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Scenario Forecast of Carbon Emission Peak in China's Heavy Pollution Industries

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Abstract: This paper takes China's heavy pollution industry as the research object. It analyzes the important factors affecting carbon emissions of heavy pollution industry and constructs the STIRPAT expansion model. The model parameters are estimated by ridge regression method. Three scenarios of baseline, emission reduction, and high carbon are designed to predict carbon emissions with reference to policy planning documents and analysis of historical data. It is found that the carbon peaking time of China's heavy pollution industry is between 2026 and 2040, and the peaking amount is between 6711.6794 and 8117.3815 million tons. Among the three scenarios designed in this paper, the emission reduction scenario is able to achieve carbon peaking by 2030.

Keywords: Heavy Pollution Industries; Carbon Dioxide Emissions Peak; Scenario Analysis; STIRPAT Model

1. Introduction

As the world's largest carbon emitting country, China, in order to actively respond to global climate change, the Chinese government has committed in 2020 to strive to achieve the goal of carbon peak in 2030. Heavily polluting industries, which continue to play a key role in China's economic development, account for the largest share of carbon emissions, putting enormous pressure on the timely realization of the carbon peaking target. In the whole carbon peak work, whether the heavy polluting industries can realize carbon peak is of great significance for China to realize the overall carbon peak, and it is the key link to decide whether the "Peak Commitment" can be fulfilled.

For the prediction of peak carbon scenarios, scholars use different models to fit carbon emissions, design different development scenarios, and predict carbon peaking under different development modes, and the research involves the national level, key regions, and key industries. Su et al. predicted that China will peak in 2028[1]. Gao et al. set up four scenarios to predict the time of peak carbon emissions for 11 urban agglomerations in China[2]. And Wang Y et al. predicted that the earliest time for China's industrial carbon to peak is 2030[3]. Summarizing the relevant studies, we find that there are relatively few studies on heavily polluting industries, and the lessons that can be provided for practice are relatively insufficient. Based on this, this paper takes China's heavy pollution industries (including thermal power, iron and steel, cement, aluminum cathode, coal, metallurgy, chemical, petrochemical, building materials, paper making, brewing, pharmaceutical, fermentation, textile, tannery, and mining, as announced by the "List of Listed Companies Classification and Administration of Environmentally Friendly Verification Industries".) as the research object, and builds the STIRPAT expansion model to fit the carbon emissions of heavy pollution industries, and sets three development scenarios to predict the carbon peak.

2. Construction of the STIRPAT Expansion Model

2.1 Variable Selection and Model Construction

The STIRPAT model considers that the factors affecting the environment are mainly divided into demographic, economic and technological factors. The STIRPAT model can be expanded according to the different research objects, and this paper expands the factors affecting the heavy pollution industry to include employment scale, industry development level, technology level, and energy consumption as model independent variables. The dependent variable is carbon emission from heavy pollution industry. The STIRPAT Expansion Model is shown in equation (1):

$$C=aPb1Rb2Ab3Fb4Qb5Eb6Tb7e \tag{1}$$

where a is a constant term, P denotes the employment size, R, A, and F denote the business revenue, investment scale, and R&D investment of industry enterprises, Q denotes energy intensity, E denotes total energy consumption, T denotes energy structure, and e is the error term. In order to reduce the effect of model heteroskedasticity, expression (1) is obtained by taking logarithms of both the left and right sides of equation (2) as:

$$lnC=lna+b1lnP+b2lnR+b3lnA+b4lnF+b5lnQ+b6lnE+b7lnT+lne \qquad (2)$$

According to the standard of National Economic Industry Classification, the heavy pollution industry includes B06, B08-09, C13, C17, C19, C22, C25-28, C30-33, and D44 16 subsectors. Carbon emissions from heavy polluting industries are calculated using the emission factor method in the IPCC, data from China Energy Statistics Yearbook, 2000-2021.

The independent variables are respectively characterized by average number of employees by sub-industry, main business income of industrial enterprises above designated size by sub-industry, total current assets and fixed assets, internal funding for R&D, share of energy consumption in industrial industries in the total output value of industrial industries, total energy consumption by sub-industry, and share of coal consumption in the total energy consumption. The data all span the period 2000-2021, and are derived from the China Statistical Yearbook.

2.2 Analysis of Ridge Regression Results

A correlation test of the independent variables revealed significant multicollinearity between the independent variables. In order to overcome multicollinearity, this paper adopts the method of ridge regression to obtain stable regression coefficients. The macro program Ridge Regression was applied in SPSS software to carry out ridge regression. The analysis results show that the regression coefficients can basically remain stable at K=0.16, at which time the R2 is 0.9871, the F-value is 153.4818, the sigF is 0.0000, and the results of the regression equation are significant. The results of ridge regression fitting for heavy polluting industries are shown in equation (3).

$$lnC=7.0453+0.1476lnP+0.0796lnR+0.0841lnA+0.0513lnF-0.0909lnQ+0.2669lnE-0.1292lnT \quad (3)$$

3. Peak Carbon Scenario Projections for Heavily Polluting Industries

This paper sets up three scenarios: baseline, high carbon and emission reduction, taking full account of policies, research and historical data related to the future development of the heavy pollution industry. The scenarios are designed to span from 2022 to 2050, and based on China's five-year national plan, the time is divided into five phases: 2022-2025, 2026-2030, 2031-2035, 2036-2040, and 2040-2050.

3.1 Different Scenario Variables Up and Down Settings

3.1.1 Employment Size

The Party Group of the National Health Committee of the Communist Party of China predicts that the population size will peak during the 14th Five-Year Plan period. Population decline will lead to a decrease in labor supply, which in turn will lead to a decrease in the number of employed people[4]. The data show that the average annual employment in heavy polluting industries has been declining since 2011, with an average annual growth rate of -6.12% during the 13th Five-Year Plan period. However, as the energy saving and emission reduction efforts in heavy pollution industries are becoming effective, the decline in employment will level off[5]. In view of this, this paper sets the average annual growth rate of employment size in the first stage at -6.00% in the baseline scenario. The high carbon and emission reduction scenarios rise and fall are set at -4.00% and -8.00% respectively. The average annual growth rate of employment size rises at a rate of 0.5% in the next two stages, and gradually declines at the same rate from the third stage onwards.

3.1.2 Industry Development

The average annual growth rate of business revenue in heavily polluting industries has changed from rapid growth during the period of rough development to steady growth, and a downward trend has been observed during the 13th Five-Year Plan period, with a growth rate of -1.58%. Zhang X L et al. predicted that the value added of China's secondary industry will decline by 2.94% during the 14th Five-Year Plan period[6]. Based on this, this paper sets the first-stage growth rate of business revenue of heavy polluting industries at -1.5% in the baseline scenario. The growth rates of the high carbon and emission reduction scenarios are 1% and -3%, respectively, and thereafter the growth rates of the phases gradually decline.

With the basic completion of China's industrialization, the investment structure is reduced in the secondary sector, and the growth rate of the whole society's fixed assets declined by an average annual rate of 1.275% from 2010-2021, and will change from increasing to decreasing around 2035[7]. The growth rate of investment in heavily polluting industries is gradually declining, but the growth rate gradually decreases, with an average annual growth rate of 2.05% in 2016-2020. Therefore, it is set that the average annual growth rate of the investment scale of the heavy pollution industry in the first stage is 2% in the baseline scenario. Thereafter the growth rate decreases by 1% in each phase and becomes negative in the 2030-2035 phase. The growth rates for the high carbon and abatement scenarios are set at 4% and 0, respectively.

With regard to R&D investment, China's 14th Five-Year Plan states that the average annual growth rate of society-wide R&D investment should be greater than 7%. R&D investment in the heavy pollution industry will continue to increase since 2000, but the growth rate will gradually decrease, and the average annual growth rate during the 13th Five-Year Plan period will be 7.03%. The average annual growth rate for the first stage is set at 7% in the baseline scenario, and the growth rates for the high-carbon and emission reduction scenarios are set at 5% and 9%, after which the growth rate of R&D investment in the industry gradually decreases in all stages.

3.1.3 Technology Level

According to the World and China Energy Outlook 2050 published by the China Academy of Petroleum Economics and Technology in 2020, China's energy intensity in the mid-century will be reduced by 76% compared to 2015, respectively, with an average annual decline of 4%. And the data show that the energy intensity of the industrial sector was reduced by an average of 4.60% annually from 2000-2021. Meanwhile, Sun et al. pointed out that China's energy intensity growth rate in 2016-2040 is not faster than -5.56% and the downward trend is gradually slowing down[8]. Therefore, the energy intensity growth rate of the first stage of the heavy pollution industry is set at -4.5% in the baseline scenario, and -3.5% and -5.5% in the high carbon and emission reduction scenarios, respectively, and the decline gradually decreases in the subsequent stages.

3.1.4 Energy Consumption

Total energy consumption in heavily polluting sectors is transitioning from a fast-growth phase to a slow-growth phase. The average annual growth rate for 2016-2020 is 2.30%. Lin B Q expects China's energy consumption to grow at a rate of 2% during the 14th Five-Year Plan[9]. The World Energy Outlook 2050 report projects that China's energy demand will peak around 2035. Therefore, the total energy consumption of heavy polluting industries is set to grow at a rate of 2% in the first stage in the baseline scenario, and then decreases by 1% in each stage of the isochronous reduction, with the growth rate decreasing to a value of 0 in 2035. The high carbon and emission reduction scenarios are set at 3% and 1% respectively.

The energy mix of heavily polluting industries has been declining since 2005, with an average annual growth rate of -3.53%. The "14th Five-Year" Comprehensive Work Program for Energy Conservation and Emission Reduction indicates that coal consumption should be strictly controlled, and the proportion will reach about 20% by 2025, which is 5% more than that of the 13th Five-Year Plan, and will reach more than 20% by 2030. It can be inferred that the proportion of coal consumption in heavy polluting industries will decrease year by year in the future, but the rate of decrease tends to stabilize. As a result, the rate of change in the energy structure of heavy polluting industries in the first stage is set to be -3.5% in the baseline scenario. The high carbon and emission reduction scenarios are -2.5% and -4.5% respectively. Thereafter, the rate decreases by 0.5% in each stage.

3.2 Results of Peak Carbon Scenario Projections for Heavily Polluting Industries

Based on the regression results of the STIRPAT extended model, the carbon emissions of heavy polluting industries are projected for 2022-2050 under the baseline, abatement, and high carbon scenarios, respectively. The predicted results are shown in figure 1.

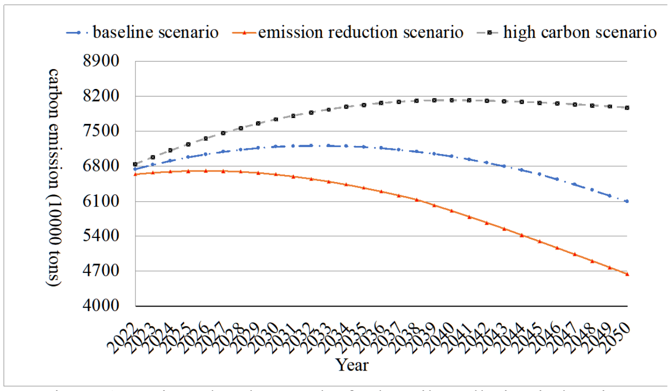

Figure 1: Projected carbon peaks for heavily polluting industries.

From the prediction results, it can be seen that under the baseline scenario, the heavy polluting industry achieves carbon peak in 2032, with a peak value of 7208.9439 million tons. Under the Emission Reduction Scenario, the heavy polluting industries are able to achieve peak carbon in 2026, six years earlier than the baseline scenario, with a peak value of 6711.6794 million tons. Under the high carbon scenario, the heavy polluting sectors will not achieve peak carbon until 2040, 10 years later than the baseline scenario peak, with a peak of 8117.3815 million tons.

4. Conclusion

The carbon peaking time of heavy polluting industries is between 2026-2040, and the peaking amount is between 6711.6794 and 8117.3815 million tons. Among the three scenarios designed in this paper, the emission reduction scenario is able to realize carbon peaking by 2030. The Chinese government should carry out reasonable regulation of heavily polluting industries, adjust employment and industry development patterns, reduce energy consumption, and encourage the reduction of energy intensity and the adjustment of energy structure brought about by technological advances, so that heavily polluting industries can realize carbon peaking by 2030.

References

[1] Su, K., C. M. Lee. When Will China Achieve Its Carbon Emission Peak? A Scenario Analysis Based on Optimal Control and the STIRPAT Model[J]. Ecological Indicators,2020,(112):106-138.

[2] Gao Guoli, Wen Yang, Wang Li et al. A study on carbon peaking in urban agglomerations based on carbon emission influencing factors[J]. Business and Management Journal,2023,45(02):1-20.

[3] Wang Yong, Bi Ying, Wang Endong. Scenario prediction and assessment of emission reduction potential for industrial carbon peaking in China[J]. China Population, Resources and Environment,2017,27(10):131-140.

[4] Shi Dan, Li Peng. Simulation of Industrial Carbon Emission Structure and Policy Impacts under the “Dual Carbon” Target[J]. Reform, 2021, (12): 30-44.

[5] Zhang Zhi, Zhang Henglai, Zhang Huiqun. Green construction and sustainable development of pulp and paper industry with the help of engineering industry under the target of “double carbon”[J]. China Pulp & Paper, 2022, 41(03):92-96.

[6] Zhang Xiliang, Huang Xiaodan, Zhang Da et al. Pathways and policies for energy economy transition under carbon neutrality[J]. Journal of Management World, 2022, 38 (01): 35-66.

[7] Liu Chunmei, Qian Xiaoyin. Forecasting carbon emissions from energy consumption in China under the “double carbon” target[J]. Resource Science, 2023, 45 (10): 1931-1946.

[8] Sun Z R, Liu Y D, Yu Y N. China’s Carbon Emission Peak Pre-2030: Exploring Multi-Scenario Optimal Low-Carbon Behaviors for China’s Regions[J]. Journal of Cleaner Production, 2019(231): 963-979.

[9] Lin Boqiang. China’s high-quality economic growth in the process of carbon neutrality[J]. Economic Research Journal, 2022, 57 (01): 56-71.