Drivers of the Peaking and Decoupling Between CO2 Emissions and Economic Growth Around 2030 in China

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Drivers of the Peaking and Decoupling between CO_2 Emissions and Economic Growth around 2030 in China

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Abstract: Reaching the peak of carbon dioxide emissions is the basis and premise of carbon neutrality. In this paper, the factor decomposition model was used to analyze the influencing factors and effects of carbon dioxide emissions. Causal chain model of elastic decoupling was established. The historical decoupling state between carbon dioxide emissions and economic growth and the decoupling effect of its influencing factors were analyzed. The prediction model of carbon dioxide emissions was used to explore the change trend of China's carbon dioxide emissions and its peak in the short and medium term in the future. The elastic decoupling trend between carbon dioxide emissions and economic growth was predicted. The results show that economic growth is the main force driving carbon dioxide emissions. Both energy intensity and energy consumption structure have a strong inhibiting effect on carbon dioxide emissions except for a few years, but the former has a more significant inhibiting effect than the latter. In general, the elastic decoupling between carbon dioxide emissions and economic growth has experienced a state from weak decoupling to growth linkage and then to weak decoupling. And this weak decoupling trend will continue to increase in the short and medium term. During the 14th Five-year and 15th Five-year period, if the average annual economic growth rate will be maintained at 4.61% to 5.85%, and energy intensity will be reduced by 16.14% to 18.37%, and the proportion of non-fossil energy in the energy consumption structure at the end of the 14^{th}, 15^{th} and 16^{th} Five-Year Plan period will be around 19.9%, 23.2% and 26.1%, respectively, then the intensity of carbon dioxide emissions will continue to decline. It is expected to reach the peak of carbon dioxide emissions between 10,453 and 10,690 billion tons from 2025 to 2027. And the earlier the peak time is, the smaller the peak is, which would provide valuable time for carbon neutrality and room to reduce carbon dioxide emissions in the medium and long term.

Key words: carbon emissions; peaking; elastic decoupling; factor decomposition; Markov chain

1. Introduction

Peaking carbon dioxide emissions is not only one of China's international commitments in global climate negotiations, but also an inevitable choice for China to achieve structural transformation and high-quality development. China has made important contributions to adopting the Paris Agreement and has made active efforts toward implementing it. In November 2014, the Chinese government announced that China plans to peak carbon dioxide emissions around 2030 and will strive to reach the peak as soon as possible in the China-US Joint Statement on Climate Change. In September 2020, the Chinese government announced at Climate Ambition Summit that China would scale up its nationally determined contributions and adopt more vigorous policies and measures. We aim to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. China will lower its carbon dioxide emissions per unit of GDP by over 65 percent from the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 25 percent, and so on. In December 2020, the Central Economic Work Conference further pointed out that " China will seize time to formulate an action plan for peaking carbon dioxide emissions before 2030. The country will support areas with favorable conditions to peak the emissions ahead of the schedule, according to the statement released after the annual Central Economic Work Conference. China will still adjust and optimize industrial structure and energy structure, promote coal consumption to peak as soon as possible, vigorously develop new energy, and improve the dual control system of energy consumption." Peaking carbon dioxide emissions is an important turning point in the transformation of economic development mode and an important node in the eventual realization of carbon neutrality. The earlier the peak time, the more conducive to achieving the goal of carbon neutrality. Therefore, in the "*14th Five-Year Plan*" and beyond in the medium and long term, our country must attach great importance to adjusting industrial structure and strengthening technological progress to save energy and improve efficiency. It is important to encourage green, low-carbon ways of life and production, and seek development opportunities and impetus from green development. Peaking carbon emissions before 2030 will force a green and low-carbon transformation of the energy structure. Therefore, exploring the path of carbon emissions peaking and the further decoupling between it and economic growth is of great significance to achieving high-quality development.

There are many methods to explore the influencing factors of carbon emissions, such as structural decomposition method, “IPAT” model, STIRPAT model, Granger causality test and so on. The IPAT equation means that the environment will be affected by the population, wealth, and technological level (Ehrlich and Holdren, 1971). Haroldo et al. (2019) analyzed the impact of population density on urban carbon dioxide emissions. However, this model has certain limitations and can only analyze the proportional changes in the environment and its influencing factors. Therefore, scholars have expanded the model to explore the relationship between carbon emissions and its influencing factors (Ang and Zhang, 1998). In addition, many scholars have added other economic and social factors to analyze this model (Lin et al., 2016). Based on the analysis of the majority of scholars, indicators such as the level of urbanization, industrial structure, and energy utilization will all have a significant impact on carbon emissions (Wang et al., 2019). Du et al. (2018) studied the driving factors of energy-related CO_2 emissions changes in China’s energy-intensive industries based on the logarithmic mean index (LMDI) method. Quan et al. (2020) also used the LMDI decomposition model to decompose the factors affecting the carbon emissions of China’s logistics industry from five aspects: carbon emission coefficient, population size, and energy structure, and concluded that energy structure is the main limiting factor affecting carbon emissions in the logistics industry. Jiang and Han (2019) compared the carbon intensity of different countries based on the level of economic development and the perspective of industrial transfer. Wang and He (2020) used the LMDI method to decompose the influencing factors of carbon dioxide emissions in China’s provinces and found that different influencing factors have different effects on carbon emissions in different regions.

Exploring the peak of carbon emissions is essentially studying the maximum amount of carbon emissions that can be reached in the future, and the time interval during which changes in carbon emissions will reverse. Domestic and foreign scholars' prediction methods for peak carbon emissions can be roughly classified into three categories. One is to judge whether there is an inflection point through the EKC model. If there is an inflection point, it means that there is a peak in carbon emissions (Lin and Jiang , 2009). The other is to first decompose the influencing factors of carbon emissions. Among them, the models that can be used include STIRPAT model, IPAT model and logarithmic average Di decomposition model, etc., and then combined with scenario analysis to predict the future carbon emission trend (Liu et al., 2018). Part of the research will also directly use scenario analysis to predict future carbon emissions (Guan et al., 2008; Liu et al., 2018; Li, 2019; Zhang, 2020). Tian et al. (2019) analyzed the carbon footprint of China's industrial supply chain based on a life cycle assessment model of input and output. Huang et al. (2019), Li et al. (2018), and Zhang (2017) related to the third prediction method that constructs a system model to directly predict carbon emissions. Such methods include gray prediction models and CGE models. Lu et al. (2020) used the back propagation neural network (BP) model optimized by the particle swarm optimization (PSO) algorithm to predict the future carbon emissions of the heavy chemical industry. The results showed that the energy processing industry, the steel industry and the building materials industry during the forecast period. The proportion of medium carbon emissions accounts for a larger proportion of the carbon emissions of the heavy chemical industry. Li et al. (2021) established a prediction model through system dynamics in order to accurately predict the peak of carbon emissions from the provincial construction industry, and obtained a more reasonable low-carbon development route map.

Peaking carbon emissions is based on the decoupling of economic growth and carbon dioxide emissions. Regarding the research on the decoupling between carbon emissions and economic growth, Tapio (2005) established the Tapio decoupling indicator system to analyze the decoupling between the economic growth of the European transportation industry from 1970 to 2001. According to the decoupling value, the state of the decoupling elasticity is divided into connection, decoupling, and negative decoupling. Domestic scholars' research on decoupling theory mainly focuses on energy and environment. Qi et al. (2015) applied it at the provincial level. Guo et al. (2017) applied it at the regional level. Ma (2016) applied it at aspect of life. Zhao (2006) used a relative "decoupling" and "recoupling" theories and concluded that China's economy and energy have been in a weak decoupling relationship since the early 1980s, and there has been an expansionary recoupling trend in recent years. Liu (2014) used the elastic decoupling method to analyze the weak decoupling of carbon emissions and economic growth in Henan Province from 2000 to 2010. Yu et al. (2020) used the Tapio decoupling model to examine the relationship between the economic growth of low-carbon pilot cities. It is proposed that for low-carbon mature cities, vigorously developing renewable energy and increasing R&D investment are effective ways to reduce emissions. Jie et al. (2020) used a system dynamics model to assess the potential of carbon decoupling in China's energy mining industry. From 2020 to 2030, it is estimated that China's coal, oil, and natural gas extraction industry will show a weak decoupling effect under the baseline scenario from carbon emissions and GDP growth. And there will be a strong decoupling effect from 2024 to 2030 under the planning scenario.

In summary, the existing literature has conducted research on peaking carbon emissions and its decoupling from economic growth, which provides a useful reference for the study of this article. Few documents have studied and judged the issue of peaking carbon emissions from the historical evolution of economic growth, energy intensity, and energy consumption structure. This article intends to analyze the influencing factors and effects of China's carbon dioxide emissions, and predict economic growth, energy intensity and primary energy consumption structure in scenarios. It intends to construct a carbon dioxide emissions prediction model from the perspective of economic growth, energy intensity and energy consumption structure, and combine it with scenario analysis. The change trend of China's carbon dioxide emissions in the medium and long term in the future will be predicted. The peak of carbon emissions will be researched and judged. The elastic decoupling between carbon emissions and economic growth will be predicted. It provides scientific reference for the formulation of action plan for peaking carbon emissions before 2030.

2. Carbon emission prediction model construction

2.1 Factor decomposition model of carbon emissions

In this paper, the Logarithmic Mean Divisia Index (LMDI) of carbon emissions was constructed from the perspectives of population size, economic development level, energy intensity, and carbon intensity of energy consumption:

$$C=\sum_{j=1}^{n} P\times\frac{Y}{P}\times\frac{E}{Y}\times\frac{E_j}{E}\times\frac{C_j}{E_j}=\sum_{j=1}^{n} P\times YP\times I\times SE_j\times F_j \tag{1}$$

Where, j represents the type of energy. *P*, *Y*, *E*, and *C* represent the population, GDP, energy consumption and carbon dioxide emissions, respectively. Then, $YP=Y/P$ represents per capita GDP. $I=E/Y$ represents energy intensity. $SE_j=E_j/E$ represents the proportion of j energy consumption in total primary energy consumption. F_j is the carbon emission coefficient of the j -th primary energy. Unless there is a major technological change, F_j is a constant. Therefore, the carbon emissions coefficient per unit energy is determined by the energy consumption structure.

This model can be used to determine the carbon increase factors and carbon reduction factors. The comprehensive effect of carbon emissions from energy consumption is:

$$\Delta C=\Delta C_P+\Delta C_{YP}+\Delta C_I+\Delta C_{SE}+\Delta C_F \tag{2}$$

In the above formula, the effect value of each decomposition factor is expressed as:

$$\Delta C_P=\sum_{j=1}^{n}\omega\cdot\ln\frac{P^t}{P^0} \tag{3}$$

$$\Delta C_{YP} = \sum_{j=1}^{n} \omega \cdot \ln \frac{YP^t}{YP^0} \tag{4}$$

$$\Delta C_{I} = \sum_{j=1}^{n} \omega \cdot \ln \frac{I^t}{I^0} \tag{5}$$

$$\Delta C_{SE} = \sum_{j=1}^{n} \omega \cdot \ln \frac{SE_j^t}{SE_j^0} \tag{6}$$

$$\Delta C_{F} = \sum_{j=1}^{n} \omega \cdot \ln \frac{F_j^t}{F_j^0} \tag{7}$$

Among them, t represents the analysis period, 0 represents the base period, and the common weight in the above formula is:

$$\omega = (C_j^t - C_j^0) \big/ (\ln C_j^t - \ln C_j^0) \tag{8}$$

Since the primary energy consumption carbon emission coefficient is constant during the sample period, that is $F_j^0 = F_j^t$, therefore, $\Delta C_F = 0$. The comprehensive effect of energy consumption on carbon emissions is further expressed as:

$$\Delta C = \Delta C_P + \Delta C_{YP} + \Delta C_I + \Delta C_{SE} \tag{9}$$

According to formulas (3) to (6), the influencing factors of carbon emissions, and show the contribution of the influencing factors of carbon emissions was decomposed and analyzed.

2.2 Elastic decoupling model of carbon emissions

The Tapio model is used to measure the elastic decoupling index between carbon dioxide emissions and economic growth:

$$e_{(C,Y)} = \frac{\Delta C}{C} \bigg/ \frac{\Delta Y}{Y} = \left(\frac{\Delta E}{E} \bigg/ \frac{\Delta Y}{Y} \right) \times \left(\frac{\Delta C}{C} \bigg/ \frac{\Delta E}{E} \right) = e_{(E,Y)} \times e_{(C,E)} \tag{10}$$

Among them, $e_{(C,Y)}$ is the ratio of the growth rate of carbon emissions to the growth rate of GDP, which represents the elastic decoupling index between carbon emissions and economic growth; $e_{(E,Y)}$ is the ratio of energy consumption growth rate to GDP growth rate, which represents the elastic decoupling index between energy consumption and economic growth; $e_{(C,E)}$ is the ratio of the growth rate of carbon emissions to the growth rate of energy consumption, and represents the elastic decoupling index between carbon emissions and energy consumption.

The effect of decoupling index of carbon emissions based on LMDI decomposition method is expressed as:

$$\Delta e_{(C,Y)} = \Delta e_{(C,Y)}^{E} + \Delta e_{(C,Y)}^{Y} \qquad (11)$$

Among them, $\Delta e_{(C,Y)}$ represents the change of the carbon emission elasticity index, $\Delta e_{(C,Y)}^{EY} = \frac{e_{(C,Y)}^{t} - e_{(C,Y)}^{0}}{\ln e_{(C,Y)}^{t} - \ln e_{(C,Y)}^{0}} \times \ln \frac{e_{(E,Y)}^{t}}{e_{(E,Y)}^{0}}$ indicates the impact of the elastic decoupling between energy consumption and economic growth on the decoupling of carbon emissions, $\Delta e_{(C,Y)}^{CE} = \frac{e_{(C,Y)}^{t} - e_{(C,Y)}^{0}}{\ln e_{(C,Y)}^{t} - \ln e_{(C,Y)}^{0}} \times \ln \frac{e_{(C,E)}^{t}}{e_{(C,E)}^{0}}$ indicates the impact of the elastic decoupling of carbon dioxide emissions from energy consumption on the decoupling of carbon emissions.

2.3 Prediction model of carbon dioxide emissions

Due to the complicated change trend of population size, population factors are not considered in the built model for the time being, and a carbon emission prediction model is constructed:

$$C^{t} = Y^{t} \times \frac{E^{t}}{Y^{t}} \times \left(\sum_{j=1}^{n} \frac{E_{j}^{t}}{E^{t}} \times \frac{C_{j}^{t}}{E_{j}^{t}} \right) = Y^{0} \left(1 + r_{Y}\right)^{t} \times I_{0} \left(1 - r_{I}\right)^{t} \times \left(\sum_{j=1}^{n} SE_{j} \times F_{j} \right) \qquad (12)$$

Among them, 0 represents the base period, and t is the final period period. $[0, t]$ represents the time interval for analysis. Y^{0} and Y^{t} are the base period and final GDP respectively, r_{Y} is the average annual growth rate of GDP during the analysis period. $I_{0} = E_{0}/Y_{0}$ is the base period energy intensity, r_{I} it is the average annual rate of decline in energy intensity during the analysis period. The symbols of other parameters are the same as before.

3. Data source and parameter determination

3.1 Source of data

The data used are from the "China Energy Statistical Yearbook", "China Statistical Yearbook" and "New China Sixty Years Collection" over the years, and the sample period is 2000-2019. Since my country first proposed in 2009 that my country's carbon dioxide intensity per unit of GDP in 2020 will be 45% lower than that in 2005, the GDP will be at a constant price in 2005, and the national carbon dioxide emissions will be calculated using the carbon emission coefficient method. The carbon emission coefficients of energy coal, oil, and natural gas are 0.7476 kg carbon/kg standard coal, 0.5825 kg carbon/kg standard coal, and 0.4435 kg carbon/kg standard coal, respectively, using the recommended values of the National Development and Reform Commission.

3.2 Parameter determination

The parameters in the carbon emission prediction model are determined below. The GDP in 2019 was 60,671.593 billion yuan (constant prices in 2005), and the energy intensity in 2019 was 0.8027 tons of standard coal per 10,000 yuan.

3.2.1 Gross Domestic Product (GDP)

From the new normal stage to the current period of high-quality development, my country's GDP growth rate has slowed down, hovering at around 7%. The quadratic parabolic model is used to predict GDP (as shown in Table 1). Based on the four scenarios of 2000-2019, 2005-2019, 2010-2019, and 2015-2019, the forecast results of GDP from 2020 2035 (constant prices in 2005) are shown in Table 1.

Table 1. Forecast of GDP from 2020 to 2035 Unit: 100 million yuan

years	The first scenario	The second scenario	The third scenario	The fourth scenario
2020	650238.1	641235.7	643647.8	644326.6
2021	690506.8	677778.8	681678.3	682532.6
2022	732027.2	715113.4	720769.9	721742.6

2023	774799.3	753239.8	760922.6	761956.6
2024	818823.0	792157.8	802136.3	803174.7
2025	864098.4	831867.5	844411.1	845396.7
2026	910625.5	872368.8	887747.0	888622.8
2027	958404.2	913661.8	932144.0	932852.9
2028	1007434.6	955746.5	977602.0	978087.1
2029	1057716.7	998622.8	1024121.1	1024325.2
2030	1109250.5	1042290.8	1071701.3	1071567.4
2031	1162035.9	1086750.4	1120342.5	1119813.6
2032	1216073.0	1132001.7	1170044.8	1169063.8
2033	1271361.8	1178044.7	1220808.2	1219318.0
2034	1327902.3	1224879.3	1272632.7	1270576.3
2035	1385694.4	1272505.6	1325518.2	1322838.5
"*Fourteenth Five-Year*" Average annual growth rate	0.0585	0.0534	0.0558	0.0558
"*Fifteenth Five-Year*" Average annual growth rate	0.0512	0.0461	0.0488	0.0486
"*Sixteenth Five-Year*" Average annual growth rate	0.0455	0.0407	0.0434	0.0430

3.2.2 Energy intensity

Exponential model was used to predict energy intensity. The results are shown in Table 2. It can be further obtained that in the "*fourteenth five-year*", "*fifteenth five-year*", and "*sixteenth five-year*" energy intensity scenarios. The reduction rate of energy intensity is 12.75%, 18.20%, 18.37%, and 16.14%, respectively.

Table 2. The predicted value of energy intensity from 2020 to 2035 Unit: kgCO_2/kg tec

years	The first scenario	The second scenario	The third scenario	The fourth scenario
2020	0.8273	0.7618	0.7611	0.7705
2021	0.8050	0.7318	0.7309	0.7438
2022	0.7834	0.7030	0.7018	0.7181
2023	0.7623	0.6753	0.6739	0.6933
2024	0.7418	0.6487	0.6470	0.6693
2025	0.7218	0.6231	0.6213	0.6461

2026	0.7024	0.5986	0.5966	0.6238
2027	0.6835	0.5750	0.5728	0.6022
2028	0.6651	0.5524	0.5501	0.5814
2029	0.6472	0.5306	0.5282	0.5613
2030	0.6298	0.5097	0.5072	0.5419
2031	0.6129	0.4896	0.4870	0.5231
2032	0.5964	0.4704	0.4676	0.5050
2033	0.5803	0.4518	0.4490	0.4876
2034	0.5647	0.4340	0.4311	0.4707
2035	0.5495	0.4169	0.4140	0.4544

3.2.3 Primary energy consumption structure

A Markov forecast model of primary energy consumption structure is constructed:

$$\left(SE_1^t, SE_2^t, SE_3^t, SE_4^t\right) = \left(SE_1^0, SE_2^0, SE_3^0, SE_4^0\right) P^t \qquad (13)$$

Among them, SE_1^t , SE_2^t , SE_3^t , SE_4^t are the predicted values of the proportion of coal, oil, natural gas and non-fossil energy in the total primary energy consumption during the reporting period, respectively. SE_1^0 , SE_2^0 , SE_3^0 , SE_4^0 are the proportions of coal, oil, natural gas, and non-fossil energy in the total primary energy consumption in the base period respectively. The primary energy consumption structure in the base period in 2019 is $\left(SE_1^0, SE_2^0, SE_3^0, SE_4^0\right) = \left(57.7\%, 18.9\%, 8.1\%, 15.3\%\right)$. P is the average one-step transition probability matrix per year during the analysis period. And its determination is also calculated from the geometric average of the one-step transition probability matrix year by year during the analysis period. That is, $P^t = P_1 \times P_2 \times \cdots \times P_t$, where P_i is the one-step transition probability matrix from the i-1year to the i year.

The related data during 2000-2019, 2005-2019, 2010-2019, and 2015-2019 are as sample data. Using the above Markov forecasting model, the structure of China's primary energy consumption from 2020 to 2035 is predicted as shown in Table 3.

Table 3. Prediction of primary energy consumption structure in various scenarios Unit:%

years	The first scenario	The second scenario	The third scenario	The fourth scenario

	Coal	oil	natural gas	non-fossil energy	Coal	oil	natural gas	non-fossil energy	Coal	oil	natural gas	non-fossil energy	Coal	oil	natural gas	non-fossil energy
2020	57.2	18.7	8.4	15.7	56.8	18.9	8.5	15.8	56.6	19.0	8.5	15.9	56.2	19.0	8.7	16.1
2021	56.6	18.6	8.7	16.1	55.9	19.0	8.9	16.2	55.4	19.2	9.0	16.4	54.7	19.1	9.2	16.9
2022	56.1	18.4	9.0	16.4	55.0	19.0	9.3	16.7	54.3	19.3	9.4	16.9	53.3	19.2	9.7	17.7
2023	55.6	18.3	9.3	16.8	54.1	19.1	9.7	17.1	53.3	19.4	9.9	17.4	52.0	19.4	10.3	18.4
2024	55.1	18.2	9.5	17.2	53.3	19.1	10.0	17.5	52.3	19.6	10.3	17.9	50.6	19.5	10.8	19.2
2025	54.6	18.0	9.8	17.5	52.5	19.1	10.4	18.0	51.2	19.7	10.7	18.3	49.3	19.6	11.3	19.9
2026	54.2	17.9	10.1	17.9	51.7	19.2	10.8	18.4	50.3	19.8	11.1	18.8	48.0	19.7	11.8	20.6
2027	53.7	17.7	10.4	18.2	50.9	19.2	11.2	18.8	49.3	19.9	11.6	19.2	46.8	19.8	12.2	21.2
2028	53.2	17.6	10.7	18.5	50.1	19.2	11.6	19.1	48.4	20.0	12.0	19.6	45.6	19.9	12.7	21.9
2029	52.8	17.4	10.9	18.9	49.3	19.2	11.9	19.5	47.5	20.1	12.4	20.0	44.4	19.9	13.1	22.5
2030	52.3	17.3	11.2	19.2	48.6	19.2	12.3	19.9	46.6	20.2	12.8	20.4	43.2	20.0	13.6	23.2
2031	51.9	17.2	11.5	19.5	47.8	19.3	12.7	20.2	45.7	20.3	13.2	20.7	42.1	20.1	14.0	23.8
2032	51.4	17.0	11.8	19.8	47.1	19.3	13.0	20.6	44.9	20.4	13.6	21.1	41.0	20.2	14.4	24.4
2033	51.0	16.9	12.0	20.1	46.4	19.3	13.4	20.9	44.1	20.5	14.0	21.4	40.0	20.3	14.8	25.0
2034	50.6	16.7	12.3	20.4	45.7	19.3	13.8	21.2	43.3	20.6	14.4	21.7	38.9	20.4	15.2	25.5
2035	50.2	16.6	12.6	20.7	45.0	19.3	14.1	21.5	42.5	20.7	14.8	22.0	37.9	20.5	15.6	26.1

In the first scenario, the prediction of primary energy consumption structure shows that along the historical evolution trend, the proportion of non-fossil energy will be 19.2% , and the proportion of coal will show an overall downward trend by 2030. In the second scenario, the proportion of non-fossil energy will be 19.9% , and the proportion of coal will decline even more by 2030. In the third scenario, the proportion of non-fossil energy will be 20.4% , and the proportion of coal will reach 46.6% by 2030. In the fourth scenario, the proportion of non-fossil energy will be 23.2% , and the proportion of coal will decline the most by 2030.

4. Empirical analysis and forecast of China's carbon dioxide emissions

4.1 The historical evolution trend of carbon dioxide emissions and its influencing factors

China's resource endowment determines that coal is still the main source of energy consumption. The historical change trend of carbon dioxide emissions from various primary energy consumption is shown in Figure 1.

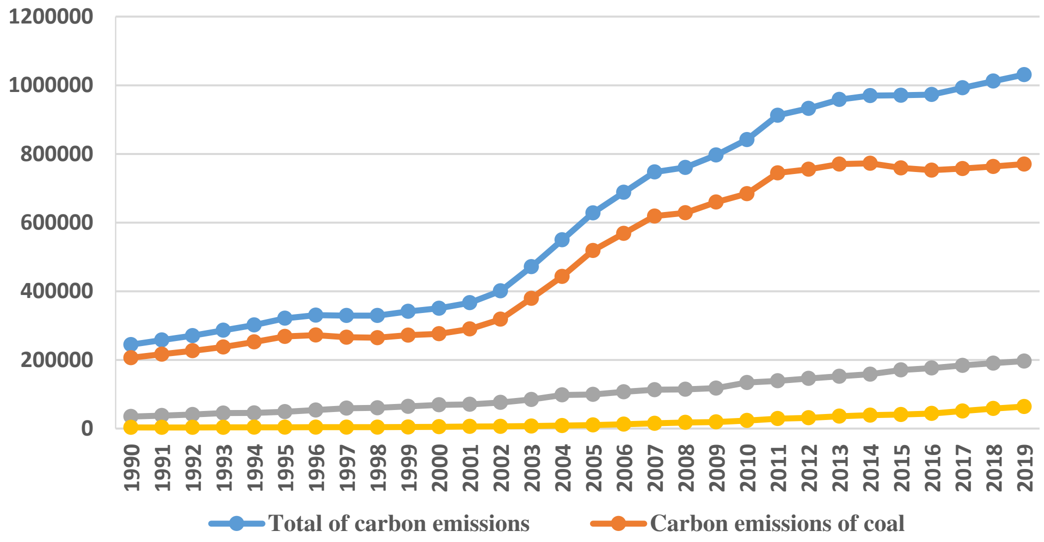

Figure 1. The trend of carbon dioxide emissions from China's energy consumption during 1990-2019 Unit: 10,000 tons

The trend of total carbon dioxide emissions is basically similar as the trend of carbon dioxide emissions from coal consumption, which is determined by China's resource endowments in Figure 1.

The slow growth of coal consumption from 1990 to 2002, which led to a slower growth of carbon dioxide emissions. However, China's economy entered the mid-term stage of rapid industrialization from 2003 to 2013. Due to the extensive economic development, coal consumption increased rapidly, which in turn led to a large amount of carbon dioxide emissions throughout the country. After 2013, China's economy has entered a new normal, and the growth rate of economy has slowed down, and industry structure faces transformation. So the growth rate of coal consumption slowed down, especially the growth rate of carbon dioxide emissions from coal consumption were very slowly in 2014 and 2015. There was a slight increase during 2016-2019, but it was basically controlled within 8 billion tons, indicating that coal has been effectively controlled after 2014, which has led to a slowdown in the growth of national carbon dioxide emissions. In recent years, the consumption of oil, natural gas and non-fossil energy has grown rapidly, replacing part of the consumption of coal and slowing down carbon dioxide emissions. On the whole, the total carbon dioxide emissions during the sample period have been increasing year by year. The growth rate of carbon dioxide emissions was relatively fast from 2000 to 2013, and the growth rate of carbon dioxide emissions was slow from 2014 to 2019. At present, carbon emissions have not reached a peak, but the growth rate has slowed down year by year. The carbon dioxide emissions from the consumption of oil and natural gas is increasing year by year.

According to the decomposition of the influencing factors of carbon dioxide emissions, the effects of population size, economic development level, energy intensity, and primary energy consumption structure on carbon dioxide emissions can be obtained in Table 4. It can be seen that the population size and the level of economic development both promoted carbon dioxide emissions to varying degrees in the sample period. In addition, energy intensity promoted carbon dioxide emissions during 2002-2004, and energy intensity have different degrees of restraint on carbon dioxide emissions during other periods of time. During the individual years of 2001, 2002, 2004 and 2010, China's primary energy consumption structure has a promoting effect on carbon dioxide emissions. The energy consumption structure has a different degree of restraint and promotion effect on carbon dioxide emissions during other years.

Table 4. The influence and contribution rate of various factors on carbon dioxide emissions

years	Influence effect					Contribution rate				
	Population size	The level of development	Energy intensity	Energy structure	Total effect	Population size	The level of development	Energy intensity	Energy structure	Total effect
2000-2001	2602.5	26083.7	-8349.8	-4163.78	16172.7	16.1	161.3	-51.6	-25.75	100
2001-2002	2568.6	30939.3	-400.1	1268.77	34376.5	7.5	90.0	-1.2	3.69	100
2002-2003	2709.8	38905.4	23780.8	5014.31	70410.2	3.8	55.3	33.8	7.12	100
2003-2004	3025.6	46053.4	30225.4	-910.82	78393.6	3.9	58.7	38.6	-1.16	100
2004-2005	3457.8	59986.0	11008.8	4211.05	78663.6	4.4	76.3	14.0	5.35	100
2005-2006	3672.8	75091.4	-18453.6	-417.10	59893.4	6.1	125.4	-30.8	-0.70	100
2006-2007	3746.1	91688.7	-35477.7	-912.39	59044.7	6.3	155.3	-60.1	-1.55	100
2007-2008	3862.4	65584.9	-47575.5	-8630.61	13241.3	29.2	495.3	-359.3	-65.18	100
2008-2009	3871.5	66049.7	-33136.8	-669.57	36114.8	10.7	182.9	-91.8	-1.85	100

2009-2010	3954.3	78802.2	-25101.7	-12631.71	45023.1	8.8	175.0	-55.8	-28.06	100
2010-2011	4200.1	75759.8	-18044.4	9105.70	71021.2	5.9	106.7	-25.4	12.82	100
2011-2012	4494.7	65337.8	-34537.8	-15415.62	19879.1	22.6	328.7	-173.7	-77.55	100
2012-2013	4667.5	66041.6	-36597.2	-8141.55	25970.3	18.0	254.3	-140.9	-31.35	100
2013-2014	4881.5	64179.0	-43004.2	-14666.65	11389.6	42.9	563.5	-377.6	-128.77	100
2014-2015	4930.0	61087.7	-53015.8	-12105.93	896.0	550.2	6818.1	-5917.2	-1351.2	100
2015-2016	5262.0	59113.1	-47995.6	-14259.38	2120.2	248.2	2788.1	-2263.8	-672.56	100
2016-2017	5493.3	60496.0	-34595.0	-11920.21	19474.1	28.2	310.6	-177.6	-61.21	100
2017-2018	4568.6	60886.8	-30674.9	-15060.29	19720.3	23.2	308.8	-155.5	-76.37	100
2018-2019	3649.6	56931.2	-28461.9	-13184.77	18934.2	19.3	300.7	-150.3	-69.63	100

From the perspective of the contribution rate of various influencing factors to carbon dioxide emissions, the positive contribution rate of economic development level to carbon dioxide emissions is the highest, followed by population size. Energy intensity and energy structure have a negative effect on carbon dioxide except for a few years. The negative contribution rate of energy intensity to carbon dioxide emissions is the highest, followed by the primary energy consumption structure. From the overall changes in the contribution rate of various influencing factors to carbon emissions, the contribution rate of the economic development level shows a fluctuating upward trend, indicating that the main driving force for the increase in carbon dioxide emissions is the increasing level of economic development. The contribution rate of population size to carbon dioxide emissions fluctuates, but the overall change is not significant. The overall negative contribution rate of energy intensity has shown an increasing trend, indicating that the increase in energy utilization can curb the increase in carbon dioxide emissions. However, after 2016, the negative contribution rate of energy intensity to carbon dioxide emissions has shown a downward trend year by year. The overall negative contribution rate of the primary energy consumption structure is on the rise, indicating that the adjustment and optimization of China's primary energy consumption structure have significantly inhibited carbon dioxide emissions.

4.2 Analysis of the elastic decoupling between carbon dioxide emissions and economic growth

From the previous analysis, economic development plays a decisive role in promoting carbon dioxide emissions, so it is very necessary to analyze the decoupling relationship between carbon dioxide emissions and economic growth. The trend of elastic decoupling between carbon dioxide emissions and economic growth from 2000 to 2019 is shown in Figure 2.

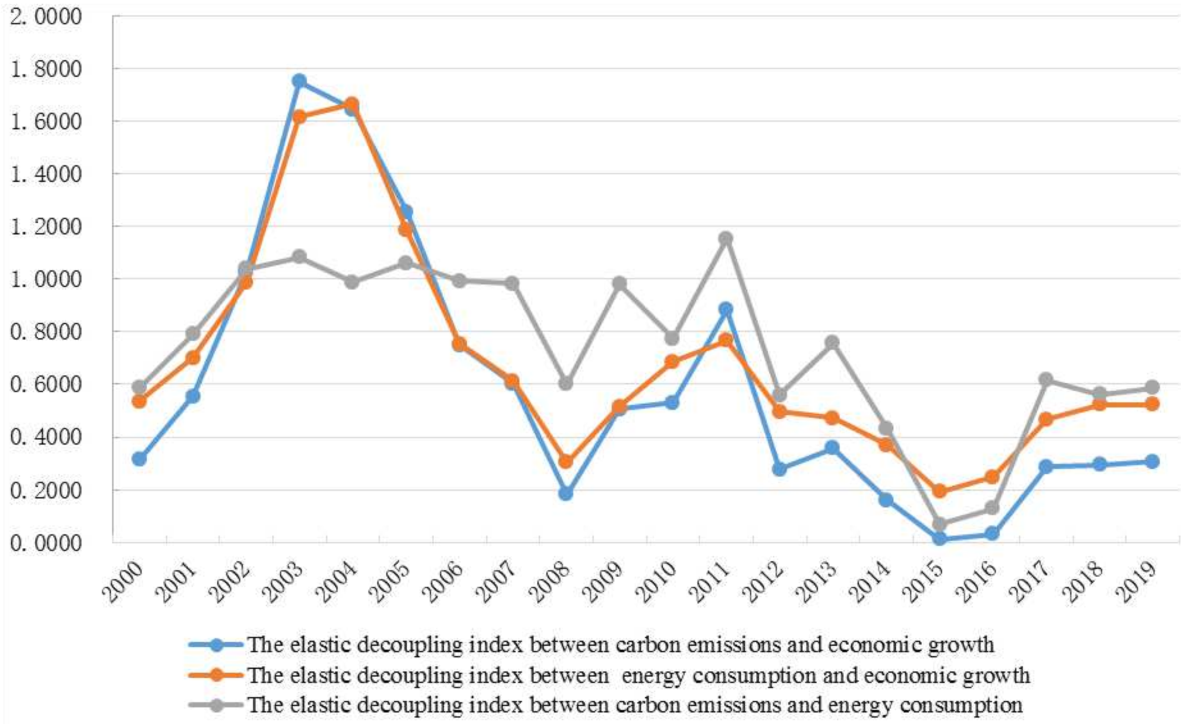

Figure 2. The elastic decoupling index between carbon emissions, energy consumption and economic growth from 2000 to 2019

In Figure 2, the elastic decoupling index between carbon dioxide emissions and economic growth has increased year by year from 2000 to 2003. The elastic decoupling state between carbon dioxide emissions and economic growth had changed from weak decoupling state to growth link state. And the growth link state remained unchanged until 2005. After 2005, it dropped to a minimum quickly in 2008, and then rose to 0.8836 in 2011. The possible reason is that China's economic growth reached its peak from 2002 to 2007, and then economic growth gradually declined. However, the basic trend of the overall improvement of the economic growth has not changed. Compared with previous years, the economic environment has undergone major changes. Affected by the financial crisis around 2008, China's economic growth has been under pressure from a decline in growth since 2008. From 2007 to 2010, the elastic decoupling index of carbon emissions fluctuated down and fluctuated up, but it has been weakly decoupled basically. The elastic decoupling index between carbon dioxide emissions and economic growth was a weak decoupling state during 2015 - 2016. The decline in carbon dioxide emissions is mainly due to the decline in energy intensity brought about by energy conservation and technological progress. The industrial structure and energy consumption structure are basically stable. Energy intensity and energy structure have little effect on the elastic decoupling state between carbon dioxide emissions and economic growth.

From the causal chain model of the elastic decoupling index between carbon emissions and economic growth, the elastic decoupling index between carbon dioxide emissions and economic growth is determined by the elastic decoupling index between energy consumption and economic growth and the elastic decoupling index between carbon dioxide emissions and energy consumption. Using LMDI decomposition method, the decoupling effect of the above two indexes on the elastic decoupling index between carbon dioxide emissions and economic growth and their contribution are shown in Table 5.

Table 5. The decomposition effect of the elastic decoupling index between carbon dioxide emissions and economic growth and the contribution rate of each effect

years	Decoupling effect			Decoupling contribution rate	
	$\Delta e_{(C,Y)}^{EY}$	$\Delta e_{(C,Y)}^{CE}$	$\Delta e_{(C,Y)}$	$\Delta e_{(C,Y)}^{EY}$ %	$\Delta e_{(C,Y)}^{CE}$ %
2000-2001	0.1134	0.1260	0.2395	0.4736	0.5264
2001-2002	0.2630	0.2102	0.4732	0.5559	0.4441
2002-2003	0.6680	0.0549	0.7229	0.9241	0.0759
2003-3004	0.0514	-0.1565	-0.1051	-0.4887	1.4887
2004-2005	-0.4911	0.1022	-0.3888	1.2629	-0.2629
2005-2006	-0.4422	-0.0645	-0.5067	0.8728	0.1272
2006-2007	-0.1406	-0.0059	-0.1465	0.9599	0.0401
2007-2008	-0.2459	-0.1734	-0.4193	0.5865	0.4135
2008-2009	0.1663	0.1553	0.3217	0.5171	0.4829
2009-2010	0.1487	-0.1225	0.0261	5.6894	-4.6894

2010-2011	0.0767	0.2754	0.3522	0.2179	0.7821
2011-2012	-0.2275	-0.3791	-0.6066	0.3751	0.6249
2012-2013	-0.0149	0.0965	0.0816	-0.1828	1.1828
2013-2014	-0.0612	-0.1374	-0.1986	0.3083	0.6917
2014-2015	-0.0385	-0.1084	-0.1469	0.2619	0.7381
2015-2016	0.0055	0.0133	0.0188	0.2914	0.7086
2016-2017	0.0737	0.1826	0.2562	0.2876	0.7124
2017-2018	0.0329	-0.0266	0.0063	5.2320	-4.2320
2018-2019	-0.0002	0.0120	0.0118	-0.0211	1.0211

The elastic decoupling index between carbon dioxide emissions and economic growth increased by 0.2395 from 2000 to 2001. The increase in the elastic decoupling index between energy consumption and economic growth increased the carbon emissions decoupling index by 0.1134, and the increase in the elastic decoupling index between carbon dioxide emissions and energy consumption increased the carbon emissions decoupling index by 0.1260. It shows that the increase of elastic decoupling index between energy consumption and economic growth and the increase of elastic decoupling index between carbon emissions and energy consumption jointly inhibit the further decoupling between carbon emissions and economic growth during 2000-2001. Similar to exploring the reasons for the change of carbon emission index in other years, the following results can be seen. Economic growth and energy consumption structure jointly suppressed the further decoupling between carbon emissions and economic growth during 2001-2003, 2008-2009, 2010-2011, and 2015-2017. Economic growth and energy consumption structure jointly promoted a further decoupling between carbon emissions and economic growth during 2005-2008 .

In some years, the above two indexes have inconsistent effects on the elastic decoupling between carbon emissions and economic growth. The increase in the elastic decoupling index between energy consumption and economic growth inhibited the elastic decoupling between carbon emissions and economic growth from 2003 to 2004, but the decrease in the elastic decoupling index between carbon emissions and energy consumption promoted the decoupling between carbon emissions and economic growth. But the inhibition effect of the former was greater than the promotion effect of the latter. During 2004-2005, the decrease in the elastic decoupling index between energy consumption and economic growth promoted the elastic decoupling between carbon emissions and economic growth, and the increase in the elastic decoupling index between carbon emissions and energy consumption inhibited the elastic decoupling between carbon emissions and economic growth. But the former's promotion effect was greater than the latter's inhibitory effect. The increase of the elastic decoupling index between energy consumption and economic growth restrained the elastic decoupling index between carbon emissions and economic growth, while the decrease of the elastic decoupling index between carbon emissions and energy consumption promoted the elastic decoupling index between carbon emissions and economic growth. During 2009-2010 and 2017-2018, the increase of the elastic decoupling index between energy consumption and economic growth inhibited the elastic decoupling between carbon emissions and economic growth, and the decrease of the elastic decoupling index between carbon emissions and energy consumption promoted the elastic decoupling between carbon emissions and economic growth. But the inhibitory effect of the former is greater than the promotion of the latter. During 2012-2013 and 2018-2019, the decrease of the elastic decoupling index between energy consumption and economic growth promoted the elastic decoupling between carbon emissions and economic growth, but the increase in the elastic decoupling index between carbon emissions and energy consumption inhibited. However, the former's promotion effect is less than the latter's restraining effect.

4.3 Predictions of carbon emissions, carbon intensity and carbon decoupling

4.3.1 Carbon dioxide emission

Bring the predicted values of the three parameters of GDP, energy intensity, and primary energy consumption structure into the above constructed carbon dioxide prediction model to predict the change trend of China's carbon dioxide emissions in the medium and long term in the future. The predicted values of carbon dioxide emissions under various scenarios are shown in Table 6.

Table 6 The predicted values of carbon dioxide emissions Unit: 10,000 tons

years	The first scenario	The second scenario	The third scenario	The fourth scenario
2020	1131860.5	1025490.0	1026795.5	1036430.6
2021	1162512.1	1032660.8	1033973.8	1045432.1
2022	1192056.2	1038128.8	1039713.9	1052855.9
2023	1220479.1	1041996.3	1044087.1	1058778.0
2024	1247766.3	1044363.4	1047161.8	1063279.2
2025	1273910.5	**1045326.1**	1049009.4	1066438.8
2026	1298909.3	1044972.5	**1049694.6**	1068330.6
2027	1322758.7	1043389.3	1049285.2	**1069025.4**
2028	1345463.9	1040661.4	1047843.6	1068598.5
2029	1367030.3	1036868.4	1045430.1	1067115.6
2030	1387464.2	1032081.7	1042106.8	1064642.6
2031	1406772.7	1026375.8	1037930.1	1061244.1
2032	1424972.6	1019819.3	1032953.5	1056982.0
2033	1442073.0	1012477.5	1027234.1	1051912.4
2034	1458089.9	1004411.6	1020818.4	1046094.3
2035	1473038.8	995679.5	1013757.5	1039579.3

In the first scenario, carbon dioxide emissions will not reach the peak in 2035, according to the historical evolution trend of carbon dioxide emissions from 2000 to 2019. In the second scenario, carbon dioxide emissions will reach its peak in 2025, with a peak value of 10,453 million tons. In the third scenario, carbon dioxide emissions will reach its peak in 2026, with a peak value of 10,453 million tons. In the fourth scenario, carbon dioxide emissions will reach its peak in 2027 with a peak value of 10,690 million tons. The latter three scenarios can all achieve the goal of peaking carbon dioxide emissions before 2030 announced at Climate Ambition Summit. The result show that that the sooner the peak of carbon emissions is reached, the peak will be smaller, and the time left for carbon neutralization in 2060will be longer. After peaking carbon dioxide emissions, which will enter a plateau period of slow decline.

4.3.2 Prediction of carbon dioxide emissions intensity

Based on the predicted value of carbon dioxide emissions and the predicted value of GDP, the results of carbon dioxide emissions intensity are shown in Table 7.

Table 7 Prediction values of carbon dioxide emissions intensity Unit: ton/10,000 yuan

years	The first scenario	The second scenario	The third scenario	The fourth scenario
2020	1.7407	1.5992	1.5953	1.6085
2021	1.6836	1.5236	1.5168	1.5317
2022	1.6284	1.4517	1.4425	1.4588
2023	1.5752	1.3834	1.3721	1.3896
2024	1.5239	1.3184	1.3055	1.3238
2025	1.4743	1.2566	1.2423	1.2615
2026	1.4264	1.1979	1.1824	1.2022
2027	1.3802	1.1420	1.1257	1.1460
2028	1.3355	1.0888	1.0719	1.0925
2029	1.2924	1.0383	1.0208	1.0418
2030	1.2508	0.9902	0.9724	0.9935
2031	1.2106	0.9444	0.9264	0.9477
2032	1.1718	0.9009	0.8828	0.9041
2033	1.1343	0.8595	0.8414	0.8627
2034	1.0980	0.8200	0.8021	0.8233
2035	1.0630	0.7825	0.7648	0.7859

It is known that the carbon dioxide emission intensity in 2005 was 2.404 tons per 10,000 yuan (constant price in 2005). In the four scenarios, the reduction rate of carbon dioxide emission intensity in 2030 compared with 2005 is 62.71%, 70.48%, 71.01%, and 70.38 %, respectively. Except for the first scenario, the other three scenarios have achieved the goal of “By 2030, China’s carbon dioxide emissions per unit of GDP will drop by more than 65% from 2005” announced by the central government at the Climate Ambition Summit.

Forecast of the elastic decoupling between carbon dioxide emissions and economic growth. The elastic decoupling state between carbon dioxide emissions and economic growth and the prediction results of the decoupling effect are shown in Table 8.

Table 8 Prediction values of elastic decoupling index between carbon emissions and economic growth

years	The first scenario	The second scenario	The third scenario	The fourth scenario
2020	0.4373	0.1227	0.1183	0.1465
2021	0.4226	0.0961	0.0968	0.1236
2022	0.4081	0.0699	0.0755	0.1010
2023	0.3935	0.0440	0.0544	0.0786
2024	0.3789	0.0184	0.0335	0.0565
2025	0.3645	-0.0069	0.0127	0.0347
2026	0.3499	-0.0320	-0.0078	0.0131
2027	0.3355	-0.0568	-0.0282	-0.0082
2028	0.3212	-0.0812	-0.0484	-0.0294
2029	0.3068	-0.1056	-0.0684	-0.0502
2030	0.2924	-0.1296	-0.0883	-0.0709
2031	0.2782	-0.1534	-0.1081	-0.0913
2032	0.2639	-0.1770	-0.1276	-0.1116
2033	0.2497	-0.2004	-0.1471	-0.1316
2034	0.2356	-0.2236	-0.1664	-0.1514
2035	0.2215	-0.2466	-0.1856	-0.1710

In table, according to the historical evolution trend from 2000 to 2019, carbon emissions and economic growth will be weakly decoupled from 2020-2035, and no real strong decoupling has been achieved. According to the historical evolution trend from 2005 to 2019, there will be a weak decoupling from 2020 to 2024, and a strong decoupling from 2025 to 2035, indicating that a strong decoupling between carbon emissions and economic growth can be achieved by the end of the "*14th Five-Year Plan*" period. According to the historical evolution trend from 2010 to 2019, the weak decoupling will be realized from 2020 to 2025, and the strong decoupling will be realized from 2026 to 2035, indicating that the strong decoupling between carbon emissions and economic growth can be achieved at the beginning of the "*15th Five-Year Plan*". According to the historical evolution trend from 2015 to 2019, the weak decoupling will be realized from 2020 to 2026, and the strong decoupling will be realized from 2027 to 2035, indicating that the strong decoupling between carbon emissions and economic growth can be achieved by the middle of the "*15th Five-Year Plan*". In short, if economic development, energy intensity, and energy consumption structure can follow the trend of changes since 2005, there will be a strong decoupling between carbon emissions and economic growth before 2030, which coincides with the peak time of carbon emissions.

5. Conclusions and policy implications

5.1 Main conclusions

In this paper, the factor decomposition model is used to analyze the influencing factors of carbon dioxide emission and their influencing effects.

paper uses a factor decomposition model to analyze the influencing factors and effects of carbon dioxide emissions. Combining the factor decomposition method and the elastic decoupling model, a causal chain model of elastic decoupling is constructed, and the historical trend of the decoupling state between carbon dioxide emissions and economic growth and the decoupling effect of influencing factors are all analyzed. China's economic development level, energy intensity and primary energy consumption structure are all predicted. From the perspectives of economic growth, energy intensity and energy consumption structure,a carbon dioxide emission prediction model are established. The trends and peaks of China's carbon dioxide emissions in the medium and long term are explored. The trend of the elastic decoupling between carbon dioxide emissions and economic growth in the medium and long term. The conclusion is as follows:

(1) From the perspective of the influencing factors and effects of carbon dioxide emissions, since the "*Fifteenth Five-Year Plan*", population size and economic growth can promote carbon dioxide emissions. Energy intensity and energy consumption structure have a strong inhibitory effect on carbon dioxide emissions except for a few years, but the inhibitory effect of energy intensity on carbon dioxide emissions is more obvious than that of energy consumption structure. Since the contribution rate of the population size to carbon dioxide emissions fluctuates but the overall change is small, the contribution rate of the economic development level shows a fluctuating upward trend, indicating that the main driving force for the increase of carbon dioxide emissions is the increasing level of economic development. Since the negative contribution rate of energy intensity is generally increasing, it shows that the increase in energy utilization can help curb the increase in carbon emissions. However, since 2016, the negative contribution rate of energy intensity to carbon dioxide emissions has shown a downward trend year by year. The overall negative contribution rate of the primary energy consumption structure is on the rise, indicating that the adjustment of China's primary energy consumption structure has become more and more obvious in restraining carbon dioxide emissions.

(2) From the perspective of the forecast of peak carbon dioxide emissions, the average annual growth rate of GDP during the period from the "*14th Five-Year Plan*" to the "*16th Five-Year Plan*" is maintained at 4.61%-5.85%, and the decline in energy intensity remained at 16.14%-18.37%, and the proportion of non-fossil energy consumption in the energy consumption structure at the end of the 14th, 15th and 16th Five-Year Plan was maintained at 19.9%, 23.2% and 26.1%. The carbon dioxide emission reduction efforts will continue to increase, and it is expected that carbon emissions will reach a peak between 2025-2027, with a peak value of between 10,453 and 10,690 billion tons, and the sooner the peak is reached, the smaller the peak, which can provide for the future realization of carbon neutrality. Valuable time and room for carbon emissions reduction. And after reaching the peak, it enters a plateau period of slow decline. Therefore, during the "*14th Five-Year Plan*" period, economic growth needs to maintain a reasonable range, energy intensity needs to achieve the constraint targets

in the "*14th Five-Year Plan*" outline, and the energy consumption structure needs to be further optimized to achieve the "*14th Five-Year Plan*" outline. Restricting these targets can further promote the early peak of carbon emissions and reduce the peak.

(3) The elastic decoupling between carbon dioxide emissions and economic growth has generally experienced a state of weak decoupling to growth connection and then to weak decoupling. In particular, the weak decoupling is very good in 2015 and 2016. This is because China's economy is in a new stage of "structural adjustment and transformation" in the past two years. The economic growth rate is stable at about 7%, the industrial structure and energy consumption structure are basically stable, and the decline in carbon dioxide emissions is mainly due to the decline in energy intensity brought by energy conservation and technological progress. The degree of elastic decoupling between energy consumption and economic growth and the degree of elastic decoupling between carbon dioxide emissions and energy consumption have time differences in the impact of the degree of elastic decoupling between carbon dioxide emissions and economic growth. If economic development, energy intensity, and energy consumption structure can follow the evolution trend since 2005, the weak decoupling between carbon dioxide emissions and economic growth after the "*14th Five-Year Plan*" will continue to increase, and it will be reversed before the "*15th Five-Year Plan*". It is a strong decoupling state, which coincides with the peak time of carbon.

5.2 Policy implications

Peaking carbon emissions is an important turning point in the transformation of economic development mode and an important node in the eventual realization of carbon neutrality. Through the analysis of this article, the following policy recommendations are put forward:

(1) Energy intensity need be vigorously reduced, energy need be saved, and energy utilization efficiency need further improved. Although the negative effect of energy intensity on the decoupling of carbon emissions

is gradually diminishing, it is still a factor hindering the decoupling of China's economic development from carbon emissions. The improvement of energy-saving and emission-reduction technologies is the fundamental way to solve carbon emissions. Increasing investment in science and technology, updating talent introduction measures, and improving independent innovation capabilities are the key ways to decouple China's economic development from carbon emissions.

(2) Energy consumption structure need be vigorously optimized, and the proportion of non-fossil energy need be increased. The essence of the carbon peak problem is the energy transition. The speed and intensity of the development of renewable energy power generation to promote low-carbon energy structure. End-energy energy conservation and re-electrification can promote the decoupling between carbon emissions and energy consumption, which in turn can promote the early realization of carbon peak. Therefore, during the "*14th Five-Year Plan*" period, energy growth should be promoted to shift from fossil energy to non-fossil energy, the proportion of non-fossil energy need to be continuously increase, and rely on technological innovation to achieve an increase in the proportion of non-fossil electricity through electrification, informatization and intelligence. The measure of optimizing the energy structure, vigorously developing renewable energy, increasing the proportion of new low-carbon energy sources, promoting the development and utilization of new energy sources such as nuclear energy and solar energy should be adopted. The coal-based energy structure to achieve a balance between carbon dioxide emissions and economic growth. Then, the goal of decoupling state between carbon dioxide emissions and economic growth can be achieved.

(3) The policy implementation mechanism is the fundamental guarantee for peaking carbon emissions. Maintaining policy determination is particularly important for peaking carbon emissions. The top-level design of science needs to be implemented. Governance policies need to be formulated at the source. Economic development methods need to be transformed. Energy structure need to be transformed and optimized through

market adjustment. Green upgrades need to be done autonomously. The consistency and effectiveness of policy implementation need to be ensured. On the one hand, China must actively formulate and implement corresponding policies and regulations. At the same time, China must also levy carbon taxes, improve the carbon emission trading market, raise the threshold of high-polluting and high-energy-consuming industries, improve the elimination mechanism, and improve efficiency. On the other hand, China need strictly control the consumption of fossil energy, step up research and development and the use of clean energy. The government should actively formulate appropriate preferential policies to guide enterprises to carry out green reforms and innovations. The target of peaking carbon emissions should be regarded as a long-term strategic task supplemented by government guidance, and market regulation as the main task, so as to gradually realize the substitution of green and clean energy for fossil energy. The government need to take full advantage of peaking carbon peak plateau, strive to promote the improvement and development of the modern industrial system, promote the further optimization of the energy consumption structure. Improving technologies such as carbon capture and carbon storage after carbon peaks will provide a beneficial guarantee for achieving carbon neutrality.

Availability of data and materials

Not applicable.

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Not Applicable

Consent for publication

Not Applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Weifeng Gong: Conceptualization, Methodology, Writing – original, Funding acquisition.

Chuanhui Wang: Formal analysis, Writing - review & editing.

Zhenyue Fan: Investigation, Project administration.

Yang Xu: Investigation, Formal analysis.

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Figures

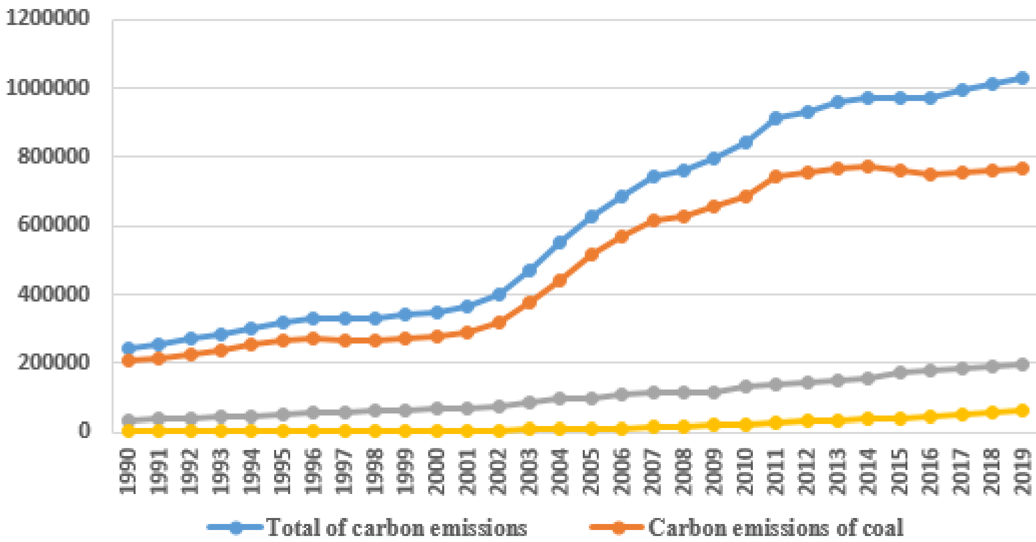

Figure 1

The trend of carbon dioxide emissions from China's energy consumption during 1990-2019 Unit: 10,000 tons

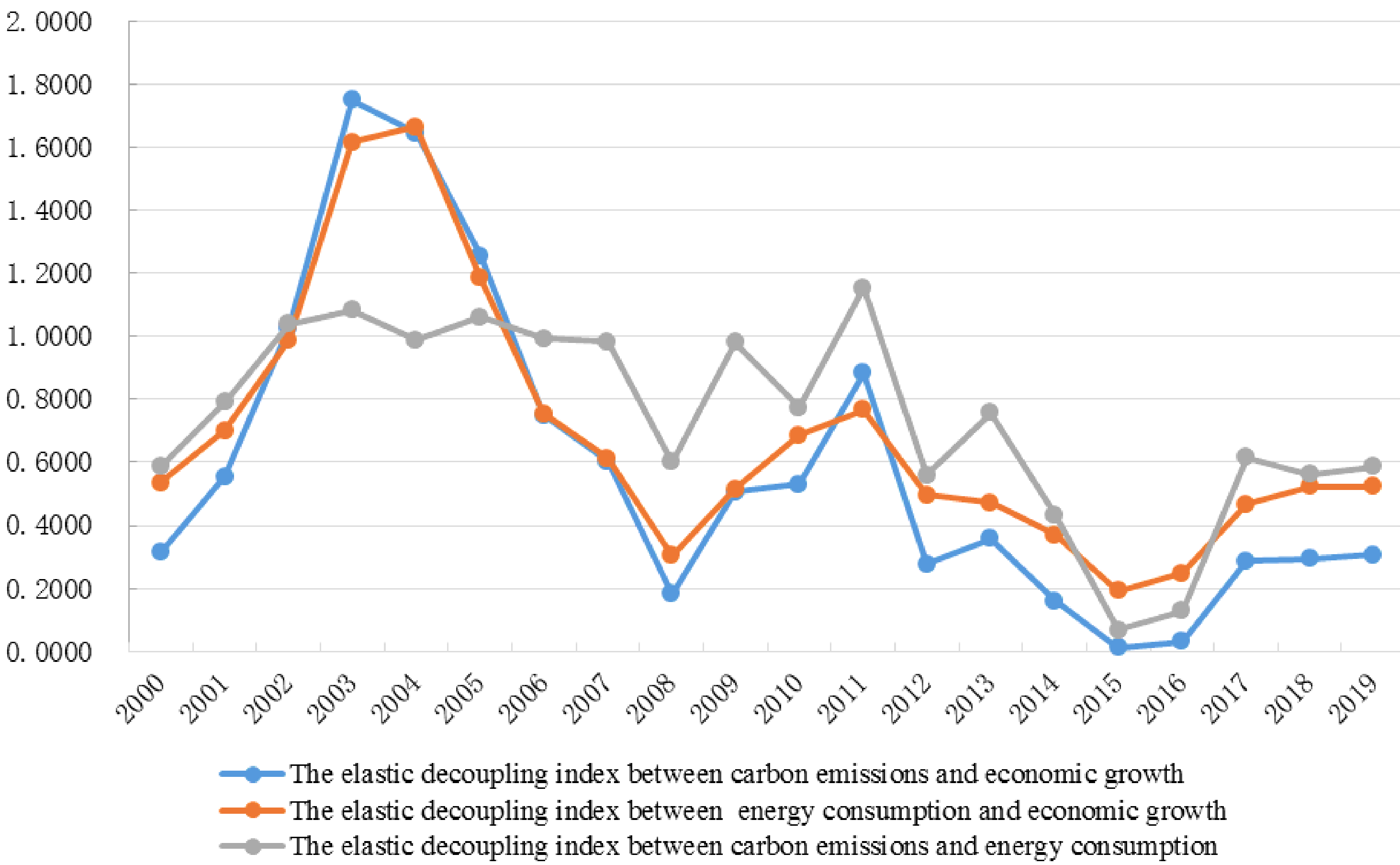

Figure 2

The elastic decoupling index between carbon emissions, energy consumption and economic growth from 2000 to 2019