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Policy modeling consistency analysis during energy crises: Evidence from China's coal power policy

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ABSTRACT

The coal power crisis threatens global energy security and hinders the achievement of the sustainable development goals. Regarding energy security, quantitative analysis of the coal power policy is required for the sustainable development of the coal power industry. Therefore, by using the methods of text mining and content analysis and taking three large-scale coal power crisis series of policies in China as examples, this paper constructs a PMC index model of coal power policy and analyzes the evolution of coal power policy system from the perspective of crisis management. The results show that: (1) China's coal power policy is characterized by diversification of policy areas and policy instruments, but there are problems such as poor coordination between sectors and insufficient supply-demand early warning. (2) According to the different periods of the coal power crisis, the gestation period mainly involves the instruments of target planning and regulatory constraint, which can play a guiding role but may also have the reverse effect due to the shortage of power supply. During the explosive period, price and multisubject governance mechanisms are used to intervene in the crisis. During the processing period, the government mainly strengthens the supply-oriented policy to meet the structural adjustment of energy industry demand. (3) Throughout the three coal power crises, the supply policy instruments and multisubject governance mechanisms have gradually become the primary means to address the coal power crisis. Finally, suggestions are put forward for the implementation of the coal power policy from multiple perspectives.

1. Introduction

Since September 2021, regions in China have "pulled the switch" and started a wave of power rationing and shutdown. For example, more than 1000 enterprises in Jiangsu "open two stop two". Guangdong "open two stop five", only retains less than 15 % of the total load. Yunnan Province cut the output of yellow phosphorus and industrial silicon by 90 %, and Liaoning imposed power restrictions on 14 municipalities. Power shortages have become an important factor restricting the stable development of China's economy (Xiao et al., 2022). According to statistics, coal power accounts for nearly 68 % of China's total power generation. As the main power source in China, coal power has played a fundamental role in stable supply, emergency peak regulation and central heating for a long time. However, with the development of the social economy and the improvement of people's quality of life, China's electricity demand is growing rapidly, which leads to a shortage in the coal electricity supply, and the coal price is constantly increasing. Finally, the outbreak of energy crises is becoming more prevalent (Zhang et al., 2014).

In essence, a coal power shortage is the imbalance of supply-demand in the coal power market, which is an imbalanced phenomenon in economic theory. In the case of an emergency shortage of coal power, two adjustment mechanisms can be adapted to move from a nonequilibrium state to an equilibrium state: a price mechanism and a quantity mechanism (Aliyu et al., 2013). The price mechanism is a price adjustment mechanism; this means that when the supply-demand of coal electricity is out of balance, the supply-demand will be adjusted automatically through the electricity price rise and fall until the final automatic balance of supply-demand. The quantity mechanism is when there is a gap between the supply-demand of coal power; the price cannot

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change rapidly due to information asymmetry or other reasons to make the two reach equilibrium. Therefore, when there is disequilibrium in the electricity market, if the price remains basically unchanged, the electricity market can only be balanced by adjusting the quantity of supply-demand sides. However, in the case of a power shortage, the demand of demanders usually cannot be fully met due to quantity constraints. The final equilibrium is manifested as quota equilibrium until the coal power crisis is triggered.

In China, as electricity is a kind of public product, administrative regulation is the most important means for the government to solve the coal power crisis or power shortage (Imran and Amir, 2015). Coal power policies are a series of policies and strategies formulated by the government and energy departments at all levels around the production, supply and consumption of coal power. From the perspective of policy-making, there are two main ways to alleviate the shortage of coal power; in times of crisis, one is taking short-term measures to address supply disruptions and price spikes (Imran and Amir, 2015). The other is adopting medium- and long-term strategies to adjust and stimulate the coal power industry after the crisis (Heffner et al., 2010).

Specifically, when a coal power crisis occurs, a power rationing policy is usually adopted. For example, Zambia and many other developing countries have implemented load-shedding schemes, in which electricity supply to some consumers is subjectively interrupted to meet local demand through quantitative adjustments (Ngoma et al., 2018). At present, countries all over the world are facing the serious challenge of inadequate electricity supply. For example, system operators in Nepal adopt a rolling blackout approach (Poudyal et al., 2019), while those in South Korea generally adopt a rolling blackout policy for cities with relatively low social costs when facing power shortages (Kim et al., 2020). Overall, rolling blackouts are the most common way to address the coal power crisis, but from the perspective of energy rationing, rolling blackouts are the least ideal response policy because it is inconvenient to users and does not save energy. Therefore, some countries have adopted price adjustment mechanisms, such as subsidies and price limits, to ensure energy consumption for people's livelihood (Helm and Mier, 2021). However, in the case of tight coal supply, it is difficult to determine whether the high prices are the result of market forces or malicious competitive behavior. If there is malicious competitive behavior, regulators will mitigate deficiencies and control price spikes (Xingang et al., 2011). However, from the subjective point of view, some developed countries such as Germany, the United States and the United Kingdom have little or no intervention in the price of coal and electricity, but the market regulates the price of coal and electricity, and some developing countries such as China also need transitional government intervention regarding the price of coal and electricity. With the continuous improvement of the coal and electricity mechanism, the continuous reduction of government intervention will become a developing trend (Öhrlund et al., 2019).

After the coal power crisis, medium- and long-term policies are usually adopted to adjust and encourage the coal power industry, which can be roughly divided into two mechanisms: seeking renewable energy and improving energy efficiency (Zhang and Ding, 2022; Zhao et al., 2022). It is generally accepted that energy efficiency improvements stem from two types of policy support. First, industrial restructuring, i.e., energy flows from low-productivity industries to high-productivity industries (e.g., agriculture to industry, industry to services, and traditional industry to new industry). Second, to strengthen technical information support, technical policy support is reflected not only in the application of technology in the coal power industry but also in the whole process of economic output from coal power entering the economic system as a factor of production. For example, the improvement of transportation technology can reduce the loss of coal electricity during the transportation process, the introduction of advanced equipment can reduce the energy loss in the production process, and the optimization of the management system can efficiently allocate resources. Thus, you get more output with the same input or get the same output with fewer factor inputs. However, relying on industrial restructuring to improve energy efficiency results in difficulties meeting current requirements. Technological progress is a long-term incremental process with uncertainty that generally requires sustained investment in R&D (Salah et al., 2021; Gholamalizadeh et al., 2022; Zhu et al., 2023).

Because of the environmental impact, the World Energy Outlook 2016, released by the International Energy Agency (IEA), links energy, air pollution and health issues and recommends avoiding conventional fuels, transitioning to renewable energy sources, and developing low-carbon and carbon-capture technologies to reduce atmospheric emissions. Therefore, a large number of policies have been shifted to solve the power shortage by developing renewable energy power plants (Su et al., 2020a; Zhang et al., 2023). Many countries and regions around the world have proposed the idea of transitioning to 100 % renewable energy power systems (100 % REPS) in the future. As an example, Nepal uses CCS technology to retrofit some gas power units, shutting down all coal power units, and adding renewable energy such as natural gas and nuclear power units to support load-side electricity consumption and form a clean renewable energy power system (Poudyal et al., 2019). Germany has cut coal mining by about 30 % in the past 10 years, and renewable energy sources such as wind power will fill the gap left by the decline in traditional energy generation (Zugno et al., 2013). Despite the vast global availability of renewable energy sources, only approximately 27 % of the world's population has access to electricity from renewable sources. The reason is that the high capital costs associated with renewable energy technologies have hindered their adoption, so developed countries are trying to develop new technologies to reduce implementation costs (Lohani et al., 2023; Su et al., 2020b; Kyriakopoulos, 2021).

Therefore, policy regulation plays a key role in alleviating regional coal power shortages and promoting the healthy development of the industry. Coal power policies mainly play roles such as guiding incentives, controlling norms, leverage adjustment, etc. Such policies are not only introduced to solve the problem of overcapacity in the coal power industry but also to improve the supply structure and quality of the coal power industry. Finally, a higher level of supply and demand balance can be achieved (Yao et al., 2022). At present, countries all over the world are facing the serious challenge of inadequate electricity supply. The shortage of power supply and the soaring price are bound to threaten China's energy security. However, most countries, especially developing countries, have not established a systematic and phased energy crisis emergency management and regulation mechanism. That is, early warning and defense in the early stage of a crisis, taking effective measures to prevent the spread of a crisis when a crisis occurs, and formulating long-term solutions to the causes of coal power shortages after a crisis to effectively minimize the impact of the initial crisis is necessary (Oscarsson, 2022). Therefore, an effective strategy to mitigate the coal power crisis should be phased.

The motivation of this paper is to explore the effectiveness of policy means in dealing with China's coal power crisis by analyzing the policy formulation and evolution during the occurrence of the coal power crisis. The contributions can be concluded as follows: (1) From the perspective of whole life cycle management, the concept of the coal power crisis life cycle is put forward, and it is divided into three stages, the gestation period, explosive period, and processing period, which expands the application scope of crisis management theory. (2) The text mining method and social network analysis technique are adopted to compare the effectiveness of the policy instruments adopted by different subjects to deal with the different stages of the energy crisis, which provides a new perspective for our research. (3) It constructs a quantitative evaluation framework for China's coal power policy based on the Policy Modeling Research Consistency (PMC) Index model and exploring the evolution path of coal power policy, which provides a new method for the existing literature.

The rest of this paper is structured as follows: Section 2 is on the theoretical framework; Section 3 is on the coal power policy analysis from the perspective of crisis; Section 4 is on the dynamic quantification of the coal power policy based on the PMC model; Section 5 is on the result analysis based on the PMC model and Sections 6 further discusses the policy implementation. Finally, Section 7 provides conclusions.

2. Theoretical framework

This paper aims to construct the PMC index evaluation system of the coal power policy from the perspective of crisis. Then, a quantitative analysis and objective evaluation of the policies issued during the coal power crisis in China is performed. In the research process, the following three research hypotheses are followed:

Hypothesis 1. Mandatory policy interferes with the supply and price of thermal coal, which easily forms an energy supply-demand gap.

Mandatory policy relies on government authority and coercive power, including the control of coal power enterprises and the restriction of the power coal market. It is the most intrusive and direct method of government regulation and is mainly manifested by the government standardizing various behaviors through legislation, and regulations (Yang et al., 2022; Li et al., 2021). Mandatory policy instruments can have a large effect in a short period. However, with the increasing diversification and fragmentation of society and the general requirements for deregulation, mandatory policy instruments may fail to have such an effect (Zhu et al., 2019).

As shown in Fig. 1, it is assumed that when the coal power industry is in equilibrium, the thermal coal demand curve D_0 and the supply curve S_0 intersect at point a; then, the thermal coal price is P_0, and the output is Q_0. As China's industrial structure and high-speed economic growth have increased the demand for thermal coal (Gosens et al., 2022), the thermal coal demand curve has shifted to the right D_1. If the thermal coal supply remains unchanged, the thermal coal price will rise to $P^{'}$, and higher prices will boost supply further. If the supply and price are not restricted in reality, it is assumed that the thermal coal supply will increase to $S_1^{'}$, the thermal coal price will be $P_0^{'}$, and the output will be $Q_0^{'}$. Considering that the country has raised the coal market access standard, the supply and price of thermal coal have been restricted. Therefore, suppose the thermal coal supply curve shifts from S_0 to S_1. At this time, the curve of thermal coal demand and supply intersects at point b, the thermal coal supply will be Q_1, and the price of thermal coal will be P_1. The thermal coal supply Q_1 deviates from the actual demand $Q_0^{'}$, that is, the gap between power supply and demand occurs, and the coal power crisis appears. Thus, it can be seen that although the implementation of mandatory policies can regulate the market, it may also result in insufficient power supply and ultimately have the opposite effect.

Hypothesis 2. A coal power crisis can be divided into three stages, and each stage has different response methods.

The coal power crisis refers to the crisis caused by the shortage of coal power supply and rising prices (Gohli, 2022). Because the coal power crisis is not "life or death" and has no after-effect, there is a dynamic evolution process (see Fig. 2). Therefore, based on the life cycle theory of crisis proposed by Dou (Dou et al., 2020), this paper divides the development law of a coal power crisis into the gestation period, the explosive period and the processing period, which are described as follows:

(1) Gestation period, i.e., within the OPBM rectangular range. This stage in crisis is hidden in normalized management. There are hidden signs that show up through market trends, changes in energy consumption patterns, instability in the coal supply chain, etc., which is easily ignored by managers. Therefore, at this stage, the government should focus on the early warning work of coal power supply-demand, identify the crisis, and finally prevent a large-scale outbreak of the crisis.
(2) Explosive period. With the gradual increase and aggregation of the cause of the crisis, the crisis enters the full explosive period, as shown in the rectangular BFGD. At point P, the coal power market shocks are intensified. With the continuous constraints of supply-demand, energy saving, coal merger and reorganization and other policies, the intensity of the crisis increases significantly and rises to Q point in the explosive period. This stage has rapidly developed from a potential state to an urgent crisis, which has a serious impact on the power supply, market stability and national economy, and the energy market turmoil may trigger international energy price fluctuations, and the energy supply chain may also be affected. At this stage, the central and local governments are required to respond actively and make timely decisions to contain the spread of the crisis through temporary intervention policies such as price regulation and transportation management.
(3) Processing period, the crisis intensity gradually recovers from D to E. The crisis is preliminarily controlled, and the coal power supply gradually returns to the original normal level. The harm degree of the coal power crisis has been reduced to the minimum and gradually disappears, but economic recovery and social satisfaction will take time, and global energy markets are stabilizing, with international cooperation and supply chains in focus.

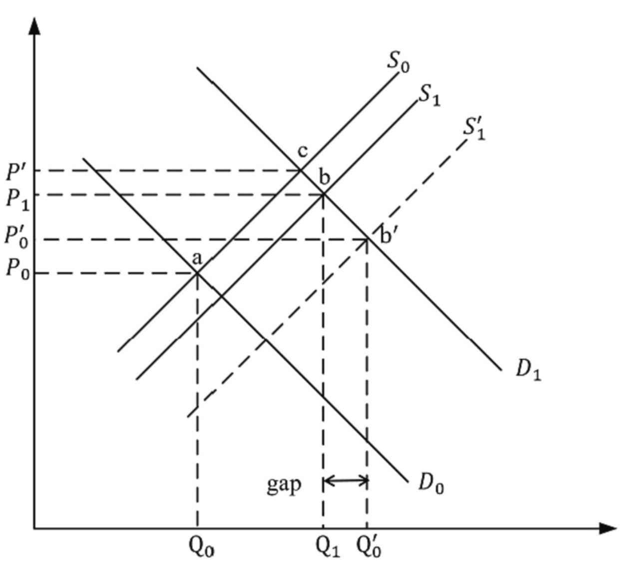

Fig. 1. Price and supply of thermal coal.

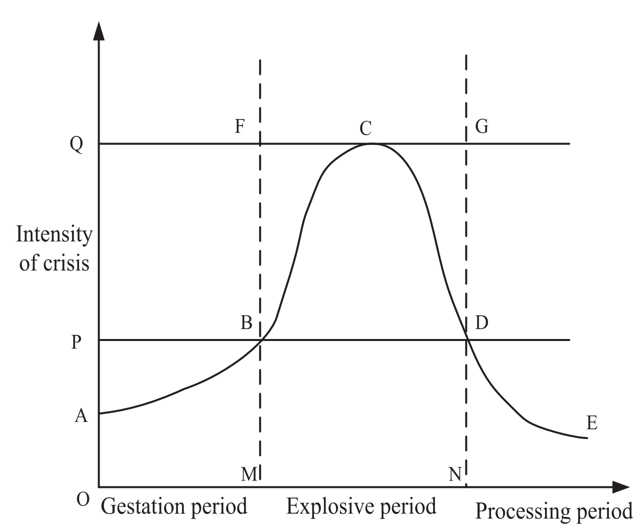

Fig. 2. Crisis life cycle diagram.

Therefore, at this stage, the government needs to analyze the reasons for the occurrence and failure to control the crisis in a timely manner and adhere to the combination of deepening reform of the coal power industry and technological innovation. Finally, the development quality and efficiency of the coal power industry should be improved.

Hypothesis 3. Supply policy instruments and multisubject governance mechanisms have become the primary means to address the coal power crisis.

Supply policy instruments refer to the top-down support provided by the government as the most direct driving force for the coal power industry (Chung et al., 2022). Specifically, the government directly expands the supply of coal power to improve the shortage of supply by providing basic production factors, such as capital, information, science and technology, and manpower, for the coal power industry. Thus, the development process of the coal power industry will be promoted (Zhang et al., 2020). Driven by the dual-carbon target, coal power will gradually transform into both a basic guarantee and system regulation power supply (Li et al., 2020; Du et al., 2009). Therefore, the government is more inclined to adopt strategies such as infrastructure construction, human resources training, scientific and technological information support to directly promote the development of the coal power industry.

The core issue of crisis management is the power-responsibility mechanism construction and adjustment of each participant with the government as the center (Gao et al., 2022; Cheng and Qin, 2021). To deal with the coal power crisis effectively, it is necessary to reasonably divide the power and responsibility of each participant (Debardeleben, 2020). Within the government, all departments are required to do a good job in coal power market supervision and coal power project planning. Outside the government, coal power enterprises should be provided positive incentives such as tax incentives and financial support for crisis treatment and accept strict supervision in return. At the same time, the public should be required to do a good job saving energy and actively participating in crisis treatment. Therefore, the joint participation of multiple subjects in energy crisis management is a new decision-making and governance mechanism (Cheng and Qin, 2021) that can make the relationship between the government and the public develop sustainably to achieve the best harmonious state so that the government can better cope with the coal power crisis.

3. Analysis of coal power policy from the perspective of crisis

3.1. Data sources for policy texts

3.1.1. The selection and period division of the coal power crisis

Since the development of the coal power industry, the industrial structure has become more mature and has more effective cost control means, more continuous improvement of scientific and technological innovation, and stronger initiative to participate in the market. However, in the nearly 20 years of coal power industry development, there are still three shocks and impacts of energy supply-demand imbalance, namely, three large coal power crises in China. From 2002 to 2005, after the Asian financial crisis, the power supply was restricted, affecting as many as 24 provinces in one year at most (Pollitt, 2021). From 2009 to 2012, the power shortage was not only in coastal areas but also in central provinces such as Hunan and other resource-rich provinces such as Shanxi, making the power supply-demand balance more fragile (Ming et al., 2013). From 2020 to the present, power rationing has occurred in many regions, not only in China but also in many Western countries, such as the United States (Wang et al., 2022).

Taking the three coal power crises in China as an example, according to the crisis life cycle theory and combined with the reality of coal power shortages on the degree of economic and social impact, this paper divides the three coal power crises into stages. The specific division rules are shown in Table 1.

3.1.2. Data source and collection

The coal power policy texts selected in this paper are all derived from public data, mainly through two channels; the policy texts are collected through the relevant official websites of various ministries and commissions (gov.cn; nea.gov.cn), and the relevant policy information is determined by the Smart Law Retrieval database launched by the Law Department of Peking University (pkulaw.cn). Due to a large number of coal power policy documents, to ensure the integrity of the study, we screen them according to the following three principles. (1) The main body of the policy sample are policies that are only issued by the National Development and Reform Commission, the Energy Administration, the Ministry of Finance and other departments at the national level, and the local policies are not considered. (2) The policy texts mainly include all kinds of laws, regulations, opinions, notices, letters and other rules related to the coal power industry issued during the three major coal power crises in China. (3) The downloaded policy documents are further analyzed, and policies that are too weak or too small in scope are excluded, such as notices or announcements concerning the establishment of national coal planning mining areas. If a policy contains multiple pieces of content, only the items related to coal power are interpreted.

According to the classification rules of the three coal power crises (see Table 1) and the issuing time of the policies, the selected coal power policies are grouped. For example, the Notice on the Transformation and Upgrading of National Coal Power Units (No. [2021]1519), jointly issued by the National Development and Reform Commission and the National Energy Administration on October 29, 2021, is classified as the coal power policy of the third coal power crisis treatment period.

3.2. Co-occurrence network features of policy text subject words

After grouping the selected 114 coal power policy texts according to the coal power crisis period, the ROST-CM6 text analysis software is used to perform word segmentation and word frequency statistics on the policy texts in different crisis periods. Words that appear frequently in policies are popular issues of concern to the coal power industry, which can reflect the dynamic changes of policies to a certain level. Words such as "national" and "sector" appear more frequently but have no specific meaning when analyzed, and adverbs regarding the degree such as "very" and "special" and a series of verbs such as "promote", "increase" and "improve" should all be excluded. Finally, some high-frequency words that are effective for this paper are sorted out, and the specific results (part) are shown in Table 2.

To clearly show the relevance and difference of the policy text feature words in different periods of the coal power crisis, we selected the top 20 high-frequency words in different periods of the coal-electricity crisis based on Table 2 to establish a correlation matrix of crisis periods and high-frequency words and then imported it into Gephi.0.9.4 bata software to obtain the correlation network diagram shown in Fig. 3.

As shown in Fig. 3, the middle area enclosed by the high-frequency

Table 1
Coal power crisis period division.

Times	Gestation period	Explosive period	Processing period
First coal power crisis	January 2002 to June 2003	July 2003 to December 2004	January 2005 to December 2005
Second coal power crisis	January 2009 to December 2010	January 2011 to December 2011	January 2012 to December 2012
Third coal power crisis	January 2019 to September 2020	October 2020 to September 2021	October 2021 to present

Table 2
Frequency statistics table of keywords in China's coal power industry policy text.

Serial number	First coal power crisis			Second coal power crisis			Third coal power crisis		
	G1	E1	P1	G2	E2	P2	G3	E3	P3
	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency	Keywords/ frequency
1	safety/438	safety/672	safety/493	coal/210	coal/158	coal/315	coal/259	construction/ 391	market/238
2	coal/312	coal/386	coal/235	electricity/144	reserve/118	electricity/ 213	construction/ 233	safety/329	electricity/232
3	accidents/109	electricity/ 193	monitor/204	safety/128	accidents/101	construction/ 177	develop/218	intelligent/ 292	energy/182
4	manage/109	manage/193	manage/108	integrate/95	emergency/86	develop/151	capacity/208	manage/191	trade/169
5	trade/108	monitor/142	develop/86	merger/83	safety/85	safety/148	safety/201	coal/173	construction/ 116
6	electricity/ 104	construction/ 119	gas/75	closure/83	price/68	resource/109	electricity/ 167	surrounding/ 169	transportation/ 107
7	monitor/76	market/117	grid/72	distribute/77	manage/61	trade/98	assure/152	develop/165	green/100
8	construction/ 71	trade/110	area/68	articulate/77	trade/46	manage/94	invest/118	technology/ 158	develop/94
9	order/70	schedule/104	implement/ 68	reorganization/ 70	transportation/ 45	contract/80	implement/ 116	control/151	manage/82
10	closure/70	price/87	closure/66	manage/68	develop/42	surrounding/ 78	intelligent/ 101	monitor/139	safety/80
20	regulation/42	run/32	finance/19	assure/38	assure/27	saving/32	surround/36	green/72	clean/36

Note: The data of the 11th to 19th high-frequency policy words are omitted, which is the analysis result of ROST-CM6 software.

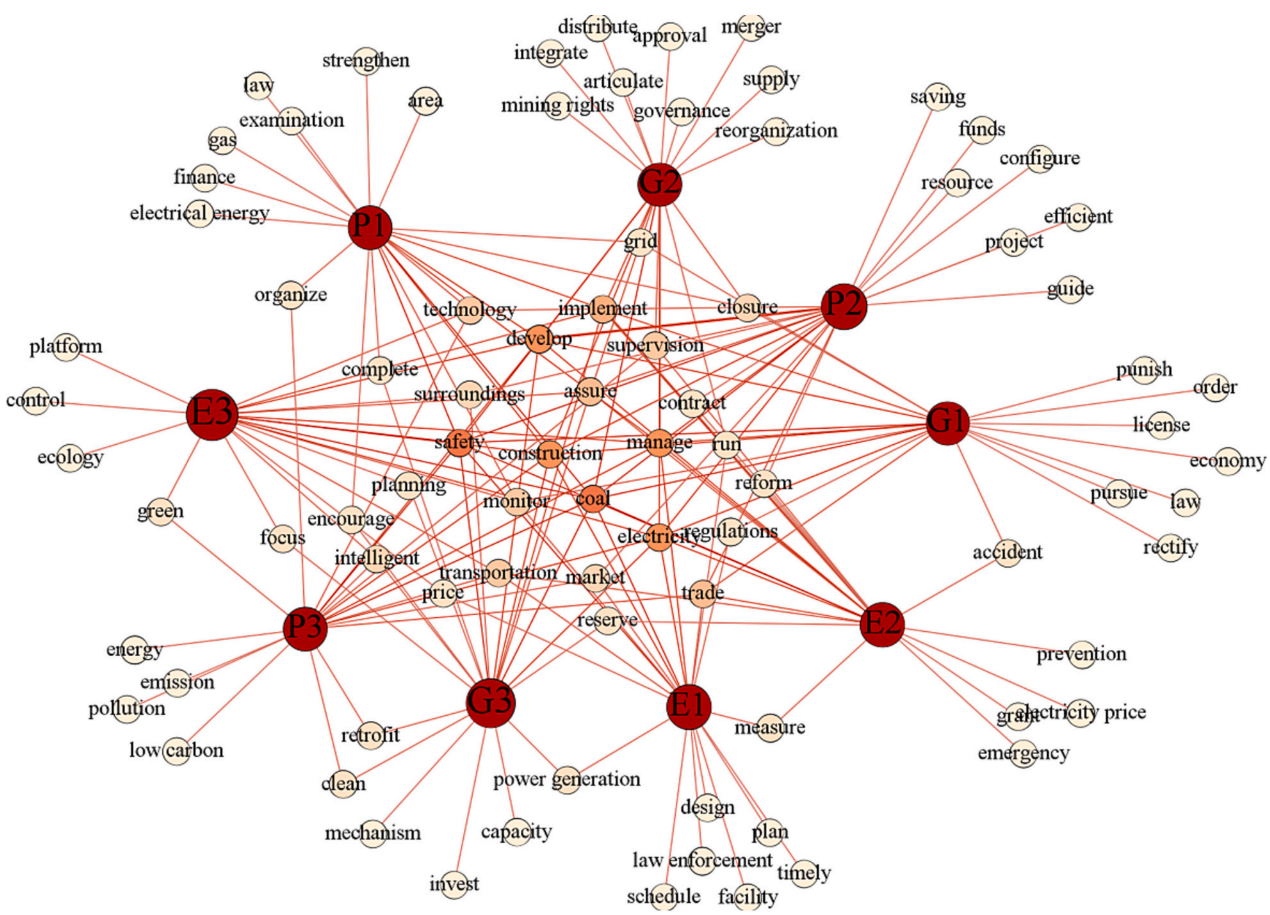

Fig. 3. High-frequency policy words relationship network of coal power policies in the crisis period.

policy words is the common focus of the government in different crisis stages. Some of the high-frequency words are of high conceptual nature, such as "coal" and "electricity". In general, the policies involve more words such as "safety" and "regulation", indicating that the issue of safety production is the focus of the government during the development of the coal and electricity industry. The marginal areas have relatively unique information about coal power policies in different crisis periods, which also indicates the different focuses of policy attention in different periods, suggesting that China's policy-making from the perspective of the coal power crisis is a dynamic evolutionary process.

The policies of the first crisis gestation period involved words such as "consolidation", "permits", "penalties", and "orders". This is due to the State Council's proposal since 2000 to speed up the progress of small coal mine closure, increase consolidation efforts and strengthen coal safety regulations. The policies of the second crisis gestation period involve "mergers", "reorganization", "integration", etc. The State Council encourages all kinds of coal mining enterprises to merge and reorganize in the form of property rights and shares to optimize the structure of the coal power industry. The third crisis gestation period involves words such as "intelligence", "mechanism", "capacity", etc. During this period, the state was required to actively promote the optimization and upgrading of electricity, combining intelligence and efficiency with green environmental protection. Although the focus of attention during the gestation period differs from crisis to crisis, the gestation period policy text features words mainly involving structural change and strategic adjustment of coal power enterprises.

The policies of the first and second crisis explosive periods all involve words such as "electricity prices", "emergency response", "prevention and control", and "transportation". The government mainly manages the price regulation of electricity and coal through various supporting services, for example, executing transportation security work to meet the development needs of the coal power industry. Finally, the policies of the three crisis processing periods all involve words such as "financial", "support", and "funding", indicating that the government mainly improves the coal power industry system and strengthens infrastructure construction through financial support. As China's coal power crisis evolves, the measures used to address the crisis are forced to adjust and keep pace with the times, and as a result, the development mode of the coal power industry has gradually shifted from traditional rough development to green and sustainable development (Su et al., 2020c).

4. Dynamic quantitative analysis of the coal power policy based on the PMC model

4.1. Policy options

In the empirical selection of policy samples: (1) We read through the 114 coal power policy texts selected above. If the content of the policies promulgated in each crisis stage was similar, we selected the representative policies. (2) The number of representative policy texts selected for each stage had to be no less than three and no more than six. Finally, 31 policy texts under the coal power crisis were selected (Table 3).

4.2. Establishment of the PMC index model

The policy modeling consistency (PMC) index model is a policy measurement model that aims to scientifically and quantitatively evaluate policies. This model can be used to analyze the internal consistency of a policy from various dimensions. Estrada (2011) believed that policy modeling is an academic or empirical research work that is supported by various theories and quantitative or qualitative models to scientifically evaluate the policies issued by society. Generally, the PMC index model is mainly composed of four parts: (1) variable selection; (2) building a multi-input output table; (3) measurement of the PMC index; and (4) construction of the PMC-Surface (see Fig. 4).

Table 3
Representative coal-power policies.

Item	Policy name (release agency)	Release time
P1	Notice on further improving the closure and consolidation of small coal mines and coal mine safety work (State Council)	2001.09.16
P2	Notice on the Release of the National Coal Production and Development Plan for 2003–2010 (State Economic and Trade Commission)	2003.01.14
P3	Notice on the regulation of the electricity market order to address the supply of electricity related issues (National Electricity Regulatory Commission)	2003.05.19
P29	Notice on the issuance of the Guidance on Energy Work in 2022 (State Council)	2022.01.30
P30	Notice on further improvement of the coal market price formation mechanism (Development and Reform Commission)	2022.02.24
P31	Opinions on improving institutional mechanisms and policy measures for green and low-carbon energy transition (National Energy Administration)	2022.03.17

Note: A total of 31 coal power policies were omitted due to space limitations.

4.2.1. Variable selection

Variable classification and parameter identification are the deep processing of texts on coal power policies in the period of the coal power crisis and the key steps before the quantitative evaluation of subsequent policies. This section is based on existing studies (Dong and Liu, 2020; Kuang et al., 2020) and improves the original PMC policy quantitative index evaluation system from three aspects: policy effectiveness level, regulatory scope and content coverage. The evaluation system has established three first-level indicators, policy intensity (S), policy perfection (P), and policy breadth (B), and nine second-level indicators, policy nature, policy timeliness, issuing institution, policy instrument, policy content, policy tendency, incentive method, policy domain, and policy object. In detail, policy intensity is distinguished from the basic characteristics of the policy, and policy perfection is reflected from three aspects of measure diversity: content coverage and policy orientation. Policy breadth is reflected in three aspects: guarantee comprehensiveness, field extensiveness and policy object. Combined with the actual situation of the policy text and with the help of the above policy text mining, the third-level indicators are determined, as shown in Table 4.

4.2.2. Building a multi-input–output table

Based on the coal power policy evaluation index system (Table 4), a multi-input–output table was established. The parameters of each third-level indicator were quantified by a binary algorithm. That is, when the policy meets the corresponding indicators, the value of the indicators is set as 1; if not, the value is 0. To avoid the errors of individual operations and ensure the accuracy of the assignment results, the above operations were carried out as evaluators and the input–output tables were completed. Except for a few indicators, the results are basically the same each time. According to the policy text and evaluation criteria, the sub-indicators are further checked and repeatedly discussed, and the final consistent values are maintained.

The multi-input–output table is the basic analytical framework for calculating the PMC index of the coal power policy. According to the basic principle of the PMC index model, 9 s-level indicators and 46 third-level indicators are set as equal weights, as shown in Table 5.

4.2.3. Measurement of PMC-index

The specific calculation steps are as follows:

Step 1. The second-level and third-level indicators are determined according to the established index evaluation system, and all the indicators involved are adjusted to the distribution suitable for [0,1]:

$$X - N[0,1] \tag{1}$$

Step 2. Distribution of PMC-Index. The third-level indicators identified in Step 1 are assigned using binary counting. If something related to a third-level variable appears in the policy text, it is otherwise encoded as 1 and 0. Then, the multi-input–output table is constructed.

Step 3. Calculation of the PMC-Index. According to Step 2, the scores of third-level indicators are added to each second-level variable in the following form:

$$X = \{XP; [0,1]\} \tag{2}$$

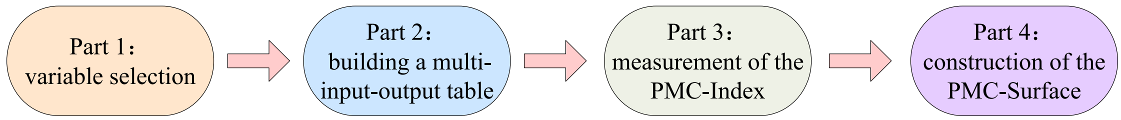

Fig. 4. Steps to build the PMC-Index model.

Table 4
Quantitative evaluation index system of the coal power policy.

Level indication	Aspects	Indicators
Policy strength	Policy nature X_1	$X_{1:1}$: prediction;
		$X_{1:2}$: supervision;
		$X_{1:3}$: suggestion;
		$X_{1:4}$: guidance
	Policy limitationX_2	$X_{2:1}$: long;
		$X_{2:2}$: temporary;
		$X_{2:3}$: mid-term;
		$X_{2:4}$: short-term
	Release agency X_3	$X_{3:1}$: State Council;
		$X_{3:2}$: National Energy Administration;
		$X_{3:3}$: Development and Reform Commission;
		$X_{3:4}$: National Electricity Regulatory Commission, etc.
Policy perfection	Policy instrumentX_4	supply side:
		$X_{4:1}$: technology information support;$X_{4:2}$: infrastructure construction;$X_{4:3}$: human resources training;
		$X_{4:4}$: public services;
		environmental side:
		$X_{4:5}$: target planning;$X_{4:6}$: restrict of the statute;
		$X_{4:7}$: tax incentives;$X_{4:8}$: financial support;
		demand side:
		$X_{4:9}$: demonstration construction;$X_{4:10}$: environmental awareness;
		$X_{4:11}$: regulatory constraints
	Policy content X_5	$X_{5:1}$: security management;
		$X_{5:2}$: coal power contracts;
		$X_{5:3}$: transportation management;
		$X_{5:4}$: price management
		$X_{5:5}$: innovative and efficient;
		$X_{5:6}$: green development
	Policy orientationX_6	$X_{6:1}$: support, encouragement;
		$X_{6:2}$: specification, regulation;
		$X_{6:3}$: strengthen, promote;
		$X_{6:4}$optimization, refinement
Policy breadth	Incentive methodX_7	$X_{7:1}$: tax deductions;
		$X_{7:2}$: platform construction;
		$X_{7:3}$: investment subsidy;
		$X_{7:4}$: legal protection
	Policy areaX_8	$X_{8:1}$: economy;
		$X_{8:2}$: social;
		$X_{8:3}$: technology;
		$X_{8:4}$: environment;
		$X_{8:5}$: politics
	Policy objectX_9	$X_{9:1}$: government departments;
		$X_{9:2}$: energy-consuming enterprises;
		$X_{9:3}$: production capacity companies;
		$X_{9:4}$: social public

$$X_t\left(\sum_{j=1}^{n}\frac{X_{tj}}{T(X_{tj})}\right)\quad t=1,2,\ldots,8,9 \tag{3}$$

where j is the ordinal number of the third-level variable, t is the ordinal number of the second-level variable, $T(X_{tj})$ is the number of third-level indicators under the second-level variable corresponding to t and n is the number of second-level indicators.

Step 4. The PMC-Index of a single policy is obtained by summing the values of the second-level indicators:

Table 5
The multi-input–output table for each policy.

Aspects	Indicators
X_1	$X_{1:1}, X_{1:2}, X_{1:3}, X_{1:4}$
X_2	$X_{2:1}, X_{2:2}, X_{2:3}, X_{2:4}$
X_3	$X_{3:1}, X_{3:2}, X_{3:3}, X_{3:4}$
X_4	$X_{4:1}, X_{4:2}, X_{4:3}, X_{4:4}, X_{4:5}, X_{4:6}, X_{4:7}, X_{4:8}, X_{4:9}, X_{4:10}, X_{4:11}$
X_5	$X_{5:1}, X_{5:2}, X_{5:3}, X_{5:4}, X_{5:5}, X_{5:6}$
X_6	$X_{6:1}, X_{6:2}, X_{6:3}, X_{6:4}$
X_7	$X_{7:1}, X_{7:2}, X_{7:3}, X_{7:4}$
X_8	$X_{8:1}, X_{8:2}, X_{8:3}, X_{8:4}, X_{8:5}$
X_9	$X_{9:1}, X_{9:2}, X_{9:3}, X_{9:4}$

Note: The multi-input–output table includes all indicators of each policy, with a total of 31 × 46 data points, which are omitted due to space limitations.

$$PMC=\begin{bmatrix} X_1\left(\sum_{i=1}^{5}\frac{X_{1i}}{5}\right)+X_2\left(\sum_{i=1}^{4}\frac{X_{2i}}{4}\right)+X_3\left(\sum_{i=1}^{3}\frac{X_{3i}}{4}\right) \\ X_4\left(\sum_{i=1}^{11}\frac{X_{4i}}{11}\right)+X_5\left(\sum_{i=1}^{5}\frac{X_{5i}}{6}\right)+X_6\left(\sum_{i=1}^{4}\frac{X_{6i}}{4}\right) \\ X_7\left(\sum_{i=1}^{4}\frac{X_{7i}}{4}\right)+X_8\left(\sum_{i=1}^{5}\frac{X_{8i}}{5}\right)+X_9\left(\sum_{i=1}^{4}\frac{X_{9i}}{4}\right) \end{bmatrix} \tag{4}$$

To further investigate coal power policy strength, perfection and breadth, the first-level indicators policy strength (S), policy perfection (P) and policy breadth (B) are calculated according to Eqs. (5), (6) and (7), respectively.

$$S(Policy\ Strength)=X_1+X_2+X_3 \tag{5}$$

$$P(Policy\ Perfection)=X_4+X_5+X_6 \tag{6}$$

$$B(Policy\ Breadth)=X_7+X_8+X_9 \tag{7}$$

Due to the 9 s-level indicators set in this study, the PMC-Index of the policies is to be investigated at [0, 9], and the PMC-Index reflect the comprehensiveness of the policies to different degrees. The larger the PMC-Index is, the more comprehensive the content of the policy text and the stronger the operability of the policy in practice. According to existing studies (Dong and Liu, 2020; Kuang et al., 2020), the PMC-Index of policies can be divided into four evaluation levels (Table 6). In particular, if the PMC-Index is between 0 and 2.50, then the policy will be valuated as a bad ranking policy. Policies that score between 2 and 3 are rated as good. If the score is between 4.01 and 5.50, it is considered an excellent policy. Finally, the policies with a score between 5.51 and 9.00 are perfect.

4.2.4. Construction of PMC surface

Using the PMC-Surface, which is a three-dimensional surface based on a 3 × 3 matrix shown in Eq. (8), the calculated PMC-Index can be shown more vividly and intuitively. The PMC-Surface can be determined by MATLAB software. The advantages and disadvantages of each policy

Table 6
Evaluation criteria of the PMC-Index of a policy.

PMC index values	0–2.50	2.51–4.00	4.01–5.50	5.51–9.00
Evaluation levels	Bad	Good	Excellent	Perfect

can be judged based on the color and the concave-convex degree of the surface.

$$PMC = \begin{bmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{bmatrix} \tag{8}$$

The PMC index model provides a new way of thinking and perspective for quantitative policy evaluation. Different from previous evaluation models, this model is based on the Omnia Mobiliz hypothesis as the guiding ideology. Omnia Mobiliz assumes that everything in the world is moving and connected, so we should not ignore any of the relevant variables or assume that they are unimportant. Therefore, the PMC index model comprehensively takes into account every variable to conduct a reasonable quantitative evaluation of the policy itself. In addition, the PMC-Index and PMC-Surface show the overall evaluation of the policy and the specific situation of each individual policy, which is objective compared with the subjective policy quantitative method of expert rating.

5. Result analysis

5.1. Overall evaluation of the policy

Based on the above evaluation framework of coal power policies and referring to Mario Arturo Ruiz Estrada's scoring standard, the PMC index and policy grade of each policy are calculated, as shown in Fig. 5 below. On the whole, the policies during the coal power crisis are in a good state, which presents the characteristics of a diversified policy field and policy instruments. The average PMC index of coal power policies is 4.40; specifically, the policy texts of "Excellent" level or above account for 61.68 %, the policy texts of "Good" level account for 35 %, and the policy texts of "Perfect" and "Bad" levels account for 9.68 % and 3.23 %, respectively. The policies cover a wide range of areas, including economy, society, environment, science and technology. There are various types of policy instruments, including supply policy instruments that promote the coal power industry (such as human resources training, scientific and technological information support, etc.), environmental policy instruments that indirectly affect the developmental environment of the coal power industry (such as tax incentives, target planning, etc.) and demand policy instruments that stabilize the coal power market by adopting measures such as demonstration construction.

(1) The issuing units of coal power policies are dominated by a single department, and the degree of coordination between departments needs to be strengthened. During the coal power crisis, only P2, P5, P15, and P17 were jointly issued, while other policies were issued by separate departments. The coal power market management system involves multiple links, such as coal power storage, emergency response, price adjustment and transportation management. The diversified mode is generated, where the highest decision-making level is the State Council, with the Energy Administration comprehensively managing the coal power industry and the National Development and Reform Commission promoting market-oriented reform of the coal power industry. In addition, ministries and commissions, such as the Ministry of Environmental Protection, the Ministry of Commerce, the Ministry of Finance and the State Electricity Regulatory Commission, participate in management strategies according to their respective functions. Furthermore, the findings of Chen et al. (2022) also corroborate this perspective; they sorted out the objects of electricity policy issuance and found that the current power market management system belongs to the ministries participating in the management strategies according to their respective functions. However, in the complex background of the coal power crisis, the "subdivided" management mode easily makes it difficult for all policies to form synergies, resulting in poor coordination of departmental responsibilities, the coexistence of decentralized use of resources and repeated investment, and even affecting the implementation effect of policies.

(2) The policy system mainly focuses on suggestion $X_{1:3}$ and guidance $X_{1:4}$ but lacks prediction $X_{1:1}$. Combined with the policy provisions, the government mainly guides the transformation and upgrading of coal power units, the optimization and upgrading of the coal production structure, and the increase in preferential credit for the coal power industry but pays little attention to the early warning mechanism of the coal power supply. Especially in the coal power shortage environment, the lack of early warning ability will lead to policy planning errors and further trigger the coal power crisis. For example, in 2003, the China Power Enterprises Association[1] predicted that the growth of China's electricity demand would be 9 % ~ 10 %, but the actual growth of the whole society's electricity consumption increased by 15.58 %. Therefore, the original power supply growth rate of the policy plan was far behind, resulting in the short supply of electricity.

5.2. Policy analysis and comparison under the life cycle of crisis

Based on the PMC index model, comparative radar charts of policy indicators in different stages of the crisis cycle are constructed (Figs. 6 and 7). Figs. 6 and 7 show that with the evolution of the crisis, the government's policy orientation differs at various crisis stages.

5.2.1. Policies during the gestation period

During the gestation period, the policy orientation is command-control oriented. A total of 59 policy instruments are used in this period, forming a policy instrument usage structure mainly based on target planning and regulatory constraints. According to the data, the total proportion of target planning $X_{4:5}$ and regulatory constraints $X_{4:11}$ is approximately 37.30 %, with a lack of policy instruments related to demonstration construction $X_{4:9}$ (3.39 %) and tax incentives $X_{4:7}$ (5.85 %). The policy orientation mainly regards specification and regulation $X_{6:2}$. This characteristic of the gestation period is due to the influence of mandatory programming at the national level. For example, in 2009 (the gestation period of the second coal power crisis), mainly due to the influence of the policy of "developing large units and suppressing small ones" and the binding targets of energy conservation and emission reduction in the 11th Five-Year Plan, a number of small thermal power units were forced to shut down, with a total scale of 26.17 million kW.[2] Mandatory policies can regulate and adjust market entity behavior and market competition order. Although these policies play a guiding role, they may also have a reverse effect due to the lack of power. Thus, Hypothesis 1 is supported.

5.2.2. Policies during the explosive period

During the explosive of crises, the government mainly implements the price adjustment mechanism to alleviate the supply-demand gap and relies on the participation of all members of society in energy crisis management. Specifically, a total of 35 policy instruments are used in this period, among which public service $X_{4:4}$ takes the largest proportion, accounting for 25.7 %. Most of the policy contents involve price management $X_{5:4}$, indicating that the government uses the price mechanism and other short-term measures to meet the development needs of the coal power industry and the direct needs of citizens' social activities. The price mechanism is a sensitive adjustment mechanism that can guide production and consumption. Additionally, it can adjust the reasonable allocation of resources, especially in the context of intensified market volatility and rapid shortages of coal power during the explosive period, whereas other adjustment mechanisms are a long-term

[1] https://jjsb.cet.com.cn/show_103491.html.

[2] http://www.nea.gov.cn/2010-07/13/c_131054774.htm.

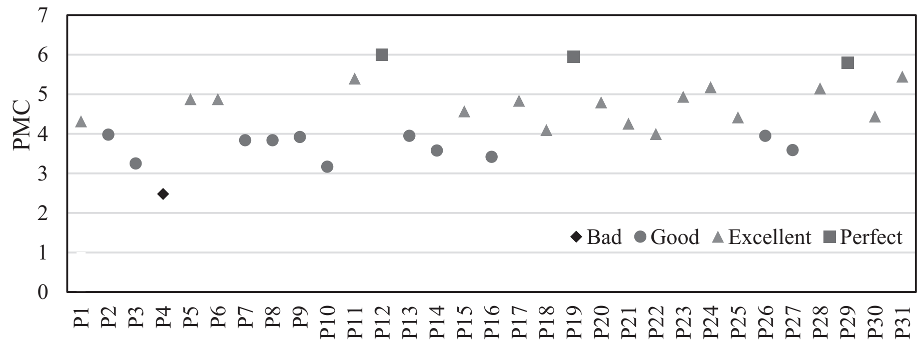

Fig. 5. PMC-Index scatter plot of 31 coal power policies during coal power crises.
Note: Created by the author based on the calculated policy PMC-Index.

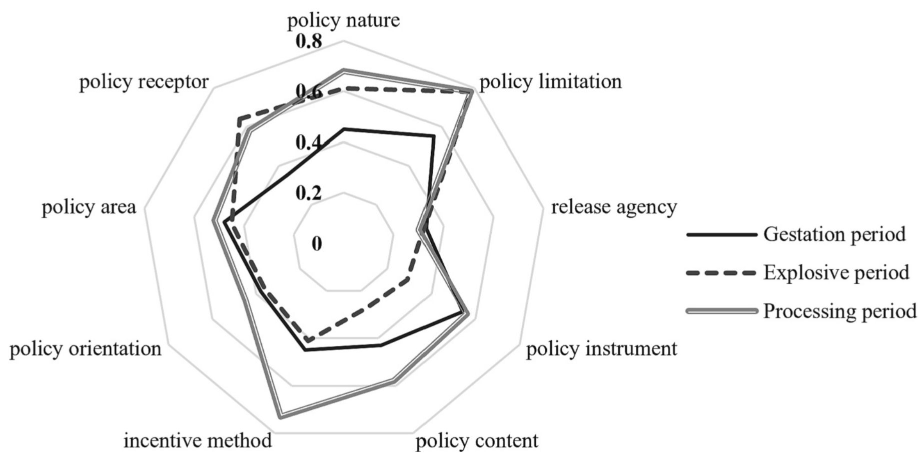

Fig. 6. Comparative diagram of second level indicators under different stages.
Note: Created by the author based on the calculated policy PMC-Index.

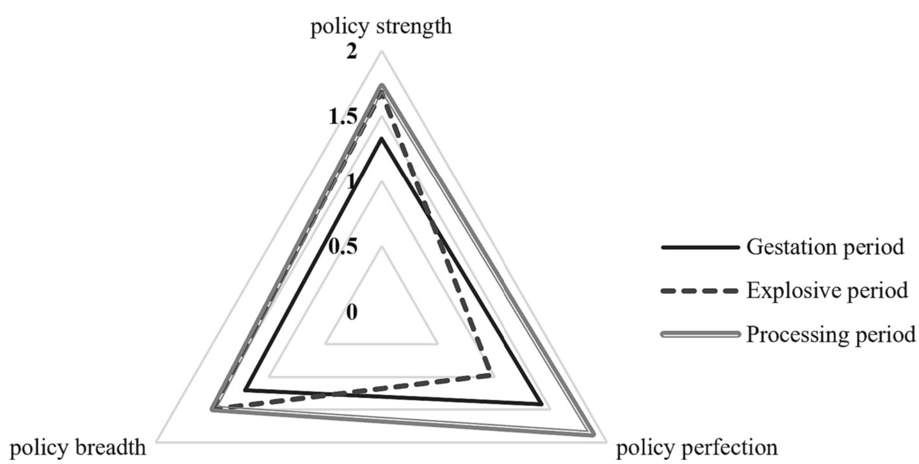

Fig. 7. Comparative diagram of first level indicators under different stages.
Note: Created by the author based on the calculated policy PMC-Index.

asymptotic process. Therefore, a variety of temporary price intervention measures have become the government's preferred countermeasures during the explosive of crises, such as upstream power coal price control, coal-power price linkage mechanism and floating electricity prices. Wang et al. (2017) also found that the tiered electricity pricing is often adopted during the power shortage period. However, in actual implementation, the effect of price control may not be obvious. For example, during the first coal power crisis, the coal-power price linkage mechanism attempted to automatically transmit the cost of electricity-coal. However, due to the constraints of macroeconomic operation, the coal-power price linkage mechanism was not timely, and the adjustment of electricity prices was not sufficient, which eventually led to the distortion of price signal transmission. Second, the coal power crisis is characterized by destructiveness and urgency, and the power of the price control mechanism is limited. Therefore, the policies during the explosive period act on multiple subjects, and the targets are relatively specific, including coal power enterprises $X_{9:2}$, $X_{9:3}$ (47.61 %), the general public $X_{9:4}$ (16.67 %) and various supervisory and management departments $X_{9:1}$ (42.86 %). Therefore, mobilizing all sectors of society to actively carry out energy conservation and consumption reduction work together and regard it as a long-term strategic task is necessary.

5.2.3. Policies during the processing periods

During the crisis processing period, the government strengthens the use of supply-oriented policy instruments and attaches importance to the development and utilization of the coal power industry. In this period, the government uses 62 policy instruments, increasing the use of supply-oriented policy instruments such as infrastructure construction $X_{4:9}$ (22.58 %) and human resources training $X_{4:9}$ (8.65 %). That is, the industry is adjusted from the aspects of optimizing power grid construction and post management of coal power enterprises. According to the data provided by the State Grid, the power infrastructure investment in the gestation period lags behind the national infrastructure investment, and the price mechanism adopted in the explosive period can only have a certain effect for a short period of time and cannot solve the problem of coal power shortage. Therefore, during the crisis processing period, the government strengthens supply-oriented policies, providing capital investment, personnel training, facility construction and other related elements. This can not only reduce transaction costs and stabilize the fuel supply of thermal power units but also result in the establishment of a coal trading market to improve information transparency and even eliminate risks. Furthermore, strengthening supply-oriented policies causes a large-scale coal system to smooth market fluctuations and finally results in the structural adjustment of energy demand in the industry.

In conclusion, according to the different periods of the coal power crisis, the government adopts different regulatory policies. The gestation period mainly adopts the means of target planning and legal constraints, which can regulate the market but also have the opposite effect; during the explosive period, the price mechanism and the multisubject governance mechanism are used to intervene in crises; during the crisis processing period, the use frequency of supply-oriented policy instruments such as infrastructure construction and human resource training is significantly strengthened. Therefore, Hypothesis 2 in this paper is supported.

5.3. Policy analysis and comparison under three crises

To show the policy changes during the three crises, comparative radar maps of policy indicators during the three crises are constructed based on the PMC index model (Figs. 8 and 9). In the three coal power crises, the coal power policy system went through three stages: safe production, industrial structure adjustment, and green and efficient development. The main body of crisis response shifts from government-led to government-enterprise-led and then to government-enterprise and the general public. In addition, the frequency and intensity of the implementation of supply policy instruments show signs of increasing, gradually evolving from authority and coercion to incentive and systematic reform instruments.

5.3.1. Policies during the first coal power crisis

During the first coal power crisis, the main body dealing with the crisis is the government, which mainly uses policy instruments such as the restriction of the statute $X_{4:6}$ (15.52 %) and regulatory constraints $X_{4:11}$ (15.52 %) to conduct safety supervision in the coal power industry. The reasons are as follows: after the Asian financial crisis, China gradually moved to the development mode as a "world factory", the demand for electricity increased rapidly in a short time, and then the coal power industry entered the stage of unprecedented rapid development. However, at the same time, ultraroutine production and construction have led to frequent safety accidents, so the safe production of coal mines has received more attention. Therefore, the government has strengthened the supervision and constraint in the coal power industry, requiring coal mining enterprises to carry out safe production procedures in strict accordance with laws and administrative regulations. Second, the score of the policy object X_9 is 0.48, and the government regulation $X_{9:1}$ accounts for 39.13 %. Thus, it can be seen that the government dominates and leads the development of the coal power industry, which is in an absolute position in the development of industrial policies in this period. At this time, the central policies are mostly macrostrategic guidance policies, focusing on the planning and development goals of the coal power industry.

5.3.2. Policies during the second coal power crisis

The second coal power crisis management mainly relies on the concerted efforts of government enterprises, and the overall policies are to adjust the structure of the coal power industry in accordance with the principle of "integration as the main, new construction as the auxiliary". New progress has been made in the development of the coal power industry, which calls for the coordination of the construction of new large coal bases, promoting the rectification of coal bases and resource integration. Therefore, compared with the first crisis, the proportion of supply policy instruments increased from 39.65 % to 41.00 %, mainly increasing the use of policy instruments such as infrastructure construction $X_{4:2}$. The implementation of supply-oriented policy

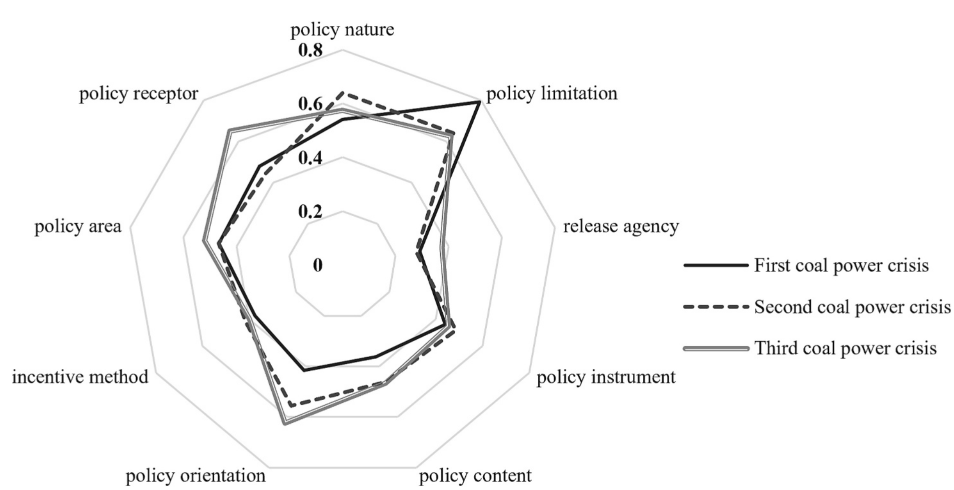

Fig. 8. Comparative of second-level indicators under three crises.
Note: Created by the author based on the calculated policy PMC-Index.

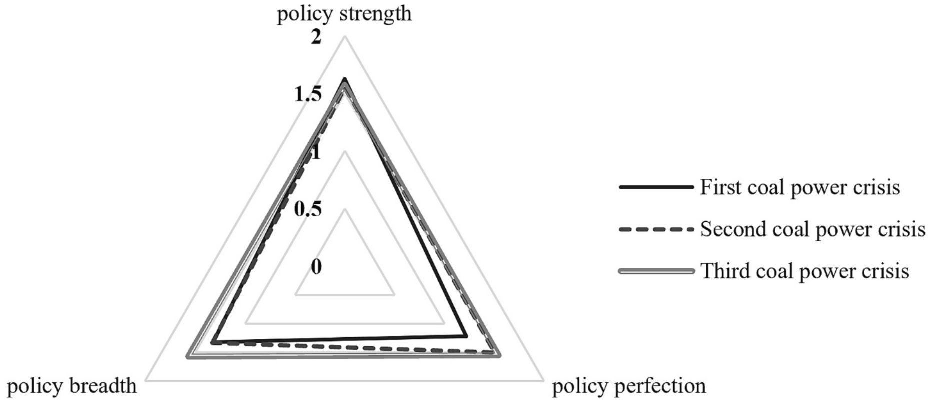

Fig. 9. Comparative of first-level indicators under three crises.
Note: Created by the author based on the calculated policy PMC-Index.

instruments can merge and reorganize coal enterprises, promote the withdrawal of excess capacity effectively, propel technological progress and upgrading, and result in the optimal allocation of coal resources. Second, the score of the policy object X_9 is 0.48, and the objects are mainly the government and coal power enterprises. On the one hand, the government should strengthen the production safety of coal power through various channels, and on the other hand, enterprises should actively carry out mergers and reorganizations to eliminate backward production capacity.

5.3.3. Policies during the third coal power crisis

During the third coal power crisis, the government encourages key technology research to achieve green and low-carbon energy transformation and then gradually formed a multisubject governance mechanism. With the promotion of cleaner production, especially since the "Five Concepts for Development" were put forward in November 2015. "Green" is taken as a necessary condition for sustainable development, and the technical policy orientation of the coal power industry during the third crisis has begun to favor green development and innovation. Although the policy content X_5 involved green development and innovation accounts for 47.83 %, problems have also been highlighted, such as the high dependence of energy technology equipment on foreign countries and the imperfect policy mechanism of technological innovation in the coal power industry. Therefore, the government encourages the integration of more technology information support $X_{4:1}$ into the coal power industry (such as safe and efficient energy storage technology and intelligent coal mining technology). Furthermore, the implementation frequency and intensity of supply policy instruments are constantly increasing (the proportion of such policy instruments increases to 46 %), which makes the development mode of the coal power industry orderly turn to green innovation and sustainable development. However, compared with China's wind power industry, its supply-oriented policy instruments are rarely used, which is not conducive to the sustainable development of wind power industry (Wang and Xing, 2022).

In addition, the power shortage is increasingly urgent for the demand side, and the score of the policy object X_9 in the third coal power crisis increases to 0.65; therefore, the proportion of the public $X_{9:4}$ increased from 12.50 % in the second crisis to 19.24 %. Adjusting the electricity structure, optimizing electricity behavior, and reducing electricity intensity not only rely on the government and coal power enterprises but also require the participation and acceptance of the whole society. The main body of crisis response has changed from government-led to a combination of government-, enterprises- and public-led, forming a new multisubject governance mechanism. Therefore, the above analysis is basically verified and Hypothesis 3 is supported.

6. Discussion

Based on the above research results, further discussion will be conducted from the perspectives of policy instruments, sustainable development of energy, government governance and the public.

First, China's coal power industry is faced with severe challenges such as ensuring safety, transforming modes, adjusting the structure and making up for weaknesses, which are essentially due to the insufficient level of scientific and technological innovation (Zhu et al., 2022). Therefore, the following is proposed. (1) Increase the support for low-carbon power technology, implement the iterative upgrading of smart grid technology, and focus on the development of customizable, scalable, system-friendly power grid technology that can use various energy sources and multiple loads (Poudyal et al., 2022). (2) Comprehensively promote the innovation of hydrogen energy technology, vigorously develop efficient and low-energy carbon capture technology and carbon recycling technology, etc., so as to ensure the sustainable coordination of a low-carbon energy transition and ecological environment (Kyriakopoulos, 2021).

Second, the coal power policy is mainly reflected in the guidance, suggestions and supervision. The effectiveness of early warning and forecasting is relatively low given that it is not timely and does not take into account the daily operation mechanism of energy supply and demand monitoring. Therefore, that the following is advised: (1) establish early warning standards for supply and demand balance at all levels (including coal power reserve, coal power demand growth, coal power production capacity, etc.) to trigger emergency measures when the early warning standards are reached (Wu et al., 2022). At the same time, the early warning system should be based on the domestic and foreign economic and energy supply and demand situation, covering the medium and long-term rolling warning of 3 to 5 years and the short-term rolling warning of 3 to 12 months (Liu et al., 2020). (2) Based on the experience of other countries or regions, factors such as coal power production, consumption, supply and demand elasticity and external dependence that affect the scale of coal power reserves should also be comprehensively considered, and a regular monitoring mechanism for the peak-valley fluctuation of coal power demand should be established (Kim et al., 2020).

Third, there is a lack of effective coordination among various departments, and problems such as loopholes and untimely supervision arise (Li et al., 2021). Therefore, that the following is advised. (1) Establish a cross-departmental information and data sharing platform so that all departments can share the latest energy market information and resource distribution (Larsen et al., 2014). (2) Analyze and position the four links of "generation, transmission, distribution and sale" in the coal power market, clarify the regulatory subjects of transmission and distribution networks under different models, and resolve the conflicts of interest between the subjects (Larsen et al., 2014).

Fourth, the scope of the coal power policy is narrow, resulting in low public participation. Therefore, the following is advised. (1) Establish incentives, such as the selection of excellent energy efficiency enterprises and environmental awareness training to encourage the public and enterprises to participate in energy governance (Helm and Mier, 2021). (2) Expand the beneficiaries of the policy, for example, provide assistance to energy-poor households in the form of tax relief (VAT) and implement financial subsidies and tax transfer payments for enterprises with electricity difficulties (Streimikiene et al., 2021).

7. Conclusions

In the process of green energy transformation, crises occur frequently. Scientific quantification and evaluation of policies can reflect the regulatory effect of government policies during an energy crisis. At the same time, it also has important theoretical guiding significance for building energy power and ensuring sustainable energy development on a national scale (Streimikiene and Kyriakopoulos, 2023). Therefore, from the perspective of crisis management, this paper proposes the concept of the coal power crisis life cycle, which is divided into the gestation period, explosive period and processing period. Taking a series of policies released in three major coal power crises in China as examples, this paper supplements the text mining theory and content analysis to construct the PMC index model of coal power policy. Finally, we quantitatively analyze the evolution of the coal power policy system from the perspective of crisis. The empirical results show that first, the overall design of the coal power policy is relatively reasonable to implement during a coal power crisis. However, there are some problems to be improved, such as the coordination capacity of departments and the early-warning mechanism of coal power supply-demand. Second, depending on the period of coal power crisis, the government adopted different regulation policies. Specifically, during the gestation period, mandatory policies such as target planning and legal constraints are the main means of response. They can serve as a “direction guide”, but may lead to power supply gap and thus a coal power crisis. During the explosive period, the government mainly implements price regulation to change the relationship between energy supply and demand. In the processing period, the government strengthens the implementation of supply-oriented policies to restructure the energy demand industry. Third, in the three coal power crises policy evolution process, supply policy instruments and multisubject governance mechanisms have become the primary means to address the coal power crisis.

However, some limitations of this study should be mentioned. First, in the selection of indicators for policy quantification, in terms of index selection, the determination of policy content variables is subjective to a certain extent. In future research, methods such as bibliometric analysis, basic theory coding and big data analysis can be combined to optimize a method. Secondly, the analysis of the implementation effect or performance of the coal power policy is not deep enough, and the indicators such as energy supply and demand balance, environmental impact, economic benefits and other aspects are not considered in the evaluation of the actual efficiency of the policy in more detail. In the future, the econometric analysis method DSGE macroeconomic model and DID econometric model can be used for further exploration. Finally, the energy crisis is a global issue and is relevant in different countries, but the stage division of the energy crisis only considers the domestic impact of the crisis, without starting from the global impact. Therefore, we need to explore the division of the energy crisis and response policies from a wider perspective, for example, including countries with energy import and export relations with China.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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