



Analysis of China's Coal Resource Safety and Enterprise Performance

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Abstract. In 2021, 56% of China's energy consumption comes from coal resources. The supply of China's coal resources mainly meets its own domestic needs and is the basis for energy security. Using the grey incidence analysis method, it is concluded that China's GDP has a high degree of correlation with raw coal production, and a relatively low degree of correlation with the profits of coal enterprises. The correlation between GDP and coal in Shanxi Province, Inner Mongolia and Shaanxi Province, the main coal producing areas, is higher than the national average. China's industrial policies have a huge impact on the coal market. Under the influence of production capacity restrictions, coal resource integration, and corporate restructuring, the coal industry market is highly concentrated, and the barriers to entry and exit are also raised accordingly, resulting in obvious economies of scale. The mergers and acquisitions of coal enterprises have not formed a monopoly price of coal. China's coal price is mainly affected by short-term demand and government regulation and control policies. China's coal enterprises are able to maintain profits all year round, and profits account for a high proportion of industrial enterprises' profits. The mortality rate of one million tons of coal mines in China has been gradually decreasing for many years, mainly due to intelligent production technology and advanced management experience. The key point for China's coal enterprises to further improve their efficiency lies in the combination of coal mine production and industrial information technology and the improvement of labor efficiency.

Keywords: Coal Resources; Energy Security; Corporate Performance; China

1 Introduction

The "2021 Statistical Bulletin of National Economic and Social Development" issued by the National Bureau of Statistics of China pointed out that China's total energy consumption in 2021 is 5.24 billion tons of standard coal, of which coal accounts for 56.0%. The steady development of the economy and society is inseparable from the guarantee of energy security. China's energy resource endowment characteristics of rich coal, poor oil and little gas determine that coal resources play a pivotal role in the development of the national economy. Under the circumstance that the external political and

economic environment has undergone major changes and the climate issue has become the focus of international attention, China's energy security issues have become more prominent. Changes in the situation require a re-judgment and understanding of the relationship between the national economy and coal resources. By analyzing the overall situation of coal market structure, conduct and performance, coal enterprises can more accurately grasp the strategic development direction.

2 Grey incidence analysis

2.1 Theoretical model

Some studies believe that there is a long-term cointegration relationship between China's economic growth and total energy consumption¹, and there is a long-term equilibrium relationship between coal production and GDP². However, in recent years, China's economic development has slowed down significantly, and the coal market has been fluctuating. The relationship between economic growth and the coal industry has changed from a stable relationship in the past to a similar relationship. In grey system theory, grey incidence analysis is a theory that judges the degree of connection between different sequences according to the geometry of sequence curves. The basic idea of grey incidence analysis is to convert the sequence values in the system into piecewise continuous polylines by means of linear interpolation and construct a model to measure the degree of relational relationship. From the perspective of similarity, the greater the degree of correlation of different sequences in grey incidence analysis, the greater their degree of correlation, and vice versa. The most widely used grey incidence analysis is Professor Deng Julong's analysis method³.

Let the reference sequence be

$$X_0 = \{x_0(1) + x_0(2) + \dots x_0(n)\} \tag{1}$$

Let the comparison sequence be

$$X_i = \{x_i(1) + x_i(2) + \dots x_i(n)\} \tag{2}$$

and $i = 1, 2, \dots, N$

Then, define the gray coefficients of X_0 and X_i

$$\xi (x_0(k), x_i(k)) = \sum_{k=1}^n \left(\frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|} \right) \tag{3}$$

Among them, ρ is the resolution coefficient, and $0 < \rho \ll 1$

The correlation between X_0 and X_i is

$$\gamma(X_0, X_i) = \frac{1}{n} \sum_{k=1}^n \xi (x_0(k), x_i(k)) \tag{4}$$

2.2 Data sources

The data on gross national product, raw coal production, and coal enterprise profits used in the grey incidence analysis are all from the National Bureau of Statistics of China. Among them, the data used for the gross national product is GDP at constant price, which is calculated by nominal GDP and GDP deflator; the profit of coal enterprises is the total nominal profit, which is calculated by deflating the producer price index (PPI) of the coal mining and selection industry. In China, Shanxi, Inner Mongolia, and Shaanxi provinces produce more than 60% of raw coal, and analysis of data from these three regions can help draw regional-level correlations.

The relationship between raw coal production and real GDP

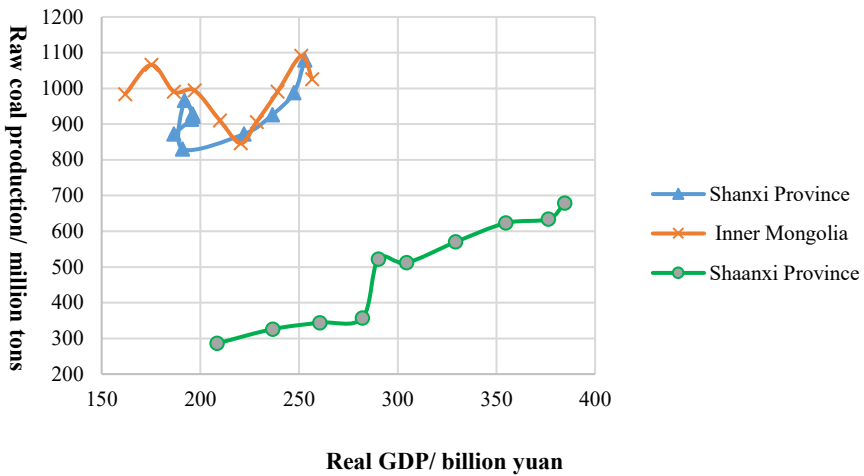


Fig. 1. Comparison of the relationship between raw coal production and real GDP in different regions

2.3 Analysis of results

After standardizing the original data, the relationship between the real GDP, raw coal output, and coal enterprise profits in China, Shanxi Province, Inner Mongolia Autonomous Region, and Shaanxi Province was calculated respectively. The results are shown in Table 1. From the graph of the relationship between GDP and raw coal production, it can be seen that during the period from 2011 to 2020, the relationship between the two in different regions of China was significantly different: Shaanxi Province as a whole showed a linear relationship, with an average of 1.6 million tons raw coal production per billion yuan of GDP; Shanxi Province and Inner Mongolia showed sharp fluctuations, with an average of 4.4 million tons and 4.61 million tons of raw coal output per billion yuan of GDP. The results of grey incidence analysis show that the correlation between GDP and raw coal output is higher than that of coal enterprise profits, whether it is the whole region of China or the main producing areas of raw coal. Shanxi Province has the highest correlation between GDP and raw coal production, followed by Inner

Mongolia and Shaanxi Province. The three main coal producing areas have higher correlations than the national average.

3 Analysis of China's coal industry organization

In the 1950s, American scholars Edward S. Mason, Joe S. Bain, and Scherer put forward the SCP paradigm theory, that is: market structure determines market conduct, and market conduct determines market performance. Therefore, the way to improve market performance is to adjust market structure through industrial policy. At present, the process of “carbon emission reduction” is accelerating⁴, and global energy consumption is shifting towards low-carbon and renewable energy⁵. The SCP paradigm analysis of China's coal market provides guidance for coal companies to make strategic adjustments when faced with external environmental shocks.

Table 1. Correlation between GDP, raw coal output and enterprise profits

Correlation between GDP and raw coal production					Correlation between GDP and coal enterprise profits				
Years	China	Shanxi	Inner Mongolia	Shaanxi	Years	China	Shanxi	Inner Mongolia	Shaanxi
	0.6471	0.9595		0.7982		0.3339	0.3361		0.4126
2011	33	73	0.637613	85	2011	75	23	0.41355	22
	0.6542	0.9580		0.7758		0.3931	0.6610		0.3651
2012	16	15	0.613938	24	2012	03	63	0.37715	74
	0.7015	0.9539		0.6983		0.6572	0.9153		0.4798
2013	48	68	0.79311	96	2013	45	21	0.488591	5
	0.7989	0.9475		0.6311		0.6210	0.5843		0.9672
2014	5	41	0.885147	35	2014	87	66	1	38
	0.9420	0.9007		0.7612		0.3928	0.4812		0.5707
2015	42	73	0.951657	31	2015	55	71	0.513517	75
	0.8073			0.9247		0.4803	0.6337		0.4004
2016	84	1	0.727096	43	2016	6	7	0.618854	35
	0.7577	0.9164		0.8269		0.9590	0.8980		0.6432
2017	24	96	0.763738	42	2017	58	08	0.492229	35
	0.7274	0.9094		0.7719			0.8571		
2018	24	35	0.828932	95	2018	1	05	0.74995	1
	0.7005	0.9202		0.8849		0.8513	0.9313		0.6219
2019	12	34	0.929104	04	2019	2	57	0.9573	32
	0.6887	0.9781		0.7386		0.5916	0.8782		0.5904
2020	72	37	0.747787	5	2020	02	66	0.595698	59
Correlation	0.7425	0.9444		0.7812	Correlation	0.6280	0.7176		0.6051
	71	17	0.787812	11		6	65	0.620684	72

3.1 Market structure

3.1.1 Market concentration.

Under the influence of coal resource integration and production capacity restriction policies, the market concentration of China's coal industry is relatively high. According to the statistics of the China Coal Industry Association, in 2021, there are 36 enterprises with coal output of more than 10 million tons in China, and the industry concentration ratio (CR8) reaches 48.8%. According to the classification standards of American economist Bain and Japan's Ministry of International Trade and Industry, China's coal industry belongs to an oligopolistic (CR8≥40) market structure. Without government intervention, coal companies have strong bargaining power over downstream coking and power companies.

3.1.2 Barriers to entry and exit.

China's coal fields are generally shallow buried, with thick coal seams, and are easy to mine. Before the policy restrictions on coal mining, the barriers to entry into the coal market were low. In the past 10 years, the Chinese government has vigorously promoted the classification and disposal of coal mines, which has greatly raised the entry threshold for the coal market. China has reduced the number of coal mines with an annual output of less than 300,000 tons to less than 800 in 2021, and all coal mines with an annual output of less than 600,000 tons in Shanxi Province have withdrawn from mining in 2020. According to the guidance of China's energy security work, the goal of the coal industry is to control the number of coal mines within 5,000, and the output of large coal bases to account for more than 96% of the total output. The specificity of coal industry assets, the high cost of personnel placement and the lag of industrial policies determine the high threshold for exiting the coal market.

3.1.3 Economies of scale.

According to data released by British Petroleum in 2020, the cumulative proven reserves of coal resources in China are 141.6 billion tons. Abundant reserves and ease of extraction have resulted in the over-expansion of China's coal production capacity. According to data from the China Coal Industry Association, in 2015, China's coal production capacity reached 5.7 billion tons, the output was only 3.7 billion tons, and the capacity utilization rate was 65%. Overcapacity has further intensified the Chinese government's efforts to limit coal production and closed a large number of small coal mines, which indirectly boosted the economic scale of the coal industry. Economies of scale do not necessarily lead to corporate performance, and in Shanxi Province, China, the result of the improved market position of coal is the lack of development momentum and capacity for economic transformation⁶.

3.2 Market conduct

3.2.1 Coal price.

The market price of coal is mainly constrained by mining costs and transportation costs. Open pit mining can obtain more profits than tunnel mining underground coal mines, and rail transportation and ocean transportation can travel farther than road transportation at the same cost. The main reason for the sharp rise in China's coal prices in 2021 is the impact of policy factors such as output restrictions, and the lack of coal supply has even led to "power shortages". Under the condition that the policy remains unchanged, coal prices are mainly affected by short-term demand factors, and have a weak relationship with coal supply. China implements a coal-electricity price linkage mechanism, and the signing of long-term agreements between coal and power companies can smooth the coal market price.

3.2.2 Mergers and acquisitions.

In recent years, on the one hand, the Chinese government has closed down coal mines with low production capacity, and on the other hand, it has accelerated the restructuring and mergers and acquisitions of coal enterprises. In 2017, China Energy Investment Ltd was established to become the largest coal production company in China, with a coal output of 570 million tons in 2021; in 2020, Jinneng Holding Group Ltd was established to become the second largest coal production company in China, with a coal output of 380 million tons in 2021. In 2020, Shandong Energy Group Ltd was established, which is the third largest coal production company in China, with a coal output of 260 million tons in 2021. Mergers and acquisitions aggravate the monopoly of the coal market, but China's administrative measures can ensure that coal market prices do not cause significant inflation.

3.2.3 Coal sales.

China divides coal into three major categories: lignite, bituminous coal and anthracite, which are subdivided into numerous subcategories. The physical and chemical properties of various types of coal are different, the mutual substitution is poor, and the differences in industrial uses are obvious, thus forming different commodity trading markets. For the same type of coal, its quality depends to a large extent on the natural environment, and enterprises with high-quality coal resources are in a favorable position in the market competition. China's coal resource endowment is at a moderately low level in the world, and it mainly meets its own domestic needs. There are large differences in coal resources in different regions. Generally speaking, the western and northern regions are better than the eastern and southern regions. The cost of sales of coal will increase dramatically with the increase in transportation distance.

3.3 Market performance

3.3.1 Operational performance level.

From 2011 to 2020, the total profit of China's coal mining and washing industry was 250.6 billion yuan (nominal price), accounting for 3.7% of the total profit of industrial enterprises above designated size, and the proportion in Shanxi, Inner Mongolia and Shaanxi was as high as 58.0%, 41.0% and 26.5%. The vertical mergers and acquisitions of Chinese coal enterprises have promoted the development of diversified industries such as coal and electric power, chemical industry, and transportation, paving the way for the realization of large-scale and intensive industries. Some studies have shown that the low efficiency of state-owned enterprises will offset the scale benefits of enterprises⁷. The improvement of the performance of China's coal enterprises mainly depends on the pull of the regional economy. Over-reliance on coal resources has led to the dilemma of economic transformation in areas rich in coal resources, and inhibited the development of other industries.

Table 2. Comparison of total profits of coal industry and industrial enterprises above designated size

Total profits of industrial enterprises above designated size/billion yuan										
Years	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	6139.6	6191.0	6837.9	6815.5	6618.7	7192.1	7491.6	7160.9	6579.9	6846.5
Shanxi	234.1	101.1	61.5	25.6	-3.1	29.5	103.2	135.6	116.5	108.6
Inner Mongolia	215.8	185.6	184.2	129.9	96.5	124.5	127.1	140.9	146.3	131.5
Shaanxi	307.5	345.7	335.2	350.6	292.2	155.0	223.8	243.6	230.6	197.9
Total profit of coal mining and washing industry/billion yuan										
Years	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	456.1	380.8	268.0	142.4	40.5	116.0	295.3	300.9	283.7	222.2
Shanxi	173.1	73.9	36.5	5.3	-13.5	12.1	59.1	69.4	64.2	49.2
Inner Mongolia	87.8	85.9	69.8	48.2	31.8	46.7	52.4	61.7	69.2	53.5
Shaanxi	88.6	90.7	75.9	61.2	43.3	37.9	82.1	85.3	74.5	70.1

3.3.2 Safety production level.

The death rate per million tons of coal mines in China has decreased year by year, from 0.803 in 2010 to 0.044 in 2021, mainly due to the closure of small coal mines and the improvement of technical levels. Compared with the death rate of 0.01-0.02 million tons in the United States and Australia (2020), China's coal safety production level still needs to be improved. Among coal mine accidents, roof accidents have the highest frequency, and the number of deaths in gas accidents accounts for a major part of coal accidents⁸, which has a wide impact.

Table 3. Death rate per million tons of coal mines in China (person)

Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Mortality Rate	0.803	0.564	0.374	0.293	0.257	0.162	0.156	0.106	0.093	0.083	0.058	0.044

3.3.3 Technological progress level.

Smart Mining has become the most cutting-edge technology in the development of the coal industry. The detection accuracy of coal seam occurrence environment and the timeliness of detection information processing directly affect the safe and efficient development of coal resources. Existing clean coal technologies, carbon dioxide capture, utilization and storage technologies reduce the resistance to developing a coal economy. For each additional unit of testing and R&D investment in the coal industry, the technical efficiency of 17 units can be significantly improved⁹. Integrate modern technologies such as the Internet of Things, big data, automatic control, and robotic equipment with coal mine development technology to establish an intelligent system for coal mine detection, data storage and analysis, decision-making and control, which significantly improves the level of development and utilization of coal mine resources.

4 Conclusions

Coal is the most important energy resource in China, which profoundly affects the development of electric power, chemical industry, steel, cement and other industries, and has an irreplaceable position in the development of the national economy. There is a dynamic gray correlation between China's GDP, raw coal output and coal enterprise profits. The data analysis from 2011 to 2020 shows that China's GDP has a high correlation with raw coal production, while GDP has a relatively low correlation with the profits of coal enterprises, while Shanxi Province, Inner Mongolia and Shaanxi Province, the main coal producing areas, have higher correlations than national average. The market concentration of China's coal industry is relatively high, the barriers to entry and exit are high, and economies of scale are obvious. China's coal prices are mainly affected by short-term demand and government regulatory policies, and mergers and acquisitions of coal enterprises will not form a monopoly price of coal. The sales mainly depend on the quality of coal and transportation costs. Chinese coal enterprises are generally profitable, and they account for a high proportion of the profits of industrial enterprises. The death rate of one million tons of coal mines in China has been gradually decreasing for many years, and intelligent production technology has also promoted efficient development of coal resources.

China's future economic development will still rely on coal resources for a long time. Under the new situation of global geopolitics, energy market changes and climate change, Chinese coal enterprises are advised to pay attention to the following points in their development. First is to strengthen the combination of industrial information technology and coal mine production technology, promote technological progress, and improve labor efficiency. The second is to establish a diversified industrial chain dominated by coal in resource-rich regions, and develop coal chemical industries such as coal-to-gas, coal-to-olefin, and coal-based synthetic oil. The third is to strengthen the protection of the ecological environment and water resources in the coal mining area, the control of waste and coal mining subsidence areas, and the use of intelligent technology to improve the safety production level of coal mines.

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