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Energy Consumption and Carbon Emissions: Analysis and Prediction-The Case of Hebei Province in China

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Abstract

From the time of reform and opening up, China's rapid economic growth attracts worldwide attention, which also brings the accompanying problems that high energy consumption, high pollution and high emission are more prominent. Therefore, the low carbon economy development model has become an inevitable choice for China's sustainable economic development. However, the stage of economic development is insurmountable and the continuing growth and the disadvantaging structure of energy consumption will become a serious obstacle for China's low-carbon economy. Selecting the relevant data from 1980 to 2009, and using not only Hebei Province as its study area but also the whole country as its reference region, this paper analyzes the relationship between the changes in energy consumption structure and the carbon emissions in Hebei Province, and basing on which predicts the energy consumption and carbon emissions in the future in order to provide policy recommendations for the optimization of energy consumption structure, the upgrade of industrial structure, and the development of carbon economy.

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Keywords: Energy consumption; carbon emissions; analysis; Model prediction; new energy

1. Introduction

The United Nations Climate Change Conference in Copenhagen has become the prelude of developing low-carbon economy, and the global financial crisis has led the world economy to the further development of low-carbon technology. The world's major developed countries have all drawn up long-term strategic planning, promoted the development of low-carbon technologies and industries, and

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actively accelerated the transition to low-carbon economy. The Chinese government, which has taken the initiative in this issue, announced on UN Copenhagen Climate Change Conference in December 2009 that in 2020 China will be reduced by 40% - 45% of that in 2005. Communist party 11th NPC standing committee meeting which closed at the end of February 2010 has made it clear that China will develop green and low-carbon economy.

However, China's economic development stage is insurmountable, so the demand for carbon emissions will be continuously increasing. China's status quo of energy endowment, energy consumption structure, low-carbon technology and other aspects, will inhibit the improvement of energy efficiency and the reduction of carbon emissions per unit of energy. Obviously, China will face tremendous pressure in energy saving in the next decade. Specifically, in China carbon emissions made by fossil fuel consumption cover 90% of the total carbon emissions. Therefore, in order to save energy and reduce emissions, change the way of economic development and implement the mode of low-carbon economic development, China must give top priority to the optimization of energy consumption structure, improvement of energy efficiency and reduction of carbon emission intensity. Selecting the eastern coastal provinces of China - Hebei Province- as its research area, and using the whole country as its background area, this paper analyzes the energy consumption and the dynamic trend of carbon emissions in Hebei Province, and basing on which makes prediction and find the bottleneck of low-carbon economy development in Hebei Province in order to provide appropriate conclusion and countermeasures.

2. Estimation and prediction of carbon emissions from energy consumption in Hebei Province

2.1. Estimation of carbon emissions from energy consumption

The formula adopted by this paper to estimate the carbon emissions from energy consumption is as following:

$$C = \sum_{i=1}^3 m_i \times \delta_i \quad (1)$$

In which, C is carbon emission, m_i is the standard amount of primary energy consumption in Hebei province, and δ_i is the coefficient of carbon emissions from energy of the i class. By consulting the relative literatures and balancing the carbon emission coefficient of energy consumption, this paper ultimately uses the average value as the carbon emission coefficient of energy consumption, which can be seen in table 1 below.

Table 1. Coefficient of carbon emissions of different energies

Data sources	Carbon emission coefficient of coal t(c)/t	Carbon emission coefficient of petroleum t(c)/t	Carbon emission coefficient of natural gas t(c)/t
Project on climate change of State Science and Technology Commission	0.726	0.583	0.409
DOE/EIA	0.702	0.478	0.389
IEEJ	0.756	0.586	0.449
Xu Guoquan	0.7476	0.5825	0.4335
Average value	0.7329	0.5574	0.4226

This paper selects GDP, population, gross energy consumption, three types of primary energy consumption, the proportion of three types of primary energy consumption, three main types of carbon emission coefficient of energy and other indicators of Hebei province and the whole country from 1980 to 2009 to generate cross section data and time series data, and to compose evaluation index database. Data sources are the “fifty-five years of New China Statistical Assembly”, “China Statistical Yearbook 2010”, “China Energy Statistical Yearbook 2009”, “Hebei Economic Yearbook 2010” and other relative statistics and data. According to the formula and the selected coefficient of carbon emissions, this paper processes the relative data and its results are shown in Figure 1, Figure 2 and Figure 3.

2.2. Model prediction of carbon emissions

Basing on the foregoing analysis, we select the series of gross carbon emissions from energy consumption in Hebei Province from 1980 to 2009 and predict future trends of it with appropriate forecasting model.

2.2.1. Model selection

It can be observed from the graph made by Eviews6.0 software that the series from 1980 to 2009 representing carbon emissions show a clear trend, especially an obvious exponential trend. Therefore, according to Grammer decomposition theorem, the carbon emission timing series will be decomposed into two sequential parts, one of which is the deterministic trend component of exponential curve and the other is random component of stationary zero-mean. That is, through combined model to fit the characteristics of series movement, and based on the model optimization according to SC criteria; the ARMA (1, 2) model is ultimately settled.

The combined model of carbon emissions (ce) in Hebei Province is as follow:

$$ce = 2121.7574e^{0.0688t} + (1 - 0.4311B - 0.5017B^2)\varepsilon_t / (1 - 0.8476B) \quad (2)$$

2.2.2. Model forecast

The model is used to forecast the data in sample period in order to gain the line charts of the original series and the forecasting series, and the result is that they are fitting better. Therefore, the model can be used to predict carbon emissions from 2010 to 2015 which are shown in Table2.

Table 2. Forecast result of gross carbon emissions of Hebei Province in 2010-2015

Year	Forecast Value of Gross Carbon emissions
2010	17923.18
2011	19200.37
2012	20568.57
2013	22034.23
2014	23604.48
2015	25286.39

Obviously, the forecast results from the model indicate that the carbon emissions of energy consumption in Hebei Province will continue to rise in the period of the Twelfth Five-Year Plan, although it has experienced the fall in 2010. Therefore, the task of energy saving and emission reduction in Hebei Province will be more severe in the future.

3. Dynamic trends and Characteristics of Energy Consumption and Carbon Emissions of Hebei Province

3.1. Energy consumption and carbon emissions continuingly rise, with consistent trend and significant stage

In the research period, total energy consumption and carbon emissions in Hebei Province continue to grow and their dynamic trends show obvious features of stage. It can be seen from the following Figure 1 that the period from 1980 to 1994 is the rapid growth stage for energy consumption and carbon emissions; 1995-1999 is the smooth growth stage for energy consumption and carbon emission; 2000-2006 is the explosive growth stage for energy consumption and carbon emissions; the period from 2007-2008 is the slow growth stage for energy consumption and carbon emissions; and in the stage of 2009 they show rapid growth again. In short, this change in different stages is basically consistent with cyclical fluctuations of economic development.

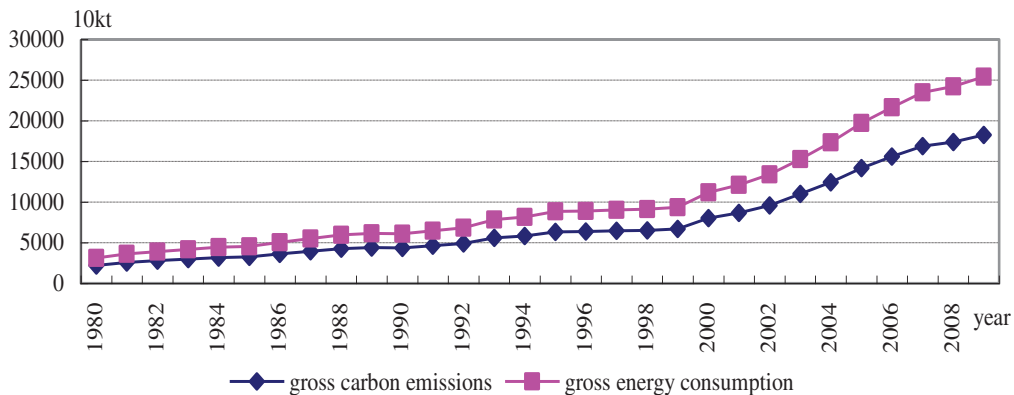


Fig. 1. The energy consumption and carbon emissions of Hebei Province in 1980-2009

3.2. Carbon emission intensity continues to decline and its gap with the national level continues to narrow

With the adjustment of economic structure, progress of production and technology and the guidance of appropriate policy, the carbon emission intensity from energy consumption (carbon emissions per unit of output) in Hebei Province constantly declines, and the speed of this decline was also evidently different during different stages. It is shown in Figure 2 that the period from 1980 to 1994 is the rapid decline stage for carbon emission intensity; the period from 1994 to 1999 is the slow decline stage for carbon emission intensity; the period from 2000 to 2004 is stable stage for carbon emission intensity; and the period from 2005 to 2009 is the stage in which the intensity begins to gradually slow down. This trend of change in carbon emission intensity is broadly consistent with the trend of the nation. However, the decline speed in Hebei is faster than the one of the nation; and its gap with the national level is gradually narrowed. Therefore, Hebei gets remarkable achievements in reducing carbon emissions.

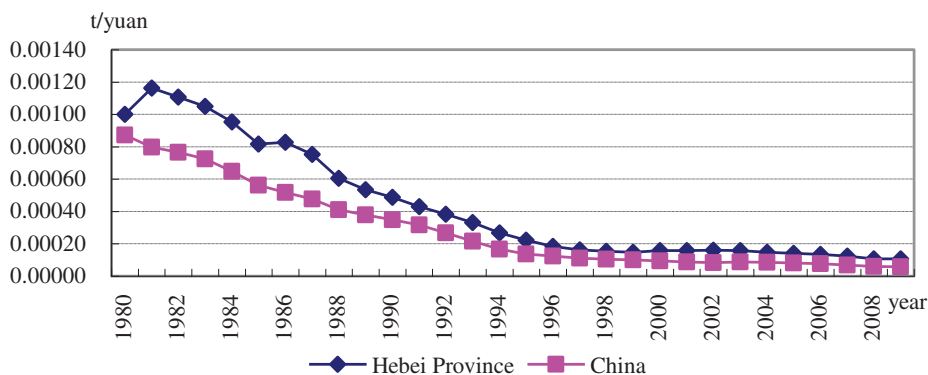


Fig. 2. The carbon emissions per unit of output in Hebei Province and China in 1980-2009

3.3. Per capita carbon emissions is higher than the national level, and the gap between them is widening

From the perspective of changes in per capita carbon emissions, the per capita carbon emissions in Hebei Province is continuing to increase, which is consistent with the trend of total carbon emissions from energy consumption. It also shows significant features of stage. From 1980 to 2009 the per capita carbon emissions in Hebei Province is higher than the national average level, and the gap is significantly expanding, especially since the beginning of the 21st century. For instance, its per capita carbon emissions are 2.594 tons / person in 2009, while the number of national average is only 1.452 tons / person.

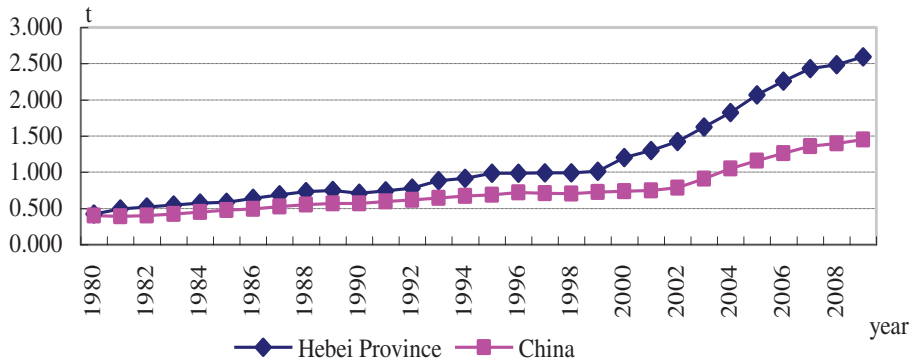


Fig. 3. The carbon emissions per capita of energy consumption in Hebei Province and China in 1980-2009

Overall, the gross energy consumption, gross carbon emissions and per capita carbon emissions in Hebei Province have rising trends and their growth rates are above the national average level. The carbon emission intensity in Hebei has shown a declining trend and the decline rate is higher than the national rate, but its absolute value of carbon intensity is still higher than the national average. Besides, per capita carbon emissions which show a rising trend are higher than the national average level and the gap with the nation is widening. Obviously, in the process of economic growth in Hebei Province, the characteristics of high emission and low efficiency in energy consumption will make the continuing expansion of demand for energy consumption and carbon emissions, so it gives great pressures for Hebei in energy conservation and emission reduction.

4. Conclusions and countermeasures

4.1. Conclusions

First, the changing trends and characteristics of energy consumption and carbon emissions in Hebei, on one hand show that Hebei Province will face increasing resistance in its development of low-carbon economy and in the achievement of its goal of energy saving and emission reduction; on the other hand show that compared with the whole country, Hebei's optimizing degree of energy consumption structure is low, that Hebei Province over-relies on coal of which the utilization rate is low and the carbon emission coefficient is high, and that Hebei's proportion of coal consumption has a rising trend. Therefore, if there is no external force to promote, the current situation with high energy consumption, low efficiency and high emission in the process of Hebei's economic growth is difficult to change.

Second, according to the prediction of carbon emissions in the model of Hebei Province, carbon emissions will grow rapidly in the next 5 years, although the carbon emissions declined slightly in 2010. In addition, as the traditional large industrial province of China, the coal consumption proportion will be still high and the proportion of secondary industry of Hebei Province will remain around 52% in the short term.

Third, the complex relations between natural resource endowments and economic system determine the inertia of the changes in energy consumption structure. That is, because of being rich in coal and lacking of oil and natural gas, Hebei's disadvantages of energy consumption structure have continued to self-increase. Therefore, Hebei's changes in energy consumption structure require a strong external force.

4.2. Measures to optimize energy consumption structure and to reduce carbon emissions

First, the establishment of long-term mechanism for low carbon policies is the key to promote low-carbon economy development. Energy consumption structure adjustment and the promotion of energy conservation and emission reduction is a long process, and will be “embedded” in a systematic project of low-carbon economic development. The establishment of dynamic, long-term mechanism of low-carbon policies can improve the stability and foresight of policies. It is helpful to achieve objectives of the dynamics and dynamic fine-tuning of policy to continuously track the footprints of policy implementation and consider the effects of policies. It is more possible for the public to accept the policy arrangements that develop in depth and meet the reality and only in this way can they be active to cooperate in improving the policy constraints and incentive effects.

Second, accelerate industrial restructuring and take a new road to industrialization. Adjustment of industry structure will lead to the evolution of the energy consumption structure. Currently, the proportion of the secondary industry in China is large, of which output growth was mainly dependent on energy and capital investment. Therefore CO₂ emissions in secondary industries are the most. As a traditional large industrial province, Hebei Province has a high proportion of industrial output which is above the national average level and its industrial output is mainly from heavy chemical industries that depend on high input, high emissions. Therefore, the development of its tertiary industry is very slow. To achieve low-carbon economic development model, Hebei Province has to accelerate the development of the tertiary industry, optimize the internal structure of the secondary industry, make technological progress as the first driving force to enhance high-tech industry and accelerate the technological transformation of traditional heavy industry.

Third, provide comprehensive support to the innovation, introduction, and promotion of low-carbon technology and build the cohesion in the transformation of energy consumption structure. The development, application and diffusion of low-carbon technology are the key factors to resolve the energy crisis, solve the climate problem, optimize energy consumption structure, and develop low-carbon economy.

Fourth, based on the advantages of natural resources, develop new energy industries. China is a large country and its temporal and spatial variations in resource distribution are significant, so every region should make full use of regional advantages, and develop new energy industries according to the local conditions. Hebei Province is rich in solar energy resources, wind energy resources, straw resources, geothermal resources and marine resources. Therefore, to accelerate the development of new energy industries will help Hebei Province to lessen the disadvantage of its energy consumption structure, improve its energy efficiency and reduce its carbon emission intensity.

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