The Forecast of Baoding’s Industrial Structure in Different Scenarios

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Abstract. In November 12th, 2014, Chinese government officially announced reaching the peak of CO2 emissions around 2030. Baoding, as one of the first low-carbon pilot cities in China, bore an important mission and set an example to other cities to reach the peak of carbon emissions before 2030. This paper employed a computable general equilibrium model to simulate the industrial structure and social welfare of Baoding in different scenarios. And the calculation results have shown that on the principle of the optimal industrial structure and the minimum social welfare loss and a consideration of industrial economic development, the best time of CO2 emissions peak for Baoding was 2025 when its total emissions would reach 2.84 million tons. Finally, some suggestions were given to guide this city to reduce carbon emissions in industrial development.

1. Introduction
In November 12, 2014, according to “the Joint Declaration on Climate Change” by the United States and China at Beijing, China announced for the first time that the peak of CO2 emissions would be occurred around 2030[1]. It is necessary for all low-carbon cities to play an exemplary role in the process of emission reduction, leading the other cities nationwide to achieve this commitment together. Baoding, a city of Hebei province, was one of the first low-carbon pilot cities and should undertake mission of reducing emissions firstly. However, there’s still no research about the peak time and quantities of carbon emission in Baoding and no report on how the industrial structure should be formed to reach the scheduled peak of CO2.

This paper focused on Baoding’s industrial structure in different scenarios, the results were conducted with computable general equilibrium (CGE) model. Various industrial structures were simulated, which found out proportions of various industries in Baoding under different scenarios. Besides, on the foundation of the principle of maximum social welfare, an optimal time that occurred the peak of CO2 emissions in Baoding was concluded.

Computable general equilibrium model (CGE) has been applied in many policy issues over the past 20 years. Researches conducted by CGE model can be classified into several aspects: fiscal and taxation policies, literatures like Dong and Whalley (2009) [2], Bao et al. (2011) [3]; international trade, researches like Li and Zhang (2012) [4]; relationship among economy, environment and energy, such as Jiang et al. (2009) [5], Bi et al. (2013) [6].

And there’s some researches on economic development and industrial reform, especially under the situation of carbon emissions reduction. Cheng et al. (2003) [7] built a CGE model to study the development strategy of high-tech industries in Hubei province. Li (2008) [8] and Liu (2013) [9] used dynamic CGE model to measure the impact of energy and environment policies on macroeconomic variables and industrial development in China. Liu et al. (2015) [10] analysed impacts of raising
China’s emission standard for thermal power plants by an extended CGE, and they found that these changes can trigger increase in economic output for industrial sectors. The research based on CGE model by Jin (2017) [11] focused on the impact of energy and environment policies on regional economic development and industrial structure. And it was suggested that regional industrial upgrading can be promoted by energy and environmental regulation, but it also need different policies to alleviate negative impacts on regional economy.

In this paper, an energy-economy CGE model was utilized to simulate the situation when Baoding reaches its peak of carbon emissions, and explore economic development and industrial structural changes in different scenarios. In addition, according to the calculation results in different scenarios, the optimal situation of CO\textsubscript{2} peak in Baoding was concluded by comparing social welfare.

2. Methodology
The energy-economy CGE model of Baoding is consisted of 3 blocks: the production block, income-expenditure block, market block. And these macroeconomics systems of mathematical equations can be calculated by General Algebraic Modelling System (GAMS), which is a type of modelling system software to solve mathematical programming problems.

2.1 Production block
The structure of production block was shown in Figure. 2-1. the first block represents the structure of the production functions, which is shown in Figure.2-2. We assume that, each producer (represented by an activity) aims to maximize profits, which are maximized subject to a production technology and each activity produces one or more commodities according to fixed yield coefficients. A commodity may be produced by more than one activity. A nested constant elasticity of substitution (CES) function has been applied for production activities with multiple nested CES functions.

![Diagram of Production Block of CGE Model](image-url)

**Figure.2-1.** The Production Block of CGE Model.
2.2 Income-expenditure block

The second block is income-expenditure block, which is constituted households, enterprises, the government, and the rest of the country. The households receive incomes from the factors sold to the enterprises under the assumption that there are no self-consumption behaviors in households. The households use their income that after taxes, savings, and transfers to other institutions to support the consumption of commodities, throughout the different combination of various commodities to achieve utility maximization. Cobb-Douglas (CD) functions have been applied to interpret the household’s behaviors in this CGE model. Domestic enterprises determine how much of each factor the economy devotes to the production of each commodity for the purpose of profit maximization. Enterprises incomes are allocated to direct taxes, savings, and transfers to other institutions. In this study, government behavior mainly contains taxation and government consumption. All the tax revenue the government receives from direct tax, indirect tax, tariff and transfer payments is totally used for the government consumption. The government consumes all the commodities in the market at a fixed consumption tendency.

2.3 Market block

As an open macroeconomic model, the difference between domestic commodities and imported and exported commodities should have been considered. Therefore, Armington Assumption is used to interpret the imperfect substitutability relationship between domestic commodities and imported commodities and exported commodities. CES functions have been applied to represent the Armington Composite Commodities (ACC), which is composed of imported commodities and relevant domestic commodities, shown as Eq. (3) and Eq. (4).

\[ Q_{D_i} = \left( \frac{\gamma_i \delta d_i P_i Q_i}{PD_i} \right)^{1/\gamma_i} Q_i \]  

\[ Q_{M_i} = \left( \frac{\gamma_i \delta m_i P_i Q_i}{(1 + \tau_i) PM_i} \right)^{1/\gamma_i} Q_i \]  

Where \( Q_{D_i} \) interprets demand for domestic sales of commodity i; \( Q_{M_i} \) represents quantity of imported commodity i. \( \gamma_i \) stands for the scale coefficient of ACC production function. \( \delta m_i \) and \( \delta d_i \) are imported and domestic scales share coefficients of ACC production function, respectively.
\( P Q_i \) is the price of composite commodity \( i \). \( PD_i \) and \( PM_i \) are the imported price of commodity \( i \) and the domestic sales price of commodity \( i \), respectively. \( \tau_i^e \) is customs duty rate of commodity \( i \). \( \eta_i \) is the substitution parameter depended on substitution elasticity \( \sigma_i \left( \eta_i = (\sigma_i - 1) / \sigma_i, \eta_i \leq 1 \right) \). \( \sigma_i \) is the substitution elasticity of imported commodity and domestic sales commodity in ACC production function.

In consideration of supply problem of exported commodities and domestic sales commodities, Constant Elasticity of Transformation (CET) functions have been used to interpret this conversion process, shown as Eq. (5) and Eq. (6).

\[
QE_i = \left[ \frac{\theta_i^e \xi_e (1 + \tau_i^e) PZ_i}{PE_i} \right]^{\frac{1}{\psi_i}} QZ_i,
\]

\[
QD_i = \left[ \frac{\theta_i^d \xi_d (1 + \tau_i^d) PZ_i}{PD_i} \right]^{\frac{1}{\psi_i}} QZ_i,
\]

Where \( QE_i \), the quantity of is exported commodity \( i \). \( \xi_e \) and \( \xi_d \) are exported and domestic scales share coefficients of ACC production function, respectively. \( QZ_i \) represents the quantity of domestically produced commodity \( i \). \( PE_i \) is the exported price of commodity \( i \); \( PZ_i \) is the domestic production price of commodity \( i \). \( \tau_i^e \) interprets the rate of added-value tax. \( \theta_i \) is the scale coefficient of the \( i \)-th commodity conversion function. \( \phi_i \) is the substitution parameter depended on substitution elasticity \( \psi_i \left( \phi_i = (\psi_i + 1) / \psi_i, \psi_i \geq 1 \right) \). \( \psi_i \) is the substitution elasticity of exported commodity and domestic sales commodity in ACC production function.

### 3. Material

Material data were adopted from the 42 sector input-output table of Hebei Province in 2007 and the energy consumption balance table in China Energy Statistical Yearbook (2008). According to the data in Input-output Table of Hebei Province, Baoding was divided into 16 productive activity: agriculture (agr), coal mining industry (min), oil and gas mining industry (o_g), mineral mining and other quarrying (omm), paper, paper products and pulp industry (ppp), light industry includes food products and agricultural products manufactory (fpr), petroleum and coal refinery industry (p_c), Chemical, Plastic and Rubber products industry (crp), Nonferrous metal, metal and metal product (nmm), steel and metal manufacturing industry (i_s), machinery and machinery equipment (mch), other manufacturing industry (omf), production and supply of electricity, heat and water supply (ely), construction industry (cns), transportation industry (trn) as well as Community and Services industry (css). In addition, the statistical data of energy consumption in Baoding was from energy balance in statistical yearbook. And the Cross-entropy Method (RAS) was used to balance the SAM tables of Baoding.

### 4. Scenarios

Before calculating CGE model, three scenarios was designed to figure out the exact time when \( CO_2 \) peak appears. And by simulating total \( CO_2 \) emissions of Baoding in three scenarios, the peak time and the quantity of \( CO_2 \) was found out, which is in Table 4-1. All of these scenarios were based on politic documents which were the 13th Five-year Plan, Joint Statement on Climate Change in China and the United States, Implementation Plan of Greenhouse Gas Emission Control in 13th Five-year Plan in Hebei Province, Annual Report on Urban Development of China No.8. Through economy-energy CGE model, the carbon emissions of Baoding in 2007-2030 were simulated. Under the corresponding peak situation, Baoding’s industrial structure and production were put forward.
Table 4-1. Different types of scenario in this paper.

|       | Energy intensity | GDP   | population | Urbanization | Third industry share | Coal proportion | Time of CO\textsubscript{2} peak | Quantity of CO\textsubscript{2} |
|-------|------------------|-------|------------|--------------|----------------------|----------------|-------------------------------|---------------------------------|
| S1\textsuperscript{a} | 2017-2020       | -4.00%| 9.00%      | 0.61%        | 2.65%                | 2.50%          | -6.59%                        | 2025                            | 2837.71                          |
|       | 2021-2025       | -4.50%| 8.00%      | 0.14%        | 0.90%                | 2.00%          | -0.50%                        |                                 |                                 |
|       | 2026-2030       | -5.00%| 6.50%      | 0.12         | 0.90%                | 2.00%          | 0.50%                         |                                 |                                 |
| S2    | 2017-2020       | -4.10%| 9.00%      | 0.61%        | 2.65%                | 2.50%          | -6.59%                        | 2027                            | 3555.00                          |
|       | 2021-2025       | -18.50%| 7.10% | 0.14%        | 0.90%                | 2.00%          | -0.50%                        |                                 |                                 |
|       | 2026-2030       | -20.50%| 7.10% | 0.12         | 0.90%                | 2.00%          | 0.50%                         |                                 |                                 |
| S3    | 2017-2020       | -3.66%| 9.00%      | 0.61%        | 2.75%                | 2.50%          | -4.59%                        | 2029                            | 4544.64                          |
|       | 2021-2025       | -18.00%| 7.10% | 0.14%        | 1.00%                | 2.00%          | -0.50%                        |                                 |                                 |
|       | 2026-2030       | -20.00%| 7.10% | 0.12         | 1.00%                | 2.00%          | -0.50%                        |                                 |                                 |

\textsuperscript{a} S was short for Scenario.

5. Results

As shown in Fig.2-2, Baoding still maintains a highly energy-consuming structure with heavy industry as its core in 2030 under the situation of no policy to adjust energy structure and reduce carbon emission.

In BAU scenario, gross output of 16 major industries in Baoding reaches 884.38 billion RMB in 2030 and it has formatted five pillar industries: a light industrial manufacturing industry depended on food and textile production, steel and metal manufacturing industry, automobile manufacturing machinery manufacturing industry, building materials industry and transportation industry including transportation equipment manufacturing. In addition, output of the first industry (agriculture) and the third industry (modern service industry) are far lower than that of the second industry. Which means in BAU scenario, Baoding become a city extremely relied on heavy industry and naturally an emitters with high CO\textsubscript{2} emissions.

5.1 Industrial analysis

Figure 5-1. showed GDP and percentage of 16 industries of Baoding when it reaches CO\textsubscript{2} peak in 2025, 2027 and 2029 respectively. Obviously, Baoding’s industrial structure in three scenarios has huge difference comparing with BAU scenario. In three scenarios, in 2030, Baoding formed a sustainable industrial structure of service industry as its core, with light industry, power industry, construction industry and transportation industry supplementary.
When CO₂ emissions in Baoding reach its peak in 2025, 2027 and 2029, the proportion of 14 sectors was as follows:

1. The third industry output becomes 75.07%, 74.09% and 73.60% respectively;
2. Transportation industry (including automobiles and other transportation equipment), accounts for 5.90%, 6.07%, 5.97%;
3. Power electricity industry is 5.40%, 5.83% and 5.53% respectively;
4. Construction industry accounts for 5.05%, 5.44%, 5.11%;
5. Light industry includes food products and agricultural products manufactory accounts for 4.28%, 4.31%, 4.24% respectively;
6. Other sectors like agriculture, coal mining industry, mineral mining and other quarrying, paper, paper products and pulp industry, steel and metal manufacturing industry, and other manufacturing industry accounts for less than 1%.

In the scenario of reaching CO₂ peak in 2025, gross production of 16 industries will be 881.4 billion RMB, while in the scenario of 2027 and 2029 gross production will be 891.6 billion RMB and 811.0 billion RMB. That means the sooner Baoding’s industrial structure adjusted to sustainable development of taking the third industry as mainstays, the earlier this city will enter a green and high-speed way to economic growth.

5.2 Social welfare analysis

The utility index was used to compare improvements of social welfare among different equilibrium solutions in three scenarios. The Hicks value equations were used to quantify the utility base price, and thus the calculation results can be compared in quantitative. In this paper, we compared the 2030 welfare gap in each scenario to indicate the welfare deficiency caused by policies on carbon emission reduction.

**Table.5-1. Comparing Social Welfare of Three Scenarios.**

|       | 2025      | 2027    | 2029     |
|-------|-----------|---------|----------|
| EV    | -2664340  | -3722890| -8087852 |

As shown in Table.5-1, values of EV in scenarios of 2025, 2027 and 2029 were all negative, which indicated that policies on reducing carbon emissions surely cause certain welfare losses. It conforms to researches of domestic and foreign scholars on the carbon emission reduction policy influence. As a
conclusion, taking changes of Baoding’s industrial structure in 2030 into consideration, whether focus on the production output or the value of social welfare, the scenario that Baoding reaches CO₂ peak in 2025 is the optimal situation.

6. Discussion
The manufacturing of light industry based on food processing and textile industry has always been one of the core industries in Baoding, whose output increase by 855% compared to 2016 in three scenarios. That means the manufacturing of light industry in Baoding need to maintain steady economic growing all through. However, industries like the power, construction and transportation need not only to keep the speed of growth but also to accelerate adjustment of their internal structure. Taking power generation as an example, proportion of electricity generated from non-fossil energy has always been emphasized in the process of sustainable development. As called “electricity valley” in China, Baoding takes the lead of renewable energy power generation interiorly for years. Based on results of economic-energy CGE model, we believe that on the one hand the power industry in Baoding should keep steady growth on total electricity generating capacity to meet social demands. On the other hand, the proportion of renewable power generation must be augmented to optimize the structure of energy generation and finally reduce carbon emissions in this city.

To achieve the goal of reaching CO₂ peak with the least social welfare losses in 2025, some suggestions on industrial development planning was made in Baoding for next decades. Firstly, the second industrial structure ought to be adjusted by promoting traditional industries upgrading and develop low-carbon industries vigorously, such as renewable energy generation and high-tech industries. And based on the results, by 2030, output of light industry includes food products and agricultural products manufactory (fpr) as well as production and supply of electricity, heat and water (ely) should account for 4.24% and 5.53% in Baoding’s gross production. While other industries in the second industry need to control their output under 1% of the total production.

Secondly, the proportion of the third industrial output should be improved intentionally. Emphasis should lay on services industry (css) and transportation industry (trn). On the basis of calculation, in 2030, output of these two industries should account for 73.60% and 5.97% in Baoding’s gross production. This means a massive economic stimulus package aimed at the modern services industry need to plan and implement soon.

All in all, the aim of industrial reform is to transform the current high-carbon industrial structure into the structure leading by the third industry which was characteristic of lower energy consumption and less carbon emissions.

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