Prediction of Carbon Peak in Shaanxi Province and Its Cities

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Abstract. Shaanxi Province is an important energy province in China. There are great differences among different regions in resource endowment, industrial advantages and economic development level. Predicting the peak value is conducive to the early realization of the carbon peak goal in Shaanxi Province and the overall green transformation of economic and social development. On this basis, the IPCC method was used to calculate the carbon emissions of Shaanxi Province and other cities, and the EKC method was used to predict the peak carbon emissions. The results showed that:(1) CO2 emissions in Shaanxi Province showed an upward trend from 2011 to 2020, reaching 276,037,500 tons in 2020, in which coal accounted for the largest proportion of CO2 emissions. The largest carbon emission is Yulin City, the least is Ankang City. (2) Shaanxi Province will reach its carbon emission peak in 2033. With the exception of Xi 'an, Tongchuan and Shangluo, all cities will reach their carbon peak by 2030. The earliest peak is Weinan City, the latest is Tongchuan City.

Keywords: peak carbon dioxide emissions · environmental kuznets curve · Shaanxi province

1 Introduction

The acceleration of the industrialization process of all countries in the world has brought a large amount of greenhouse gas emissions, resulting in global climate change (Zhang Chengdong, Song Deyong, 2011; Solomon S, Plattner G K, Knutti R, et al., 2009), carbon emission carbon neutrality goal is of great significance for China and the world. Under this goal, Shaanxi Province faces a comprehensive transformation from the traditional development mode of high energy consumption and high emission to the green, low-carbon and high-quality development mode. This paper analyzes the current situation and existing problems of the development of low carbon economy and society in Shaanxi Province, calculates the carbon emission scale of Shaanxi Province and each city, predicts the carbon peak value, and then studies the realization path of the carbon peak value of each district in Shaanxi Province, and puts forward the corresponding countermeasures.

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2 Literature Review

At present, the research on carbon emission measurement methods mainly uses measurement method, material balance algorithm, emission coefficient method, model method and life cycle method. The measurement method refers to the method of direct measurement with instruments and equipment (Zhu Xiaoli, 2014) [4]. Material balance algorithm is a method for quantitative analysis of materials used in the production process based on the law of conservation of mass (Li Yu and Li Hui, 2014) [5]. Emission coefficient method, also known as emission factor method, calculate carbon emissions in energy consumption (Liu Chang, Su Yun and Li Lingling, 2020) [6]. The carbon emission coefficient is also very certain. (Ju Ying and Chen Yi, 2015; Maupan et al., 2019) [7]. Carbon peak prediction mainly includes EKC model, scenario analysis, etc. Lin Boqiang and Jiang Zhujun (2009) [8] The EKC model is used to predict that China will reach its carbon peak around 2020. Wang Yong, Bi Ying and Wang Endong (2017) [9] Take the major industry of carbon emission in China as the research object, and use the extended STIRPAT model to predict the scenario of industrial carbon emission peak. Lin and Huang (2009) [10] used the grey prediction model to estimate the future trend and peak time of CO2 emissions in Taiwan from 2010 to 2012.

At present, scholars choose the carbon emission peak prediction model according to their own actual research needs. In this study, according to the availability of data of each city, the EKC model was selected to predict carbon emissions of Shaanxi Province and cities within the province.

3 Data and Methodologies

3.1 Study Area

Shaanxi Province, located in the middle reaches of the Yellow River in the eastern part of Northwest China, covers an area of 205,600 square kilometers, accounting for 2.1 percent of China's total land area. Coal resources are widely distributed in Shaanxi Province. In 2020, Shaanxi Province ranked third in coal production, first in oil production and first in natural gas production, making it a relatively high production level in China.

3.2 Data Source

The data sources of this study are mainly statistical yearbooks of Shaanxi Province and various cities, and 2011–2020 is selected as the research period.

The reference coefficient and average low calorific value of various energy conversion standard coals in Shaanxi Province adopt GB/T2589–2008 national standard. The data of carbon emission coefficient in this study are sorted out as shown in Table 1.

3.3 Research Methodology

3.3.1 Carbon Emissions Calculation

According to the accounting method recommended in the inventory Guide published by IPCC (2006), the calculation formula of carbon emission coefficient of various energy

Table 1. Carbon emission coefficients of various energy sources

Energy type	Raw coal	Natural gas	Crude oil	gasoline	kerosene	Diesel oil	Fuel oil	Electric power
Carbon emission coefficient	1.9003 (t CO_2/t)	2.1622 (kgCO_2/m^3)	3.0202 (t CO_2/t)	2.9251 (t CO_2/t)	3.0179 (t CO_2/t)	3.0939 (t CO_2/t)	3.1705 (t CO2/t)	0.8696 (t CO2/MWh)

sources is as follows:

$$EF_i = H_i \times I_i \times O_i \times \frac{44}{12} \tag{1}$$

where Hi is the low level heat generation of the ith energy source (kJ/kg); Ii is the carbon content per unit calorific value of that energy source (tC/TJ); Oi is the carbon oxidation factor of the ith energy source (%); 44/12 indicates the conversion factor of carbon to CO2.

The carbon emission accounting formula is as follows:

$$C_p = \sum\nolimits_i C_i \times EF_i \tag{2}$$

where CP is CO2 emissions (million tons); Ci is the consumption of the ith energy source; EFi is the CO2 emission factor of the ith energy source (tCO2/t).

3.3.2 Peak Carbon Emission Projection Model.

(1) EKC Model Construction.

In 1991, Grossman and Krueger of Princeton University proposed the environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1997) [11, 12]. EKC refers to an inverted U-shaped curve between pollutant emissions and per capita gross national product (GDP) (Selden and Song, 1995) [13].

$$LPCO_2 = \beta_0 + \beta_1 LYP + \beta_2 (LPY)^2 + \varepsilon \tag{3}$$

(2) Inflection Point of EKC Curve

On the basis of EKC showing an inverted U shape, the inflection point of the carbon dioxide Kuznets curve can be calculated. The specific formula is:

$$\xi = \exp(-\beta_1/(2 \times \beta_2) \tag{4}$$

(3) Timing Projection of CO2 Emission Inflection Point

Based on the overall urban planning of Shaanxi Province, relevant policies of Shaanxi Province and case studies, the change rate of GDP and total population at the carbon peak in the future is obtained.

Table 2. CO2 emissions in Shaanxi Province from 2011 to 2020 Unit: ten thousand tons

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total carbon emissions	19394.4	20343.59	22029.79	22202.01	22427.47	23826.2	24398.75	25293.99	27402.51	27603.75

4 Results and Analysis

4.1 Carbon Emission Calculation Results

4.1.1 Carbon Emission Results in Shaanxi Province.

The calculation results of CO2 emissions in Shaanxi Province during 2011–2020 are shown in Table 2.

From the perspective of total carbon emissions, CO2 emissions in Shaanxi Province showed an upward trend from 2011 to 2020, with an average growth rate of 4.2%, reaching 276,037,600 tons in 2020. From 2019 to 2020, the growth rate of CO2 emissions in Shaanxi Province slowed down.

4.1.2 Carbon Emission Measurement Results of Cities in Shaanxi Province.

Since Shaanxi Province does not have direct energy consumption data for each city, carbon emission is calculated by three departments, and the final carbon emission data is shown Table 3 below:

As can be seen from the change of total carbon emissions of cities in Shaanxi Province, except Weinan, carbon emissions of other cities are on the rise. Yulin saw the largest increase in total carbon emissions.

Table 3. CO2 emissions of cities in Shaanxi Province during 2011–2020 Unit: ten thousand tons

Year	Weinan	Tongchuan	Xianyang	Baoji	Xi 'an	Ankang	Shangluo	Hanzhong	Yulin	Yan'an
2011	1581.16	252.6	540.34	670.87	727.56	67.05	99.72	377.63	1484.01	426.94
2012	2290.86	244.48	652.18	681.34	799.56	79.09	94.65	388.3	1638.25	439.15
2013	1108.86	262.95	666.05	828.11	999.61	83.72	102.75	470.53	2719.78	527.33
2014	2726.65	245.29	675.79	764.88	1073.19	86.93	117.36	434.94	2179.4	489.12
2015	2839.52	232.23	729.08	693.77	1123.98	91.82	121.29	406.28	2373.29	357.51
2016	1296.43	236.21	726.01	698.22	1201.38	99.39	125.52	473.29	2555.72	391.11
2017	1290.55	226.49	496.93	857.26	1487.33	104.8	129.66	498.25	2736.22	431.96
2018	1291.3	210.03	539.39	841.12	1541.26	114.67	128.36	515.72	2745.18	493.48
2019	1388.58	262.85	742.65	877.04	1596.16	120.96	129.99	495.45	3144.76	661.12
2020	1494.31	294.31	733.27	875.02	1662.07	120.92	123.64	499.78	3437.32	719.75

Table 4. OLS estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
c	-20.331	16.599	-1.225	0.267
LnPY	5.214	3.089	1. 688	0.142
Ln^2PY	-0.222	0.144	-1.545	0.173
R-squared	0.987	Adjusted R-squared		0.984
		Prob(F-statistic)		
F-statistic	275.753			0.000000

4.2 Carbon Peak Calculation Results

4.2.1 Prediction Results and Analysis of Carbon Peak in Shaanxi Province.

(1) Model Estimation

OLS method was used to estimate the parameters of the model, and the regression results were shown in Table 4.

The regression model established according to Table 9 is:

$$LPCO_2 = 31.288 + 7.2808LYP - 0.3195(LPY)^2$$

(2) Peak Prediction.

The inflection point of the Kuznets curve of carbon dioxide environment in Shaanxi province is calculated. According to formula 4, the following is obtained:

$$\xi = \exp(-\beta_1/(2 \times \beta_2) = 125900$$

According to Formula 4, carbon dioxide emissions reach the maximum when per capita GDP reaches 125,900 yuan, which is the theoretical inflection point of carbon emissions in Shaanxi Province. Carbon dioxide emissions totaled 292.5 million tons. Shaanxi Province will reach its carbon peak in 20344.2.2 Prediction results and analysis of carbon peak in Shaanxi Province.

OLS method was used to estimate the parameters of the model, and the established regression model and prediction results were shown in Table 5.

Table 5. Prediction results of carbon peak in Shaanxi Province

region	Regression model	Peak time Per capita GDP (yuan)	Reach peak year	Peaking quantity (10,000 tons)
Xi'an	$LPCO_2 = -99.923+18.018LYP-0.7537(LPY)^2$	155287.2	2035	2349.31
Tongchuan	$LPCO_2 = -7.719+2.2792LYP-0.0966(LPY)^2$	132866.67	2040	306.43
Baoji	$LPCO_2 = -12.526+3.111LYP-0.1375(LPY)^2$	68478.15	2021	874.07
Xianyang	$LPCO_2 = -35.25+7.7623LYP-0.3608(LPY)^2$	68478.15	2018	665.00
Weinan	$LPCO_2 = -322.89+61.419LYP-3.1353(LPY)^2$	27853.95	2017	2992.84
Yan'an	$LPCO_2 = 163.67+29.605LYP-1.287(LPY)^2$	98869.29	2027	721.80
Yulin	$LPCO_2 = -156.72+27.833LYP-1.1751(LPY)^2$	139082.4	2025	3263.75
Hanzhong	$LPCO_2 = -9.7108+2.7579LYP-0.1188(LPY)^2$	110642.24	2023	552.08
Ankang	$LPCO_2 = -47.401+9.6195LYP-0.4432(LPY)^2$	51654.06	2024	120.02
Shangluo	$LPCO_2 = -12.526+3.111LYP-0.1375(LPY)^2$	78647.2	2037	234.19

5 Conclusions and Recommendations

According to these projections, most urban areas in Shaanxi province could meet the national target of peaking by 2030. Xi 'an, Tongchuan and Shangluo are expected to exceed the 2030 target. The imbalance of regional low-carbon development in Shaanxi

Province is an objective reality. There are many reasons for this imbalance. Therefore, reasonable development strategies should be adopted according to the characteristics of different regions.

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