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Assessment and management strategy of the supply vulnerability in Chinese regional coal market

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ABSTRACT

In this paper we discussed the supply vulnerability of coal market and presented a quantitative assessment to 30 Chinese regiones through factor analysis. We select the ratio of coal production to coal consumption, the ratio of coal storage to coal consumption, degree of dependence on external coal trade, coal consumption intensity and the proportion of coal in primary energy consumption structure as evaluation indexes. The result shows that the 20 regions' coal supply is fragile and it is urgent to improve the situation. According to coal supply sensitive degree and supply vulnerability coping ability, we divided the 30 regiones into four categories and proposed classified management strategy such as extending the industrial chain, enlargening the coal emergency reserve, optimizing the industrial structure, changing the growing mode and so on.

KEYWORDS

Regional coal market; Supply vulnerability; Management strategy; Factor analysis.

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INTRODUCTION

As the basic energy in China, the proportion of coal in primary energy consumption structure is about 70% in a long time. Its supply security directly influences the social stability and economic development. The storage of Chinese energy has the characteristics of "rich coal, less gas, short of oil", so that it determines the dominant position of coal will not change in a long period. The coal in China is very unevenly distributed: it is rich in the north and poor in the south and it is more in the west and less in the east[1]. In the aspect of production, the coal production is mainly concentrated in the central and western regions, especially in the west of Inner Mongolia, Shanxi and Shaanxi. In 2013 the yield of these three areas accounted for about 60% of national output. However,in the aspect of consumption, the coal consumption is mainly concentrated in the economically developed regions such as the eastern, central and southern regions. In 2013 the consumption of these three regions accounted for about 61% of the total. The uneven distribution of resources and the serious dislocation of production and consumption in the space results in the supply vulnerability of regional coal in China is gradually obvious. In addition, some events will also aggravate the supply vulnerability of regional coal and seriously threaten the energy security, such as frequent natural disasters, huge fluctuations of coal prices, competition between coal and electricity, mergers and acquisitions of enterprises, transportation obstruction, lack of rail capacity, major accidents.

LITERATURE REVIEW

In the 1970s, the first world oil crisis caused the scholars' wide attention to the energy security issues. In 1974, the International Energy Agency (IEA) was established, and proposed the concept of national energy security whose core is to stabilize the supply and price of oil. Energy supply security is the degree of stability which can meet the normal energy demand of a country, which Mainly studies the relationship between energy and economy; the energy using security is that energy consumption shouldn't threat the ecological environment of human beings' survival and development, which primarily studies the relationship between Energy and Environment[2]. With the deepening of research, scholars began to analyze the issues of energy security from the perspective of vulnerability. Willenborg, R. (2004) analyzed the supply vulnerability of Europe's oil, and proposed some response measures like establishing strategic petroleum reserve[3]. Based on the analysis of the impact of change of the energy price on electricity price in Thailand, Thanawat Nakawiro and Subhes C. Bhattacharyya (2007) assessed the economic vulnerability which was caused by the fact that the Thai electricity production was over-reliance on the natural gas[4]. With the indicators of energy intensity, the foreign dependency, CO2 emissions, and electricity supply, Edgard Gnansounou (2008) evaluated the energy supply vulnerability of the major industrialized countries in the world, and analyzed the sensitivity of these indicators[5]. Eshita Gupta (2008) proposed a kind of index system which was consisted of resource reserves, geopolitical risk, per capita GDP, oil consumption intensity, oil import bill, the proportion of oil in the primary energy consumption structure. And Using the method of principal component analysis, he conducted the empirical study of the oil supply vulnerability of 26 net importer and analyzed of the sensitivity of the indicators[6]. Based on the judgment logic, Edgard Gnansounou and Jun Dong (2010) constructed an assessment model of energy supply vulnerability. And through the empirical research in China they analyzed the advantages and disadvantages of the model[7]. Mathias Reymond (2012) evaluated the natural gas supply vulnerability of the South American countries with indicators of the strength of natural gas consumption, foreign dependency, self-sufficiency rate, geopolitical risks and so on[8]. In China, from the point of the economic structure security, Zhong Jianping (2006) analyzed the vulnerability of our country's energy security and its reason, and proposed related recommendations[9]. Zhao Yufei and Han Zenglin (2007) analyzed China's energy security system vulnerability in the two aspects of the protection and use, and proposed some measures to reduce vulnerability[10]. After defining the concept of supply vulnerability of energy security, Su Fei and Zhang Pingyu (2008) evaluated and analyzed the vulnerability of energy security supply of all provinces by the factor analysis[11]. From the aspects of high-intensity competitive pressures in Northeast Asian, zero-sum attributes of the energy competition, complex geopolitical situation in the Korean Peninsula, the energy heavily dependent on imports and the imports dependent on some particular regions, Liu Ge (2009) analyzed the energy security vulnerability of Korea and presented strategic choices from both the international and domestic levels[12].

The literatures above mainly were related to the research of the energy security supply vulnerability of the overall energy, oil and gas, but they are lack of research in the field of coal supply vulnerability. Therefore, this article will introduce the vulnerability to the field of coal supply. And on the base of exploring the meaning of the supply vulnerability of coal market, we will assess and classify the supply vulnerability of coal market of 30 provinces in China by using the factor analysis, and propose the corresponding management strategy.

THE ASSESSMENT AND CLASSIFICATION OF THE SUPPLY VULNERABILITY IN REGIONAL COAL MARKET

The connotation of the supply vulnerability in regional coal market

The concept of vulnerability dates from the research of disasters in natural scientific fields[13], but in recent years, it is widely used in the social scientific fields such as the utilization of land, sustainability science, economics and so on. Because of different perspectives, scholars who are in different fields have different understanding of the concept of "vulnerability". In the natural sciences, the "vulnerability" is generally defined as the extent or the possibility of losses of the system when it suffers from some adverse factors. In the social sciences, the "vulnerability" is generally considered as the

ability to withstand the adverse effects of the system[14]. According to these, this paper defines the supply vulnerability in regional coal market as a kind of comprehensive reflection which stands for the sensitive degree and the coping ability of the region when the coal supply is disrupted, coal prices soars, or other emergencies occur.

The selection of indexes

According to the main international and domestic researches and the key factors of coal supply and demand, the paper selects the ratio of coal production to coal consumption and the ratio of coal storage to coal consumption as the indexes to evaluate the supply vulnerability coping ability; and the paper also selects the degree of dependence on external coal trade, coal consumption intensity and the proportion of coal in primary energy consumption structure to access the coal supply sensitive degree.

(1)The ratio of production to coal consumption(X_1): namely the ratio of certain regional coal production to its coal consumption. The ratio represents the ability of the regional coal supply. If the ratio is high, it shows that there is adequate coal supply in this region. And the higher the ratio is, the supply vulnerability coping ability is stronger, and the supply vulnerability of coal is also lower.

(2)The ratio of storage to consumption (X_2): namely the ratio of coal storage to coal consumption in certain region. This ratio represents the level of protection of regional resources. The higher the ratio is, the level of protection is higher, that is to say, the supply vulnerability coping ability is stronger, and the supply vulnerability of coal is lower.

(3)The degree of dependence on external trade (X_3): namely the ratio of the net amount transferred to the coal consumption in certain region. If the degree of dependence on external coal trade is higher, the supply vulnerability of coal is higher, and the supply vulnerability of coal is higher.

(4)The coal consumption intensity (X_4): namely the ratio of regional coal consumption to GDP. If the coal consumption intensity is high, it indicates that the economic development in the region is deeply dependent on the coal. And if the coal consumption intensity is higher, the supply vulnerability of coal is higher, and the supply vulnerability of coal is also higher.

(5)The proportion of coal in primary energy consumption structure (X_5): namely the ratio of the regional coal consumption to energy consumption which reflects the importance of coal in energy consumption structure. The higher this ratio is, the coal is more important to the energy consumption structure, the supply vulnerability of coal is higher, and the supply vulnerability of coal is also higher.

The sources of data

The data of this paper comes from "China Statistical Yearbook 2013", "China Energy Statistical Yearbook 2013" and "2013 China Coal Development Report". Finishing and calculating the data of 30 provinces except Tibet, Hong Kong, Macao and Taiwan in 2013, we achieved all the above indexes: namely the ratio of coal production to coal consumption, the ratio of coal storage to coal consumption, degree of dependence on external coal trade, coal consumption intensity and the proportion of coal in primary energy consumption structure.

The assessment of vulnerability

Whereas there is a strong correlation between the indexes, in order to avoid resulting of weight bias, the paper proposes quantitative assessment and classified analysis to the supply vulnerability of regional coal through factor analysis. Factor analysis can simplify the data, reflect the basic structure and characteristics of the complex phenomenon by common factors and also solve the problem of correlation between indexes[15].

(1)Standardized indicators

First of all, to make each indicator on the same dimension and magnitude, and with a positive correlation between the vulnerability, we standardize the indicators. For the positive indicators, we use the formula (1) to process, and for the reverse indicators, we use the formula (2) to process.

$$\hat{X}_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \quad \textbf{(1)}$$

$$\hat{X}_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)} \quad \textbf{(2)}$$

Specifically, X_{ij} stands for the original value of the indicator of j in the i province; and $\hat{X}_{ij}$ stands for the standardization value of the indicator of j in the i province, $\max(X_j)$ stands for the maximum value of X_{ij}; $\min(X_j)$ stands for the minimum value of X_{ij}. After standardized, all indicators are in range of $[0,1]$.

(2)KMO and Bartlett test

Before applying the factor analysis to assess, we need test its applicability. The KMO and Bartlett test are the common methods of test. KMO is to test the partial correlation between variables, and Bartlett is to test whether the correlation matrix of variables is a unit matrix. In general, if the value of KMO is more than 0.7, and the Sig value of Bartlett's test is less than 0.01, the set of samples can be considered to be suitable for factor analysis. After calculated, this paper select the value of KMO statistic of ample is 0.786 which is more than 0.7; and the value of the Sig of Bartlett test is 0 which is less than 0.01.

(3)The correlation coefficient matrix R of each index

As shown in TABLE 1, the absolute value of the correlation coefficient between the variables is substantially more than 0.5, which indicates that there are significant correlation between these variables, and further shows that factor analysis can be carried on.

TABLE 1 : Correlation matrix

	X_1	X_2	X_3	X_4	X_5
X_1	1	0.768	0.809	-0.67	-0.584
X_2	0.768	1	0.6	-0.527	-0.375
X_3	0.809	0.6	1	-0.634	-0.683
X_4	-0.67	-0.527	-0.634	1	0.723
X_5	-0.584	-0.375	-0.683	0.723	1

(4)The eigen value λ, eigenvector u and the cumulative variance contribution rate of the correlation coefficient matrix

As shown in TABLE 2, the cumulative contribution rate of the former two factors reaches 85.641%> 85%, which shows that they contain more than 85% of information of the original variables, so the former two factors are extracted as the principal factor.

TABLE 2 : The Eigen value and contribution rate of factors

Factor	Eigen value	Variance contribution rate(%)	The cumulative contribution rate (%)
f_1	3.563	71.251	71.251
f_2	0.719	14.39	85.641
f_3	0.362	7.243	92.884
f_4	0.219	4.389	97.274
f_5	0.136	2.726	100

(5)Rotation

In order to facilitate the meaning of the principal factors, the factor loading matrix was implemented of rotation through the method of great variance orthogonal rotation, and the result is shown in TABLE 3.

TABLE 3 : Rotated factor loading matrix

Principal factor	X_1	X_2	X_3	X_4	X_5
f_1	-0.486	-0.17	-0.646	0.801	0.934
f_2	0.812	0.936	0.611	-0.382	-0.177

It is not difficult to find that the principal factor f_1 mainly explains the two indicators of coal consumption intensity and the proportion of coal in primary energy consumption structure, and the principal factor f_2 mainly explans the two indicators of the ratio of coal production to coal consumption and the ratio of coal storage to coal consumption. Therefore, we define the principal factor f_1 as the factor of sensitive degree and the principal factor f_2 as the factor of coping ability. It is worth mentioning that the absolute value of the loading of the indicator X_3 (degree of dependence on external trade) and the two principal factors are both more than 0.6, indicating that the degree of dependence on external trade deeply influents the sensitive degree and coping ability. At the same time, we also achieve the new rotated eigen value and contribution rate of principal factors, as shown in TABLE 4.

TABLE 4 : Rotated eigen value and contribution rate of principal factors

Principal factor	Contribution Value	Variance contribution rate(%)	The cumulative contribution rate (%)
1	2.196	43.917	43.917
2	2.086	41.724	85.641

(6)The factor score coefficient matrix through the regression method

After calculable, the factor score coefficient matrix is shown in TABLE 5.

TABLE 5 : The factor score coefficient matrix

Factor	X_1	X_2	X_3	X_4	X_5
1	0.055	0.38	-0.187	0.44	0.662
2	0.427	0.707	0.165	0.117	0.365

The scores of the Principal factors are calculated as following:

$$f_1 = 0.055X_1 + 0.38X_2 - 0.187X_3 + 0.44X_4 + 0.662X_5 \quad (3)$$

$$f_2 = 0.427X_1 + 0.707X_2 + 0.165X_3 + 0.117X_4 + 0.365X_5 \quad (4)$$

(7)Evaluation

With the rotated variance contribution rate of principal factors being used as the weight, we build the following assessment model of coal vulnerability:

$$CV_i = \beta_1 f_{i1} + \beta_2 f_{i2} \quad (5)$$

Specifically, CV_i stands for the index of the vulnerability of regional coal, and β_1 and β_2 are the rotated variance contribution rates of principal factors:

$$CV_i = 0.43917 f_{i1} + 0.41724 f_{i2} \quad (6)$$

Finally, as long as the value of f_i is substituted, the assessment result of the vulnerability of each regional coal can be obtained. As is shown in Figure 1, the supply vulnerability of coal market in Hunan is the highest, reaching 1.1392; and the lowest is in Xinjiang, as 0.5467.

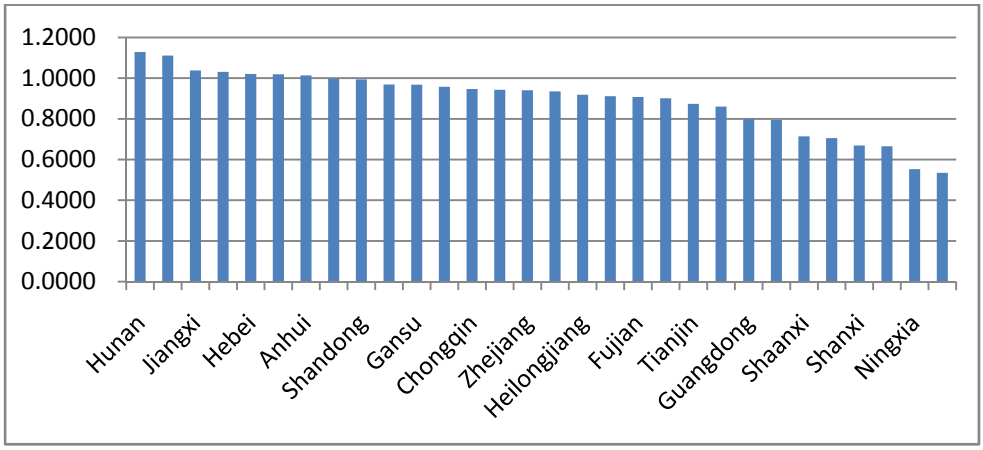

Figure 1 : The coal supply vulnerability assessment results of 30 regions

The Classification of the Vulnerability

In order to explore the reasons of the vulnerability of the regional market, this paper classifies the 30 provinces according to the two sides of coal supply sensitive degree and supply vulnerability coping ability. Specifically, the dividing

line of the coal supply sensitive degree is 0.7. If more than 0.7, it indicates the sensitive degree in the region is high, whereas it is low. With the indicators standardized, the community of the supply vulnerability coping ability is 1. If the assessment result is more than 1, it means the supply vulnerability coping ability in the region is weak, whereas is strong. China's 30 provinces can be divided into the following four categories:

(1)The first category: the low sensitive degree – the strong coping ability. Only Xinjiang and Ningxia belong to this area. Along with the development of China's coal is deepening, the production of Xinjiang and Ningxia increases every year and their ability to respond to emergencies has been continuously improved. However, because the level of economic development in these regions is low and the industrial chain is uncompleted, the coal consumption is low, the economic development of is less dependent on coal consumption, and the coal supply sensitive degree is low.

(2)The second category: the low sensitive degree – the weak coping ability. These regions mainly include Beijing, Liaoning, Qinghai, Guangdong, and Hainan. Because the coal resource in these regions is poor, the yield is very low, and the coal consumption mainly relies on external coal trade, so their supply vulnerability coping ability is weak; but the economy of these areas relatively is developed, the industrial structure is reasonable, the proportion of coal in energy consumption structure is low, and the economic development is less dependent on coal consumption, therefore its coal supply sensitive degree is low.

(3)The third category: the high sensitive degree – the strong coping ability. These regions mainly include Inner Mongolia, Shanxi and Shaanxi. Because these areas are the main producing areas of China's coal, the reserves of resources are abundant and the production is large, accounting for more than 60% of the national total production, their supply coping ability is weak. However, while they are enjoying the "Coal Dividend", because their industrial structure is unreasonable and the development model is extensive, they have trapped in the impasse of development. In these regions, the economic development deeply dependents on the coal consumption, and their coal supply sensitive degree is high.

(4)The fourth category: the high sensitive degree – the low coping ability. These regions mainly include Yunnan, Guizhou, Sichuan, Gansu, Chongqing, Anhui, Jilin, Heilongjiang, Tianjin, Henan, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, Jiangxi, Fujian, Guangxi, Hubei, Hunan. Although these areas have some coal reserves, due to having been mined for a long time, the growing potential is limited and in some areas the resources are nearly exhausted. And in recent years the growth of coal production is slow. Therefore, their supply coping ability is weak. In addition, faced with irrational industrial structure and the high proportion of coal in primary energy consumption structure, their coal supply sensitive degree is high.

THE MANAGEMENT STRATEG OF THE SUPPLY VULNERABILITY IN REGIONAL COAL MARKET

For regions of different types of the supply vulnerability of coal market, the management strategy of classification can be used.

(1)For the regions in the first category, take the strategy to extend the industrial chain, explore their potential, and promote economic development on the base of coal and related industries. Due to the strong coping ability and low sensitive degree, the supply vulnerability in these coal regions is relatively proper. The coal resource of these regions is very rich, but because of the low level of economic development, the degree of utilization of coal resource is not enough. Therefore, in order to promote regional economic development, the coal industry chain of these regions should be extended, and the coal should be to processed deeply. At the same time, we should intensify the construction of Sinotrans channels, enhance the ability of Sinotrans by the transmission of coal, power, and gas, and full play the advantage of their rich resources to make them to be the supply base of major coal and clean energy of the country.

(2) For the regions in the second category, construct the coal emergency reserve to enhance the ability to respond to emergencies and ensure energy security. Because the coal resource of these regions is poor, the yields are also low, and faced with the emergencies, there are lack of effective response measures, the ystem of coal contingency reserve should be established, define the reasonable scale reserves, and optimize the layout of the reserve point to improve the response capabilities of emergencies.

(3) For the regions in the third category, optimize the industrial structure, change the mode of growth, and reduce the sensitive degree. Because with abundant coal resource, these regions are the main producing areas of coal, and the economic development is deeply dependent on the coal consumption, we should adjust the industrial structure, change the growing mode, reduce the intensity of coal consumption, and cut down the proportion of coal in primary energy consumption structure to reduce the degree of sensitivity.

(4) For the regions in the fourth category, take compound strategy. In order to achieve the comprehensive management of the vulnerability, it is necessary to optimize the industrial structure, but also to strengthen the construction of contingency reserves of coal. These areas are more sensitive to emergencies, but they don’t have strong coping ability. So the single policy can’t effectively improve their vulnerability, and we should take compound strategy. On the one hand, optimize the industrial structure, change the mode of growth, develop the new energy, promote energy-saving technology to reduce the intensity of coal consumption, the proportion of coal in primary energy consumption structure and the degree of sensitivity; on the other hand, build coal contingency reserve and rationally plan and design the network of coal logistics to improve response capabilities.

CONCLUSION

(1) The supply vulnerability of most of the Chinese coal regions is higher. As seen in Figure 2, there are 20 provinces belonging to the fourth category, namely the region of "the high sensitive degree – the low coping ability", which account for 67% of the total regions. Therefore, when faced with emergencies, most of the provinces not only have high

sensitive degree but also are lack of adequate coping ability. The situation of management of the vulnerability in these regions is very grim.

(2) According to the reasons of the supply vulnerability of the coal market, these 30 provinces can be divided into four categories, namely "the low sensitive degree – the strong coping ability ", " the low sensitive degree – the weak coping ability " and " the high sensitive degree – the strong coping ability " and " the high sensitive degree – the low coping ability ".

(3) According to the different supply vulnerability of coal regions, we can take classified management strategy. For the first regions, we can extend the industrial chain; for the second regions, we can construct the coal contingency reserves; for the third regions, we can optimize the industrial structure and transform the mode of growth; and for the fourth regions, we should take compound strategy. Specifically, we should optimize the industrial structure, change the mode of growth, and meanwhile build the system of coal contingency reserve.

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