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A Review of the Research on the Peak Carbon Emission in China

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Abstract*:* With the further study of the peak carbon emissions in China, there is a great difference between the peak carbon emissions and the peaking time of carbon emissions in China. This study found that the current scholars mainly from the scenario analysis, the consistency of national emission reduction actions, the key sectors of emission reduction, carbon emission reduction analysis model, national policy-oriented prediction. At the same time, this paper summarizes the general situation of carbon emission peak research in China, summarizes the main factors and methods of carbon emission peak research in China, and also shows the specific research results and the development situation of China in recent years. This paper summarizes some problems in the study of peak carbon emissions in China, and puts forward some suggestions for predicting the peak carbon emissions in China in the new historical development stage.

Keywords Carbon emissions, Scenario analysis, Peak carbon emissions

INTRODUCTION

The fourth assessment report of the Intergovernmental Panel of Climate change (IPCC) points out that the global average land surface temperature may rise by 1.1 ℃ by the end of the 21st century. At the same time, the report points out that the main cause of the rise in global land surface temperature is the increasing concentration of carbon dioxide in the atmosphere [Qin, *et. al.*, 2013] and that human activities, in particular the burning of fossil fuels, are the main cause of the increase in the concentration of carbon dioxide in the atmosphere, Its contribution is as high as 63 per cent [Rodrigues, *et. al.*, 2006]. The Chinese government has made a series of positive responses to global warming. In November 2014, China formally stated in the Sino-U.S. Joint statement on Climate change that China's carbon emissions would peak around 2030, and quantified the growth peak of China's industrialization and urbanization. The Chinese government has pledged to reduce its peak carbon emissions by 60 to 65 per cent from its 2005 target. At the same time, it is planned to increase the proportion of non-fossil fuels in primary energy to 20 percent.

In recent years, different prediction models and different influencing factors have been used to study the peak carbon emissions of China and provinces and cities in a more comprehensive way. However, the methods used by scholars and the prediction results are quite different. At present, the development of China is facing a new situation. The purpose of this paper is to summarize the research done by scholars in the past, and find out the advantages and disadvantages of scholars' past research. And under the current national conditions, we should continue to study from those angles, further analyze the main influencing factors of carbon emissions, and put forward positive suggestions for China's low-carbon development, so as to promote low-carbon development. Under the premise of ensuring steady economic growth, carbon emission reduction targets will be achieved.

China is currently facing a new development situation, although scholars have done a lot of research on the peak carbon emissions in China, but in China's economy from high-speed growth to medium-high growth, economic structure optimization and upgrading, From factor-driven, investment-driven to innovation-driven, China's carbon emission peak has a new historical background, summing up the past research results of China's carbon emission peak. It has great theoretical value for the future study of the peak carbon emissions in China in the new era. According to the research of scholars, the main factors affecting China's carbon emissions are further summarized. Scholars who study the peak carbon emissions in China use different methods and come to different conclusions. This paper summarizes the main influencing factors of China's carbon emissions by different scholars , and understands the impact of the development of various sectors on carbon emissions. Through the relevant research, we can understand the carbon emissions of various sectors in detail , and provide a theoretical basis for the adjustment and optimization of industrial structure. Through summing up the past research on carbon emissions in China, the main factors affecting carbon emissions and the degree of influence are identified. Carbon emissions are affected by a variety of factors, the degree of influence of each factor varies greatly, through qualitative and quantitative methods to measure the impact of various factors, in order to provide a theoretical basis for the macro-aspect to reduce carbon emissions. By summarizing the results of China's carbon emissions research, this paper puts forward new ideas and new directions for China's low-carbon development research, and provides new ideas for the study of low-carbon development path in China. Looking for low-carbon solutions for China is a useful complement to low-carbon development planning. To provide a reference for the government planning. Through the analysis and research, we can determine which sectors are the key adjustment sectors, which are the key support sectors, and which are the key carbon emission adjustment sectors. It can be a useful complement to carbon emission-related policy making.

SUMMARY OF CHINA'S CARBON EMISSIONS

Literature review

Feng Zongxian [Rodrigues, *et. al.*, 2006] established a Kaya identity model for China's carbon emissions, which predicts that China's CO2 emissions will peak at 12.151 billion tons in 2035 under the baseline scenario. China's CO2 emissions reached a peak of 9.636 billion tons in 2028 under the low-carbon scenario. Lin Boqiang [Su, *et. al.*, 2010] established the EKC model of China's carbon emissions, and established the middle and low scenarios, predicting that China's carbon emissions will reach the inflection point in 2023, 2021, and 2017, respectively, and that China's carbon emissions will reach the inflection point in 2023, 2021, and 2017, respectively. Du Qiang [Alexeeva, *et. al.*, 2007] established an improved IPAT model for China's carbon emissions. The results show that China's carbon emissions peak in 2030, the national carbon emissions will reach 3.684 billion tons, per capita carbon emissions of 2.65 tons. Zhang Nan [Perobelli, *et. al.*, 2015] established a carbon emission model to simulate the carbon emissions of various provinces and cities in China by 2030. Finally, it is concluded that the total carbon emissions in China will peak in 2025, and the total carbon emissions in the peak year should be less than 10 billion tons. Qushenning [Jayanthakumarana, *et. al.*, 2016] established the STIRPAT model of carbon emissions in China and established eight scenarios. The results showed that the peak value appeared between 2028 and 2045 years, and the carbon emissions ranged from 7.3 billion tons to 11.6 billion tons. Chai Qimin [Jose, *et. al.*, 2015] established the total carbon emission model of China based on IAMC. The results show that the 15th Five-Year Plan period is a good window of opportunity to achieve the peak carbon emissions of 12 billion tons and 8.5 tons per person. Jiang Kejun [Yao, *et. al.*, 2015] established China's medium and long-term IPAC model of energy and greenhouse gas emissions, and set up three scenarios. The conclusion of scenario analysis shows that China will have a peak carbon emission of 3.46 billion tons of carbon by 2050 under the standard scenario, while the low-carbon scenario will reduce CO2 emissions by 31%. Zhou Wei [Peters, *et. al.*, 2007] established the MARKAL-MACRO model and the Keyfitz model of mathematical demography for "energy, economy and environment" in China, and established the MARKAL-MACRO model and the Keyfitz model for mathematical demography in China. Three scenarios of energy consumption were set up, the results showed that under the baseline scenario, the CO2 emission of China reached a peak of 11.847 billion tons in 2042, and reached a peak value of 10.753 billion tons in 2036 under the energy structure optimization scenario, and the emission of CO2 reached a peak of 10.753 billion tons in 2036 under the energy structure optimization scenario, and reached a peak of 10.753 billion tons in 2036. CO2 emissions peaked at 9.472 billion tonnes in 2031 under climate change constrained scenarios. Wang Zheng [Maddison, et. al., 2006] established the economic dynamics model of China's future carbon emissions. The results show that carbon emissions from energy consumption peaked at 2.637 billion tons in 2031. Zhu Yongbin [Lu, *et. al.*, 2016] established the models of no emission control, emission intensity control and total emission control.

The study showed that China's carbon emissions peaked in 2032 and 2031, with peaks of 3.255 billion tons and 2.637 billion tons, respectively. Jing Wu [Tzeremes, *et. al.*, 2018] has set up a model based on Agent driven by enterprise innovation. Through the model, carbon emissions and energy consumption will peak at 2027 and 2028 respectively. The energy consumption of China will reach 529.5 billion tons of standard coal by 2028. Then it will drop to 331.4 billion tons of standard coal by 2050, and the country's carbon emissions will reach 2.77 billion tons in 2027. Jinhang Chen [Shahbaz, et. al., 2016] established the model of energy supply and demand in China, set up the planned peak scenario and low-carbon peak scenario according to the requirements of peaking. According to the paper, the peak carbon emission in China will reach 10.2 billion tons in 2025. In the planned high-peak scenario, china's carbon dioxide emissions will peak at 2030. Zhifu Mi [Danish, *et. al.*, 2017] established the input-output model of carbon emissions in China. The results show that China's carbon emissions will peak at 11.2 billion tons in 2026. Hongbo Duan [Romagnoli, *et. al.*, 2014] established a 3E-integrated model of China's carbon emissions. The results show that under the basic scenario, the probability of peak carbon emissions by 2030 is only about 14.5%, and there is a 50% chance of peak carbon emissions by 2040. With a carbon tax of $90 a tonne and a 20 per cent subsidy under the policy scenario, the probability of China's carbon emissions peaking in 2030 is 54.8 per cent. The results show that a single carbon tax policy can not delay the emergence of peak carbon emissions in China, and it is necessary for China to reach a more stringent mix of carbon emissions peak ahead of time.

Methodology for measuring carbon emissions

There are no special institutions in China to publish China's carbon emissions, but some international organizations and scholars have done relevant research, such as IPCC, the Netherlands Agency for Environmental Assessment (MNP), the United States Department of Energy CO2 Information Analysis Center (CDIAC) and so on. There are four methods to calculate carbon emissions: measurement method, mass balance method, emission factor estimation method and model estimation method. The measurement method refers to the measurement of the velocity, flow rate and concentration of different types of fuel equipment such as raw coal, oil, natural gas and so on by collecting the emission gas on the spot, so as to calculate the carbon emissions. [Xu, *et. al.*, 2019]

This method has few intermediate links and accurate results, but it is relatively difficult to obtain data and has a large investment, so it is not widely used in China at present.

Quality balance method, the main principle of this method is to follow the principle of "input-output quality conservation" in the production process, and to carry out quantitative analysis of the materials used in the production process. That is, the quality of materials put into a system in the production process is equal to the sum of the quality of all the products and losses of the system. [Wei, 2019] This method can distinguish not only the difference between various facilities, but also the difference between individual and partial equipment; when the replacement of equipment is faster, this method is more simple. For example, Feng Zongxian [Fong, 2018] established the Kaya identity model of China's carbon emissions, which is the peak value of China's carbon emissions forecast based on the method of mass balance.

Emission factor estimation method refers to the use of energy consumption data and emission factors of a country or region to estimate the carbon dioxide emissions from the main fossil fuels. The IPCC reference method belongs to this kind of method, this kind of method result is quite accurate, to the original data request is not high, is easy to operate, therefore is widely used in the academic research. Emission factor estimation method is widely used, in which the national greenhouse gas inventory refers to 2006 south of the most extensive impact.

This methodology is being used in many countries around the world. Model estimation method, using econometric model quantitative analysis of various factors affecting carbon emissions, based on this estimate carbon emissions, common models are: IPAT model, STIRPAT model, LMDI decomposition method and Lespeyres decomposition method. Du Qiang [Kuai, et. al., 2015], Zhang Nan [Kazemi, et. al., 2016], Qushenning [Roberts, 2011], Jiang Kejun [Brizga, *et. al.*, 2013] have established the improved China carbon emission IPAT model, carbon emission CGE model, China carbon emission STIRPAT model, China medium and long term energy and greenhouse gas emission model forecast respectively. The peak year and peak amount of carbon emission in China were obtained.

Summary of carbon emission factors

There are many factors that affect carbon emissions. Scholars at home and abroad have done a lot of research, and research shows that. The main factors affecting carbon emissions in China include economic development factors (GDP, GDP per capita, economic growth rate, etc.), energy factors (total energy consumption, energy consumption structure, carbon emission intensity, per capita energy intensity, average energy per person). Source consumption, per capita electricity consumption, primary energy composition, depreciation and the combined cost of energy imports, etc.), demographic factors (population, population growth rate, urbanization rate), technological factors (R & D outlay, level of technological progress), Industrial factors (industrial structure, export trade structure, etc.), policy factors (carbon tax) and so on.

The factors selected in different articles are different, and the main influencing factors obtained by scholars are also not the same. The study of Qushenning [Wang, *et. al.*, 2017] shows that carbon emission intensity and technological progress are the main factors affecting carbon emissions in China. Du Qiang [Liu, *et. al.*, 2017] changes in industrial structure and scientific and technological progress are the main factors affecting China's carbon emissions. Jiang Kejun [Liu, *et. al.*, 2015] research shows that economic development, demographic changes and income changes, as well as changes in the use of technology are the main factors affecting the amount of energy consumption and China's carbon emissions. The study of Zhou Wei [Wu, *et. al.*, 2017] shows that the process of urbanization and industrialization dominates the consumption of energy and other resources in China, and has a profound impact on China's carbon emissions. Jinhang Chen [Jinhang, *et. al.*, 2017] research shows that the application of more efficient energy consumption patterns and low-carbon energy supply models to promote decarburization in the power industry is the key to reducing the peak carbon emissions. [Chen, *et. al.*, 2019] Zhifu Mi [Mi, 2017] in this paper, the uncertainty analysis was carried out. Among the factors selected in the paper, the most sensitive one is the technical progress, and the other factors have a weak effect on China's carbon emissions. The results of Hongbo Duan [Duan, *et. al.*, 2018] show that a single carbon tax policy cannot delay the emergence of the peak carbon emissions in China, and it is necessary for China to reach a stricter mix of carbon emissions peak emissions ahead of time.

Summary of research methods on peak carbon emissions

Domestic and foreign scholars have done a lot of research on carbon emission peak, mainly using the following methods to forecast. Environmental Kuznets Curves (EKC) was proposed many years ago by Western scholars to explain the relationship between per capita income and carbon emissions. They argue that there is an inverse "U" relationship between per capita income and carbon emissions [Zi, *et. al.*, 2015] Feng Yang, Philippe Garrigues, M. Shahbaz, Danish [30] and others have used the EKC curve to test environmental Kuzne in 11 countries, including the United States, Bangladesh, and Pakistan. The feasibility of the EKC hypothesis. Rodrigue, Bin Su, JohnC.V. Pezze and Frank Jotzo, Jayanthakumaran et al. used input-output models to study carbon emissions. Romagnoli, W. Fong, Kuai Peng, Kazemi and others have established dynamic models of carbon emission systems in Latvia, Malaysia, developing countries and Iran, respectively, and simulated different scenarios. The influence degree of dynamic behavior of different influencing factors on the trend of carbon emissions is obtained through analysis. T.D. Roberts, Brizga, C. Wang [Zaipu, *et. al.*, 2007] and others used IPAT model to decompose the influencing factors of carbon emissions. The three scholars analyzed the carbon emission factors of the southeastern United States, the post-Soviet Republic and Xinjiang, and concluded that population, energy intensity and fossil fuel share, economic growth and population are the main factors of carbon emissions in these three regions. According to the research of the above scholars, we can see that carbon emissions has become a hot topic of concern to all mankind, and the related research results are remarkable, including international organizations on global carbon emissions research reports, there are comparative studies between countries; There are also specific research for a country, a country's carbon emissions research methods are not the same, and the research system is more mature, the results of the study found that the factors affecting carbon emissions vary from country to region.

CONCLUSION

Through the analysis and summary above, it can be found that the domestic and foreign research on carbon emission reduction is generally carried out from the following perspectives: first, using scenario analysis to design low-carbon social scenarios, analysis of emission reduction potential, but the subjectivity is strong. [Qing, et. al., 2019]

Second, the consistency of emission reduction actions among countries, this method is mainly used for international comparative research, there is room for further development at home; third, the key sectors of emission reduction, specific and detailed research by industry, At present, many scholars mainly based on this research method have not studied in depth, and after identifying the key emission reduction sectors, how to continue to go deep, how much to reduce emissions, and what kind of technology can better meet expectations; fourth, carbon emission reduction analysis model,

Using the models constructed by scholars to forecast and analyze carbon emissions, some scholars did not carry out model tests and directly forecast, and the models may be flawed; fifthly, the national policy-oriented prediction, On the carbon tax, new energy-related support policies on carbon emissions research, this part of scholars research is mostly a single policy, there is no mixed policy research.

Scholars have used many methods to model China's carbon emissions on the issue of peak carbon emissions in China. There are CGE model, EKC model, STIRPAT model, IAMC model, Kaya identity model, IPAT model, IPAC model, MARKAL-MACRO model, economic dynamics model, control model. At the same time, it is concluded that there are differences in the year when China's carbon emissions reach the peak, as well as the carbon emissions when it reaches its peak. When studying China's carbon emissions, most scholars have used scenario analysis method, according to the different expectations of the future, set up different scenarios, from three scenarios to eight scenarios. The majority of scholars in the selection of situational analysis factors are slightly different, but mainly GDP, population, energy structure, industrial structure, energy intensity, technological progress and other factors. China's carbon emissions also peaked from 2017 to 2042, peaking from 2.637 billion tons to 11.847 billion tons (See Table 1).

RECOMMENDATIONS

Through the previous review, the current situation of development analysis, we can see that the current study of China's carbon emissions scholars still have a high enthusiasm, scholars study China's current carbon emissions issues, has done enough.

Various industries, provinces and cities have studied, the results of research methods are not the same, but there are still some problems, this paper puts forward some suggestions.

The first: when using scenario analysis to measure the peak value of carbon emissions in China, the selected factors are mainly population economy, energy consumption, technological progress, industrial structure and so on. The factor of technological progress is a vague indicator, and scholars generally use R & D instead. In this regard, scholars can try to use the relevant factors to promote technological progress in this sector in the study of specific synthesis instead.

Second, the consistency of national emission reduction actions, this method is mainly used for international comparative research, there is room for further development at home, in the study of carbon emissions in China can be further developed into inter-provincial comparison. Because of the vast territory of our country, the differences between provinces are very large, so we should measure the differences of inter-provincial carbon emissions, and promote the consistency of the actions of the provinces to reduce emissions.

Third: identify the key sectors of emission reduction, the current research methods of scholars, many did not go on in-depth research. When the key sectors of emission reduction are selected, it should be studied in detail by industry. After the key sectors of emission reduction are determined, how to go further, how much to reduce emissions, and what kind of technology can meet the expectations;

Fourth: carbon emission reduction analysis model, using the model built by scholars to predict and analyze carbon emissions, some scholars did not carry out model test, directly forecast, the model may have defects; for those models that have not been tested, There may be problems in the model itself, which makes the results do not accord with the reality of the development.

Fifth: national policy-oriented prediction, on carbon taxes, new energy-related support policies on carbon emissions research, this part of scholars research is mostly a single policy, there is no mixed policy research. At the same time, the linkage between factors and policies should be concerned by scholars, and the regulation and control of policies should not only lower or increase the relevant factors.

What's more, it's a combination of factors. As a responsible large country, the Chinese government has proposed that the peak of China's carbon emissions will be around 2030. At present, scholars should change direction when they study the peak value of carbon emissions. From continuing to study when to reach the peak and peak to study the specific measures to reach the peak. Specific to the provinces and cities how to reduce emissions, allocation of indicators and so on.

Table 1 Research results of peak carbon emissions in China

Author	Research methods	Peak time	Carbon emissions at peak (100 million tons)
Zhang Nan	CGE Model	2025	<100
Lin Boqiang	EKC Theory	2017-2023	—
Qu Shenning	STIRPAT Model	2028-2045	73.01-116.18
Chai Qimin	IAMC Model	2025-2030	120
Feng Zongxian	Kaya Model	2028-2035	96.36-121.51
Du Qiang	IPAT Model	2030	36.84
Jiang Kezhuan	IPAC Model	<2050	34.6
Zhou Wei	MARKAL-MACRO Model	2031-2042	94.72-118.47
Wang Zheng	Economic Dynamics Theory	2031	26.37
Zhu Yongbin	Control Model	2032	32.55
Jing Wu	Agent Model	2027	27.7
JinhangChen	Supply and Demand Model	2020-2030	102
Zhifu Mi	Input and Output Model	2026	112
Hongbo Duan	3E-integrated Model	2030-2040	—
Zheng Wang	Energy Supply Model	2025-2034	—
Zaipu Tao	STELLA Model	2025-2032	23—25.58
CHEN Zi	—	2020-2040	65—80
Sheng Zhou	GCAM Model	2025-2030	22.8—23.7

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