Simulation Research on the Role of Energy Revolution in the Rise of China’s Five Central Provinces

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Abstract. China’s energy revolution strategy serves as both a driving force and a hindrance to the rise of central China. Based on the six-dimensional data of GDP, industrial structure, urbanization, energy efficiency, per capita income and energy consumption of the five central provinces, this research sets three levels of growth rate, namely high, medium and low growth rates. With GDP growth as the key sub-scenario, a total of 13 rising models from SE11 to SE34 are established to simulate the high-quality rise of the five central provinces against the background of energy revolution. The results indicate that the path of high-quality rise of central China varies from SE11 to SE25, that is, from high-speed economic growth to benchmark growth model. For the model of rapid economic development, the industrial structure will be upgraded and the energy efficiency will be maximized. With the energy revolution, the emission of carbon dioxide will reach its peak in 2020. However, the adjustment of industrial structure promoting energy efficiency will be challenging, which will also cost a huge amount of energy. For the benchmark growth model, GDP growth rate is lower than that of the rapid development model, but the energy consumption is reduced, and the adjustment of industrial structure and the improvement of energy efficiency is less challenging. Improving energy efficiency has a higher effect on energy saving than upgrading industrial structure. Through energy revolution, the proportion of renewable energy will reach 23.06% in 2035, and consequently the emission of carbon dioxide will reach its peak two years ahead of schedule.

1. Introduction  
The central economic zone of China refers to the five provinces of Henan, Anhui, Hubei, Hunan and Jiangxi, which has long been regarded as the “black hole” of China’s economic development. To deal with this, China has implemented the central-China rising strategy and proposed the strategy of energy revolution, which aimed at expediting the modernization of the five central provinces by realizing the industrialization of the production mode and the urbanization of people’s lifestyle.

Energy revolution promotes while at the same time restricts the rise of the central region. First of all, efficient and rational exploitation and utilization of the abundant energy resources in central China can transform energy advantages into economic advantages, which plays a significant role in promoting the sustainable development of the economy. Secondly, the energy industry in the central region has a strong inner connection, which offers a possibility for the restructuring and upgrading of the industry to increase the added value of energy and give full play to the role of the energy industry in the development of the central region. More specifically, this is to be achieved by extending the energy industry chain and cultivating new energy industries. At the same time, studying the relationship between the energy industry and economic development of central China and establishing...
energy models can effectively reduce the blindness of energy development and provide a scientific justification for formulating feasible economic development plans for central China. Finally, exploring the changes of carbon dioxide emissions caused by high energy consumption during the development of central China can effectively control carbon dioxide emissions, realize the scientific development of economic progress and environmental protection, ensure the rationality and sustainability of high-quality rise of central China.

2. The connotation and mechanism of the energy revolution promoting the rise of central China

From an economic perspective, high-quality energy can improve energy efficiency, and then improve economic benefits, which can effectively solve the problem of economic fluctuation caused by coal price changes due to the strong dependence on coal in the five central provinces. Therefore, based on the energy revolution, changing the supply structure and consumption structure of energy can ensure the scientific and rational development of modern industries and realize economic growth smoothly and effectively. From an ecological point of view, the energy revolution promotes ecological harmony, and the energy revolution in central China should be transformed from traditional "black energy" to "green energy". On the one hand, increase technological innovation and use the coal efficiently; on the other hand, through develop renewable energy and new energy which are conducive to the harmony of ecological environment, and promote the harmony between human and ecology through energy revolution. From a social point of view, high-quality energy can promote the rise of high-quality development, and its ultimate goal is to share development achievements. The rise of Central China is not only the continuous improvement of economic aggregate, but also the improvement of people's quality of life.

3. Establishment of five Provinces energy consumption prediction model under the background of energy revolution

Elastic coefficient of energy consumption is a key index reflecting the relationship between the growth rate of energy consumption and the growth rate of national economy. The internal relationship of energy consumption elasticity coefficient shows that the more the economy develops, the more energy demand, the higher the economic benefit of energy consumption, the lower the elasticity coefficient. Based on the energy elasticity coefficient, combined with the growth rate and development rate of energy consumption, the energy consumption prediction model is constructed as follows:

\[
Q_n = Q_0 \times \left[ 1 + E_s \times \left( \frac{GDP_n}{GDP_0} - 1 \right) \right]
\]

\[
E_s = \frac{1}{n} \sum_{t=1}^{n} \frac{Q_1 - Q_{t-1} - 1}{Q_{t-1}} \sum_{t=1}^{n} \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}
\]

(1)

In the formula, \( Q_n \) is the predicted energy demand in the nth year; \( GDP_0 \) and \( Q_n \) are the GDP and energy demand of the base year respectively; \( E_s \) is the elasticity coefficient of energy consumption; \( GDP_n \) is the GDP of the nth year.

At the same time, aiming at the high carbon dioxide emission problem that needs to be solved urgently in the world, the author models and predicts the carbon dioxide emission of five provinces in central China under different rising paths, and establishes a CO₂ emission prediction model based on Kaya model:

\[
EI_{\text{CO}_2} = \frac{E}{GDP} = \frac{E_p + E_h}{GDP}
\]

\[
EI_p = \frac{E_{pp} + E_{ph} + E_{pp}}{GDP} = \sum_{i=1}^{3} (S_i L_i)
\]
In which EIGDP is the energy consumption intensity, EP is the production energy consumption, ER is the living energy consumption; EPP is the primary industry, EPS is the secondary industry, EPT is the tertiary industry, S_i is the energy consumption share of the industry, I_i is the corresponding energy intensity of each industry; EUR is urban living consumption, ERR is rural living consumption, I_U is urban disposable income, I_R is rural disposable income, e_U and e_R are urban and Per capita energy consumption in rural areas, RU is the urbanization rate of the population.

4. Path setting simulation
It can be seen from the model that the parameters affecting energy consumption and corresponding CO2 emissions include GDP, industrial structure, urbanization, energy efficiency, per capita income and energy consumption. Considering that GDP is the main measure of the rise of Central China, three key sub-scenarios are selected: high-speed GDP growth, benchmark growth and low-speed GDP growth. SE11-SE14 are high-speed economic growth, SE21-SE25 are baseline growth scenarios, and SE31-SE34 are low-speed economic growth. Path setting is as follows:

| Scene | SE11 | SE12 | SE13 | SE14 | SE21 | SE22 | SE23 | SE24 | SE25 | SE31 | SE32 | SE33 | SE34 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| GDP   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| Low   |       | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| IND   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Low   |       | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| URB   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Low   |       | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| EFF   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Low   |       | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| PER   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Low   |       | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
| LIV   | High | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |
|       | Normal | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    | √    |

In this forecast analysis, the data of GDP, industrial structure, urbanization, energy efficiency, per capita income and energy consumption of five central provinces from 2010 to 2018 are taken as the base period conditions of simulation forecast.

5. Simulation prediction results and analysis

5.1. Forecast Results of Rise Scenarios of Five Central Provinces
Under different situations of economic growth, the total GDP, GDP growth rate and per capita GDP of the rise of central China from 2020 to 2035 are predicted as follows:

| Scenario | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 |
|----------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| High     | 1553 | 1663 | 1776 | 1894 | 2016 | 2141 | 2271 | 2404 | 2541 | 2683 | 2828 | 2978 | 3132 | 3289 | 3451 | 3617 |
| Nor      | 1544 | 1649 | 1757 | 1868 | 1982 | 2099 | 2220 | 2344 | 2471 | 2601 | 2734 | 2871 | 3010 | 3153 | 3298 | 3447 |
It can be seen from Figure 1 that with the growth of the year, the GDP growth rate of high-speed economic growth and benchmark growth is obviously greater than that of low-speed growth, and the GDP growth rate drops obviously under the low-speed situation. It can be seen from Figure 2 that although there is a small gap in per capita GDP before 2025, with the passage of time to 2035, per capita GDP under the high-speed growth scenario is obviously higher than that under the benchmark growth and low-growth scenario, and the gap changes positively with the year. Therefore, in order to achieve sustainable and high-speed development of GDP, that is, to achieve high-quality economic development of the five central provinces, the GDP growth rate of the five central provinces should maintain the benchmark scenario and above.

5.2. The rising energy demand scenarios of the five central provinces

The simulation results of energy consumption under the rising path of SE11-SE34 are as follows:

|   | SE11  | SE12  | SE13  | SE14  | SE21  | SE22  | SE23  | SE24  | SE25  | SE31  | SE32  | SE33  | SE34  |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 2020| 80639 | 82294 | 81484 | 83097 | 79673 | 78678 | 79186 | 77944 | 82386 | 79232 | 77992 | 78749 | 77513 |
| 2021| 81573 | 83529 | 82840 | 84420 | 83958 | 82622 | 83402 | 81838 | 83400 | 83235 | 81676 | 82684 | 81134 |
| 2022| 82379 | 84679 | 83721 | 85626 | 85040 | 83559 | 84434 | 82554 | 84481 | 84014 | 82149 | 83417 | 81560 |
| 2023| 83060 | 85713 | 84494 | 86722 | 86015 | 85991 | 85353 | 83518 | 85361 | 84670 | 82503 | 84019 | 81863 |
| 2024| 83630 | 86635 | 85146 | 87698 | 86675 | 84508 | 86164 | 83661 | 86120 | 85159 | 82733 | 84501 | 82052 |
| 2025| 84313 | 87679 | 85914 | 88792 | 87851 | 85140 | 87095 | 84280 | 86993 | 85824 | 83066 | 85087 | 82347 |
| 2026| 85385 | 89087 | 87046 | 90269 | 89205 | 86134 | 88384 | 85243 | 88238 | 86801 | 83738 | 86005 | 82961 |
| 2027| 86085 | 90152 | 87822 | 91374 | 90157 | 86740 | 89302 | 85848 | 89115 | 87372 | 84021 | 86546 | 83218 |
| 2028| 86657 | 91093 | 88516 | 92397 | 91027 | 87265 | 90090 | 86329 | 89910 | 87854 | 84225 | 86955 | 83351 |
| 2029| 87185 | 91988 | 89132 | 93337 | 91816 | 87715 | 90835 | 86774 | 90621 | 88249 | 84348 | 87311 | 83439 |
According to the GDP growth rate and per capita GDP development trend, the path of high-quality rise of the five central provinces should be between high-speed economic development and benchmark development, that is, between SE11-SE25. If we choose the high-speed economic growth scenario and minimize the energy consumption, that is, the SE11-SE14 route, we should actively promote the industrial structure and maximize the energy efficiency. If we choose the economic benchmark growth scenario, improve energy efficiency and accelerate industrial structure adjustment in parallel, the total energy consumption will be controlled within 901 million tce in 2035. If the low-speed economic growth scenario is chosen, the effect of improving energy efficiency and upgrading industrial structure on energy conservation is lower than that of the high-speed economic and benchmark development scenario.

5.3. Prediction of Primary Energy Structure Change in Five Central Provinces
The energy structure of the five central provinces is mainly coal, and coal consumption accounts for a higher proportion of total energy. The primary energy structure is unbalanced, and new energy needs to be vigorously developed. It is assumed that the proportion of natural gas and renewable energy will increase by 0.4% in 2020, and the results are shown in the following table:

| Period | Normal (%) | Energy revolution (%) |
|--------|------------|-----------------------|
|        | coal | oil | gas | renewable | coal | oil | gas | renewable |
| 2020   | 63.05% | 17.88% | 5.13% | 13.94% | 62.72% | 17.88% | 5.13% | 14.28% |
| 2025   | 57.06% | 19.10% | 7.52% | 16.32% | 56.39% | 19.10% | 7.52% | 16.99% |
| 2030   | 50.19% | 19.63% | 10.61% | 19.57% | 49.41% | 19.63% | 10.61% | 20.35% |
| 2035   | 44.33% | 19.99% | 13.36% | 22.32% | 43.59% | 19.99% | 13.36% | 23.06% |

It can be seen that under the situation of advancing the energy revolution, the proportion of renewable energy can reach 23.06% in 2035, which is little progress than the baseline situation. Therefore, in the energy revolution of the five central provinces, if the economic development is coordinated with the energy structure adjustment to achieve high-quality rise, the energy structure adjustment will be under great pressure.

5.4. Simulation scenario of carbon dioxide emissions in the rise of Central China
According to the development of energy benchmark scenario, the carbon dioxide emissions under each route peaked in 2023 (Figure 3), and then slowly decreased. However, in the energy revolution scenario (Figure 4), the peak emission time of carbon dioxide is advanced, namely, SE11 and SE13 routes are in 2020, SE12 and SE14 routes are in 2021, and the peak emission is lower than that in the baseline scenario. This analysis can also be done in other development situations.
6. Analysis conclusion

Based on the data of GDP, industrial structure, urbanization, energy efficiency, per capita income and energy consumption of the five central provinces as the forecast base conditions, this paper draws the following conclusions:

(1) Under the situation of rapid economic growth, if the energy efficiency and industrial structure increase rapidly, the energy saving effect is remarkable. Under the benchmark growth situation, adjusting industrial structure will be more effective than improving energy efficiency. Under the situation of low-speed growth, if the industrial structure and energy efficiency increase and the energy consumption benchmark increase, urbanization and per capita income increase at a low speed, the total energy consumption will be the lowest. In order to realize the rise of Central China, the GDP growth rate of the five central provinces should keep above the benchmark scenario.

(2) In order to achieve high-speed and sustainable development of GDP, the path of high-quality rise of the five central provinces should be between SE11 and SE25. Under the scenario of rapid economic growth, that is, SE11-SE14 route, if the energy consumption is minimized, the industrial structure should be upgraded and the energy efficiency should be maximized simultaneously. Under the economic benchmark growth scenario, the total energy consumption will be controlled within 901 million tce in 2035 by improving energy efficiency and accelerating industrial structure adjustment. Under the situation of low economic growth, the effects of improving energy efficiency and upgrading industrial structure on energy conservation are lower than those under the situation of high economic growth and benchmark development.

(3) Under the situation of advancing the energy revolution, the proportion of renewable energy can be increased to 23.06% in 2035. In the energy revolution of the five central provinces, the energy structure adjustment is under great pressure.

To sum up, the high-quality rise of the five central provinces through energy revolution must be based on the premise that the basic idea of “four revolutions and one cooperation” of China’s national energy development strategy is clarified and adhered to. More specifically, it refers to the exploration of a proper way of regional energy revolution by taking the features of both energy resources and regional energy demand of the five central provinces into consideration and letting the five aspects of energy consumption, production, technology, regime and cooperation be the starting point. Only in this way can we balance energy revolution and economic development and realize the high-quality rise of the central region.

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