e^{-\hat{a}k} + \frac{\hat{u}}{\hat{a}} \qquad \mathrm{k} = (0,1,2, \ldots\ldots) \tag{13}$$

So the grey prediction model or the original sequence $x^{(0)}$ is available:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k) = (1 - e^{\hat{a}})(x^{(0)}(1) - \frac{\hat{u}}{\hat{a}})\, e^{-\hat{a}k} \qquad \mathrm{k} = (0,1,2, \ldots\ldots) \tag{14}$$

3. DATA AND RESULTS

The data this paper used came from environmental accounts of World Input Output Database (WIOD). The environment account covers the energy use, carbon dioxide emissions and air emissions of various sectors in all 27 EU countries and other major countries in the world from 1995 to 2009.

The classification of all the 35 sectors in China is shown in Table 1.

Table 1. 35 sectors of the database

Order	Industry	Order	Industry
1	Agriculture, Hunting, Forestry and Fishing	19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
2	Mining and Quarrying	20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
3	Food, Beverages and Tobacco	21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
4	Textiles and Textile Products	22	Hotels and Restaurants
5	Leather, Leather and Footwear	23	Inland Transport
6	Wood and Products of Wood and Cork	24	Water Transport
7	Pulp, Paper, Paper, Printing and Publishing	25	Air Transport
8	Coke, Refined Petroleum and Nuclear Fuel	26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
9	Chemicals and Chemical Products	27	Post and Telecommunications
10	Rubber and Plastics	28	Financial Intermediation
11	Other Non-Metallic Mineral	29	Real Estate Activities
12	Basic Metals and Fabricated Metal	30	Renting of M&Eq and Other Business Activities
13	Machinery, Nec	31	Public Admin and Defense; Compulsory Social Security
14	Electrical and Optical Equipment	32	Education
15	Transport Equipment	33	Health and Social Work
16	Manufacturing, Nec; Recycling	34	Other Community, Social and Personal Services
17	Electricity, Gas and Water Supply	35	Private Households with Employed Persons
18	Construction		

Based on Grey Model (1, 1) in chapter 2, we can predict the carbon emissions of all industries from 2010 to 2017 using the data from 2000 to 2009. The result is shown in Table 4 and Figure 1.

Table 2. prediction result of carbon emission of all sectors from 2010 to 2014

	1	2	3	4	5	6	7	8	9	10	11	12
2010	136868	228330	236850	56015.1	3881.71	13715.5	56671.2	107604	303449	25967.2	835238.26	722153.33
2011	140950	255377	268804	59343.3	4041.94	15027.3	61810.6	114437	327432	27682.2	926894.55	794045.63
2012	145155	285628	305069	62869.3	4208.78	16464.5	67416.1	121703	353309	29510.4	1028608.9	873095
2013	149485	319462	346227	66604.7	4382.51	18039.1	73529.9	129431	381232	31459.4	1141485.05	960013.95
2014	153944	357304	392937	70562.1	4563.41	19764.4	80198.2	137650	411362	33537.1	1266747.85	1055585.91
	13	14	15	16	17	18	19	20	21	22	23	24
2010	40850.8	20563.5	27817.9	5192.68	3917133.84	86878.5	205.72	4447.53	7578.41	25304.5	108356.28	107835.31
2011	43763.8	22326.7	30330.3	5167.62	4338692.56	97689.4	234.21	3897.85	7862.35	30160.1	114523.2	113916.01
2012	46884.4	24241.2	33069.6	5142.68	4805619.08	109845	266.66	3416.11	8156.93	35947.4	121041.1	120339.59
2013	50227.6	26319.8	36056.3	5117.87	5322795.85	123514	303.6	2993.91	8462.54	42845.3	127929.95	127125.38
2014	53809.2	28576.6	39312.7	5093.17	5895630.76	138884	345.65	2623.88	8779.6	51066.7	135210.87	134293.82
	25	26	27	28	29	30	31	32	33	34	35	
2010	70415.3	42858.1	6263.13	3302.95	3660.6	28764.9	29525.1	18095.9	28159.1	42243.8	0	
2011	78126.6	50257.3	6655.13	3498.42	3532.8	32639.1	34062.4	19271.8	37423.5	46927	0	
2012	86682.4	58933.8	7071.67	3705.46	3409.47	37035.2	39297	20524	49736	52129.3	0	
2013	96175.2	69108.2	7514.27	3924.75	3290.45	42023.4	45336	21857.7	66099.2	57908.3	0	
2014	106707	81039.2	7984.58	4157.02	3175.58	47683.4	52303.1	23278	87846.1	64328	0	

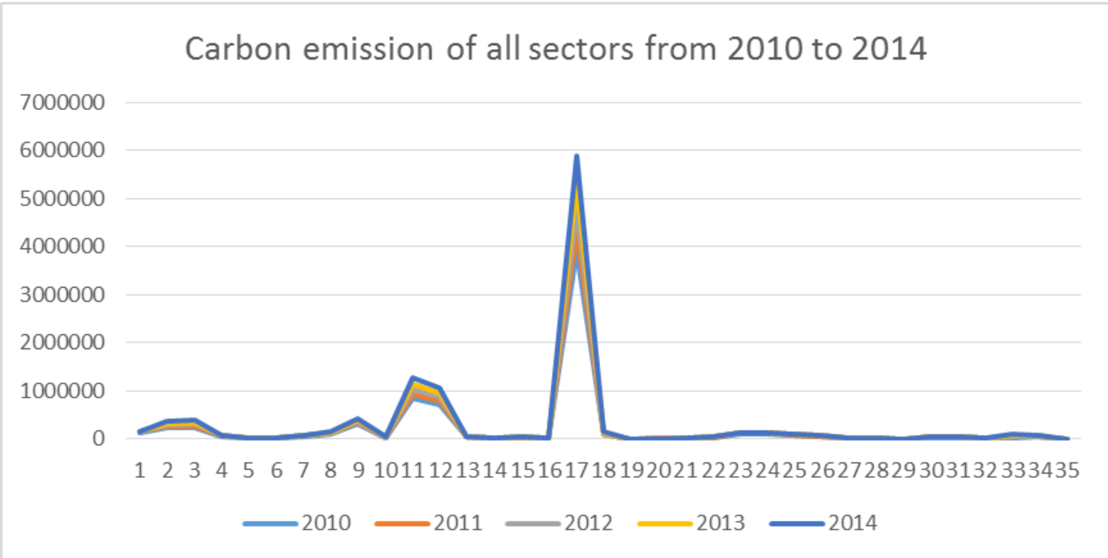

Figure 1. Prediction result of carbon emission of all sectors from 2010 to 2014

4. CONCLUSION AND SUGGESTION

(1) GM (1, 1) is suitable for short-term and medium-term forecasts with high accuracy. For long-term forecasts, due to the future disturbance factors, the accuracy will reduce. So this paper used GM (1, 1) to predict 2010 to 2014 carbon emissions of all sectors in China and

evaluate the effect of emission reduction. The result showed that electricity, gas and water supply sector is significantly higher than all the other sectors and had the biggest increment. And Other Non-Metallic Mineral sector and Basic Metals and Fabricated Metal sector made great contributions to the emissions too.

(2) A large number of studies has proved that economic development is an important reason for the growth of carbon emissions. The improvement of energy efficiency has a significant impact on reducing carbon emissions. Therefore, this paper suggested to reduce carbon emissions by developing a low carbon economy, improving energy efficiency and developing non-fossil fuels. First, to achieve the goal of reducing carbon emissions, China must develop low-carbon economy, transform the traditional mode of economic development, and gradually realize the low-carbon economy of China's economy. Second, improving energy efficiency is a direct, effective and enduring means to reduce carbon emissions. To enhance energy efficiency is not only in line with the need of China's economic growth mode to transform itself from extensive economy to intensive economy, but also helps reduce the excessive dependence of economic growth on energy. Third, since the energy structure in China in mainly built on coal, it is necessary to achieve the development of non-fossil energy by increasing clean energy sources, changing the coal-based energy structure and reducing coal consumption.

In the dilemma of "development and emission reduction", China should continue to follow the path of resource-saving and environment-friendly development so as to actively respond to climate change and achieve energy, economy and environment Coordinated development.

REFERENCES

[1] Du Qiang, Chen Qiao, Yang Yue. Prediction of Carbon Emissions in Chinese Provinces Based on Logistic Prediction Model [J]. Yangtze River Basin Resources and Environment, 22 (2): 143-151.

[2] Loehman A, Reinhardt E, Riley L. Wildland fire emissions, carbon and climate: Seeing the forest and the trees-A cross-scale assessment of wildfire and carbon dynamics in fire-prone, forested ecosystems [J]. Forest Ecology and Management, 2014, 317 (1): 9-19.

[3] Zhao Xi, Qi Jianmin, Liu Guangwei. China's Carbon Emission Prediction Based on Discrete Second - order Difference Algorithm [J]. Journal of Arid Land Resources and Environment, 2013, 27(1): 63-69.

[4] Song Jiekun. China's Carbon Emission Prediction Model Based on Support Vector Regression [J]. Journal of China University of Petroleum Natural Science Edition2012, 36 (1): 182-187.

[5] Bangzhu Z, Yiming W. Carbon price forecasting with a novel hybrid ARIMA and least squares support vector machines methodology [J]. Omega, 2013, 41 (3): 517-524.

[6] Ji Jianyue, Kong Jiaojiao. Carbon Transport Prediction of Marine Transportation Based on STIRFDT Model [J]. Science and Technology Management Research, 2012 (6): 79-81.

[7] PAO H_T, TSAI C-M. Modeling and forecasting the CO2 emissions, energy consumption, and economic growth in Brazil [J], Energy, 2011, 36(5): 2450-2458.

[8] MARCOTULLIO P J, Marshall J D. Potential futures for road transportation CO2 emissions in the Asia Pacific [J], Asia Pacific Viewpoint, 2007, 48(3): 355-377.

[9] Liu Jiancui. Energy Saving Potential and Carbon Emission Forecast of China's Transportation Sector [J]. Resource Science, 2011, 33 (4): 640-646.