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# Prediction of Carbon Emission Peak and Selection of Development Path in Gansu Province Based on the Constructed STIRPAT Model

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***Abstract:*** *The ridge regression method was applied to analyze the factors affecting carbon emission in Gansu from 2000 to 2019 based on the estimated carbon emission data, constructed carbon emission prediction model and predicted the trend of carbon emissions of Gansu Province under six scenarios. The results indicated that the overall trend of carbon emissions in Gansu Province from 2000 to 2019 is growing; and the carbon emission in Gansu was significantly affected by the size of population, industrial structure, and urbanization rate; Gansu Province could achieve carbon peak in 2040 under six development models; The peak of carbon emission in Gansu Province is proportional to the economic growth rate and inversely proportional to the emission reduction efforts, the faster its economic development rate, the more sensitive the peak size is to the emission reduction effort, and the smaller the emission reduction effort, the more sensitive the peak size is to the economic development rate; Low peaks are generally peaked early, and high peaks are generally peaked late. Based on the above analysis, it is believed that the more suitable carbon peak development path for Gansu Province is the he medium economic growth with medium emission reduction model.*

***Keywords:*** *Panel data, construction of STIRPAT model, Scenario analysis, Carbon peak prediction*

## 1. Introduction

As the world's most populous country with the largest carbon emissions, achieving carbon peaking and carbon neutrality is an intrinsic requirement for sustainable and high-quality development, and an inevitable choice for promoting ecological civilization and building a community of life between human beings and nature, for which China has proposed the " carbon peaking and carbon neutrality " goals. Based on the difficult task of energy structure adjustment and industrial structure transformation, the lack of green low-carbon technology innovation capacity, and the overall low carbon sink capacity of the ecosystem, the realization of " carbon peaking and carbon neutrality " goals is facing serious challenges. The western region of China is relatively backward in development, but its growth rate of carbon emissions has exceeded that of the central region, second only to the eastern region with the economic growth in recent years, [1], and its share in the country is also increasing year by year, facing the double pressure of economic development and carbon reduction. Therefore, it is important to explore the optimal development path of carbon emissions in the western region to achieve its carbon peak goal.

Some scholars believe that China can achieve peak carbon by 2030 through modelling, while others believe that it is still challenging for China to achieve peak carbon by 2030. At the regional level, scholars predict the carbon emission trends in the eastern [2-4], central [5-7], and western [8] regions, and explore the development paths to achieve peak carbon. At the provincial level, scholars construct models based on the current carbon emission trends in Hebei [9], Jiangsu [10], Liaoning [11], Hubei [12], Jilin [13], Shanxi [14], and Shaanxi [15] provinces, and use scenario analysis to predict their carbon peaking times and peaks.

In the context of the gradually increasing share of carbon emissions in the western region in the country [16], how to reduce carbon emissions while maintaining rapid socio-economic development is an important issue. At present, there are few studies on the prediction of carbon peaks in western regions and provinces, as one of the less developed provinces in western regions, Gansu Province has improved its socio-economic development level with the continuous promotion of the "Belt and Road" construction and the "New Pattern of Western Development". The carbon emissions of Gansu Province are still growing

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with the continuous promotion of the "Belt and Road" construction and "Western Development". Therefore, based on the panel data of Gansu Province from 2000 to 2019, this paper identifies the main factors influencing its carbon emissions based on the carbon emissions measurement, and further constructs the STIRPAT model to predict the trend of its carbon emissions under six scenarios, and explores the development path suitable for Gansu Province to reach the carbon peak, in order to provide reference for the development of energy conservation and low carbon economy in Gansu Province.

## 2. Basic model and data processing

### *2.1. Carbon Emission Forecasting Model*

There are more models applied to carbon emission projections, Considering the shortcomings of various prediction models in their application [17-18], this paper is carried out to construct the STIRPAT model to forecast carbon emissions in Gansu Province.

The STIRPAT model is developed on the basis of the IPAT model. However, the IPAT model is limited in its application due to its default that the impact of each factor on the environment is homogeneous. In order to overcome this limitation, Dietz and Rosa proposed the STIRPAT model based on it, whose expression as in (1).

$$I = a P^b A^c T^d e \tag{1}$$

I represents environmental pressure, P represents population size, A represents economic development level, T represents technological factor; a represents the model coefficient; b, c, d, represents the indices of variables P, A, and T, respectively; e is the random error term of the model. The logarithmic form of the model as in (2).

$$\ln I = \ln a + b \ln P + c \ln A + d \ln T + \ln e \tag{2}$$

Considering the representativeness of the data, six indicators such as population size, urbanization rate, GDP per capita, share of secondary industry, share of coal consumption, and energy consumption per unit of GDP are selected to construct the model, and also to verify whether there is an inverted U-shaped relationship between economic growth and carbon emissions, this paper refers to the study of York et al [19] to introduce the quadratic term of GDP per capita and construct a carbon emission prediction model for Gansu Province as in (3) :

$$\ln I = \ln a + b \ln P + c \ln U + d \ln A + f (\ln A)2 + g \ln IS + h \ln ES + j \ln EI + \ln e \tag{3}$$

I is the total carbon emission, which represents the environmental pressure; P is the population size and U is the urbanization rate, which together represent the demographic factor; A is the GDP per capita and IS is the share of secondary industry, which together represent the economic factor; ES is the share of coal consumption and EI is the energy consumption per unit of GDP, which represent the technological factor; a is the model coefficient, b, c, d, f, g, h, and j represent the elasticity coefficients of each variable, respectively , and e is the model random error term.

### *2.2. Data sources and Processing*

The energy consumption data from the China Energy Statistical Yearbook [20], the carbon emissions from energy consumption were measured using the methodology in the IPCC Guidelines for National Greenhouse Gas Inventories, and the index data required in the carbon emission impact factors from the Gansu Development Yearbook [21].

## 3. Model construction results

Based on the energy consumption data of Gansu Province, the carbon emissions from 2000-2019 were measured, and on this basis, ridge regression was used to analyze the effects of factors such as population, urbanization rate, GDP per capita, share of secondary industry, share of coal consumption, and energy consumption per unit of GDP on carbon emissions from 2000-2019 and to construct the STIRPAT model. The results indicated that the regression coefficient of coal consumption share failed the significance test, so the variable was excluded and ridge regression was conducted again. As shown in Fig .1, when k=0.06, the change of the ridge trace tends to be stable, and the corresponding $R^2$=0.987, the model fits well and the regression coefficients of all variables pass the significance test, the fitting results are shown in Table

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I, and the corresponding STIRPAT model is obtained as in (4).

$$\ln I = 5.556 \ln P + 0.131 \ln A + 0.007 (\ln A)^2 + 0.366 \ln U + 0.435 \ln IS - 0.131 \ln EI - 39.88 \quad (4)$$

The results of the ridge regression indicated that each variable has different degrees of influence on carbon emissions, among which population size, industrial structure and urbanization level have a greater influence on carbon emissions in Gansu Province. The results of the ridge regression also indicate that there is no inverted U-shaped relationship between economic growth and carbon emissions in Gansu Province, economic development is still at the stage of high dependence on carbon emissions from energy consumption, and the inflection point of the KEC for carbon emissions has not yet appeared, which further indicates the necessity of predicting the future carbon emissions in Gansu Province, clarifying the possibility and time of its peak carbon emissions, and exploring its low-carbon development path, as shown in Figure 1.

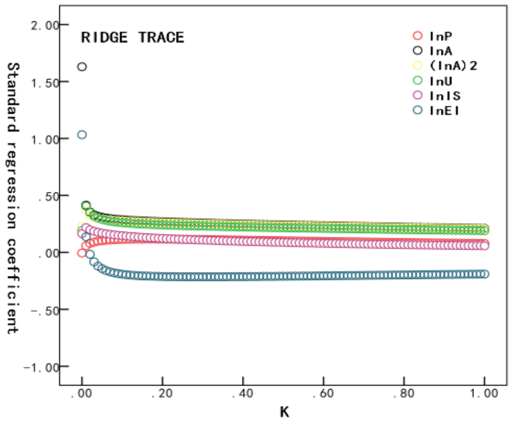


*Figure 1: Analysis on the ridge regression of the variables*

*Table 1: Ridge regression results of the STIRPAT model for carbon emissions in Gansu*

| Var | B | SE | Beta | T | Sig. |
|---|---|---|---|---|---|
| lnP | 5.556 | 2.438 | 0.106 | 2.279 | 0.040 |
| lnA | 0.131 | 0.007 | 0.302 | 19.597 | 0.000 |
| $(\ln A)^2$ | 0.007 | 0 | 0.288 | 20.536 | 0.000 |
| lnU | 0.366 | 0.042 | 0.28 | 8.678 | 0.000 |
| lnIS | 0.435 | 0.126 | 0.163 | 3.452 | 0.000 |
| lnEI | -0.131 | 0.027 | -0.16 | -4.855 | 0.000 |
| Cons | -39.88 | 18.78 | 0 | -2.124 | 0.053 |

Note: $R^2$=0.987, F=160, Sig F=0.000

In order to test the robustness of the model, the simulated values of carbon emissions in Gansu Province from 2000 to 2019 are calculated using "(3)" and compared with the actual values, and the results show that the average annual error rate between the simulated and actual values of carbon emissions in Gansu Province from 2000 to 2019 is only -3.61%, which indicates that the model fits well, the selected driving factors affecting carbon emissions have good representativeness, and its research The study has some empirical significance.

## 4. Carbon emission path options for Gansu Province

To achieve the goal of peak carbon emissions in Gansu Province around 2030, the growth rates of population, economy, and other driving factors need to be regulated in some way to find the optimal paths among the different development models set.

### *4.1. Carbon emission projections under different development patterns*

In this paper, the annual average rate of change of each variable is set based on historical data and relevant policies in Gansu Province. To facilitate the analysis, the five variables in the STIRPAT model are divided into two categories, namely, economic and social development variables and emission reduction variables. The economic and social development variables include population size, GDP per

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capita and urbanization rate; the emission reduction variables are the share of secondary industry and energy consumption per unit of GDP. Considering the uncertainty of economic development and energy use, the prediction scenarios of economic and social development variables are set into three modes, namely, low growth mode, medium growth mode and high growth mode; the prediction scenarios of emission reduction variables are set into two modes, medium emission reduction and strong emission reduction. The different models of the two types of variables were freely combined to obtain six models, namely. including the low economic growth with medium emission reduction, low economic growth with strong emission reduction, medium economic growth with medium emission reduction, medium economic growth with strong emission reduction, high economic growth with medium emission reduction, high economic growth with strong emission reduction model. According to the settings of the rate of change of each variable under the six scenario models in the paper, the predicted values of each variable are shown in Table II (for the reason of space, only the predicted values of each variable in individual years are listed).

*Table 2: Predicted values of the variables under different situations in Gansu*

| year | low growth mode | | | medium growth mode | | | high growth mode | | medium emission reduction mode | | | strong emission reduction mode | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P (ten thousand people) | A (RMB/ person) | U (%) | P (ten thousand people) | A (RMB/ person) | U (%) | P (ten thousand people) | A (RMB/ person) | U (%) | IS (%) | EI (t/ ten thousand yuan) | IS (%) | EI (t/ ten thousand yuan) |
| 2021 | 2511 | 38335 | 53.33 | 2519 | 38407 | 53.95 | 2524 | 38479 | 54.58 | 31.19 | 0.872 | 30.40 | 0.857 |
| 2024 | 2531 | 46306 | 56.76 | 2561 | 46655 | 59.47 | 2582 | 47006 | 62.29 | 29.90 | 0.796 | 26.98 | 0.746 |
| 2028 | 2532 | 59437 | 61.53 | 2593 | 60337 | 67.56 | 2635 | 61248 | 74.11 | 28.13 | 0.708 | 22.90 | 0.623 |
| 2032 | 2505 | 76163 | 66.59 | 2597 | 77898 | 76.62 | 2660 | 79669 | 80.00 | 26.36 | 0.632 | 19.36 | 0.522 |
| 2036 | 2451 | 97476 | 71.98 | 2572 | 100449 | 80.00 | 2655 | 103506 | 80.00 | 24.62 | 0.566 | 16.31 | 0.439 |
| 2040 | 2371 | 124648 | 77.72 | 2518 | 129418 | 80.00 | 2621 | 134362 | 80.00 | 22.92 | 0.509 | 13.70 | 0.371 |

### *4.2. Analysis of Carbon Emission Forecast Results and Pathway Options in Gansu Province*

Based on the setting of the rate of change of each variable under the six scenarios in Gansu Province, the trend of carbon emissions under the six scenarios was predicted by substituting the values of each variable into (4), as shown in Figure 2.

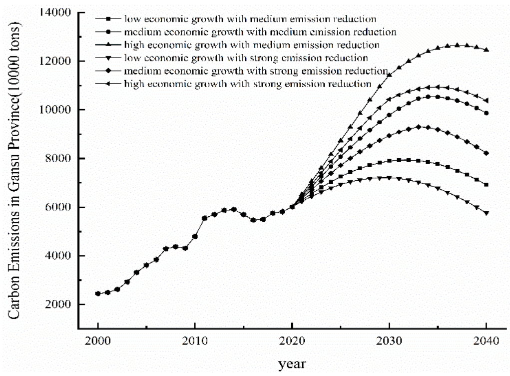


*Figure 2: Projected values of carbon emissions in Gansu under different scenarios*

In the six scenarios set up in the paper, Gansu Province is able to achieve peak carbon in 2040. Further analysis of the time and peak of carbon attainment in the six scenarios revealed that the size of the peak is directly proportional to the speed of economic development and inversely proportional to the size of emission reduction efforts, Low peaks generally reach their peaks early, and high peak values generally reach their peaks late. It shows that the slower the economic growth rate of Gansu Province, the greater the intensity of carbon emission reduction, the sooner the carbon peak can be achieved. However, according to the current actual needs of Gansu Province's socio-economic development, the low economic development model is not suitable for Gansu Province, and in the context of China's implementation of economic transformation and development, ecological protection and high-quality development of the Yellow River Basin, the high-speed economic model that is highly dependent on resources and energy is also not in line with Gansu Province's development philosophy. In terms of emission reduction intensity, on the one hand, the adjustment and optimization of the energy structure of Gansu Province is largely constrained by the local energy resource endowment. On the other hand, Gansu Province has a low capacity for scientific and technological innovation and limited ability to reduce carbon emissions through

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technological progress to improve energy use efficiency in the short term, therefore, the strong emission reduction model is also not in line with the development reality of Gansu Province. Accordingly, based on the principles of ensuring that economic growth is in a reasonable range, that emission reduction efforts are both realistic and challenging, and that the peak year is preferably around 2030, the smaller the peak the better [22], the "medium growth with emission reduction" model should be the actual carbon peak development path for Gansu Province. In this scenario, the peak of carbon emissions in Gansu Province will occur in 2034, with a peak value of 105.39 million t. This target value can meet the needs of social and economic development in Gansu Province, and also accomplish the goal of a smaller peak value and an earlier peak time.

## 5. Conclusion

The article measures carbon emissions in Gansu Province based on panel data from 2000-2019, constructs a carbon emission forecasting model using the ridge regression method, and forecasts carbon emission trends in Gansu Province under six scenarios, drawing the following conclusions.

1) The carbon emissions in Gansu Province from 2000-2019 are on an upward trend, and the main factors affecting carbon emissions are population size, industrial structure and urbanization rate, and according to the current development trend, Gansu Province cannot reach the peak of carbon emissions in 2030.

2) Low peaks are generally peaked early, and high peaks are generally peaked late; The size of peak carbon emissions in Gansu Province is directly proportional to the level of economic growth and inversely proportional to the size of emission reduction efforts; the faster its economic development rate, the more sensitive the peak size is to the emission reduction effort, and the smaller the emission reduction effort, the more sensitive the peak size is to the economic development rate.

3）In the six scenarios of low-growth emission reduction, low-growth emission reduction, medium-growth emission reduction, medium-growth emission reduction, high-growth emission reduction, and high-growth emission reduction, Gansu Province can achieve peak carbon in 2040, among which the “medium-growth emission reduction” model is a suitable carbon peak path for Gansu Province, and in this scenario, the peak of carbon emissions in Gansu Province is smaller and the peak is reached earlier.

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