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How does institutional support affect the coalbed methane industry?

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Accelerating the construction of a low-carbon, safe, and modern energy system is becoming a critical developmental path toward solving the climate change problem. China provides institutional support in various ways for this clean and efficient new energy, but there is still a gap between the developmental scale and the planned target. Considering the theory of system support and the coalbed methane industry, we combed the existing institutional support for the coalbed methane industry based on grounded theory and defined the initial model. We used the system dynamics method to construct and simulate the model and verified the system's effectiveness by using the goodness of fit. The results show that institutional support promotes the development of the coalbed methane industry, and the interaction between the two forms a dynamic system. Based on the sensitivity analysis method, the enlightenment of the management with respect to the improvement of the development of the coalbed methane industry was obtained. Firstly, the management of coalbed methane mining rights should be supervised and large-scale utilization should be strengthened. Secondly, the central government's subsidies should be raised and local governments should be encouraged to provide support. Thirdly, technological innovation should be enhanced and fair competition should be ensured.

KEYWORDS

institutional support, coalbed methane industry, grounded theory, system dynamics, goodness of fit

1 Introduction

Faced with the increasingly severe global climate change situation, China has been implementing the "carbon peaking and carbon neutral" initiative to actively promote the green transformation of energy production. As a clean and efficient new energy source, the development and utilization of coalbed methane have safety and environmental effects. They are important for the optimization of the energy structure, promotion of economic growth, creation of jobs, and promotion of the healthy and sustainable development of the energy industry. However, China's coalbed methane exploration and development are still in their initial stage of development, and the upstream, midstream, and downstream links of the industrial chain have absorbed many stakeholders. The opportunities and challenges facing the development have new characteristics, and the relevant system is still not perfect. Institutions such as laws, formal contracts, and regulations are considered soft market infrastructures (Peng and Luo, 2000). The absence of reliable institutions can create institutional weaknesses that negatively affect the market; however, institutional support can reduce the impact (Doh and Kim, 2014). To promote the development of the coalbed methane industry, national and local governments have formulated and implemented a series of institutional supports, achieving some results, but there are still certain gaps between the planned goals. China is one of the world's major energy producers and consumers. It is valuable to study how institutional support affects the coalbed methane industry in China to promote the sustainable development of global energy.

We found few studies on the coalbed methane system in the literature. In view of the problems existing in the development of deep coalbed methane, Fan, Wang, and Song proposed a balanced differential subsidy mechanism for enterprises, and they held that the unit subsidy for deep resources should be more than that for shallow resources (Lurong et al., 2023). Mosayebi and Grall's studies on coalbed methane policy and its impact on repair efficiency found a way to reduce maintenance costs (Omshi and Grall, 2021). The relevant studies mainly focused on case studies and technological development. Considering the development of coalbed methane in the Yangquan mining area as an example, Linghu, Chen, and Yan established a model for predicting the monthly demand for coalbed methane and investigated the change in demand under the influence of COVID-19 (Linghu et al., 2020). Wen et al. (2019) summarized the technologies and achievements of China National Petroleum Corporation's coalbed methane exploration and development, analyzed the opportunities and challenges in the development process, and proposed five major research directions to accelerate the development of the coalbed methane industry. Sugata and Saurabh constructed a geological model of the coalbed methane recovery process using the Jharia coalfield in India as a case study (Kumar and Datta, 2021). Li et al. combined the core ideas of machine learning algorithms, coal body deformation mechanisms, and critical layer theory to establish a prediction method for identifying the texture of coal. Their study has had an important influence on the exploration and development of coalbed methane (Cunlei et al., 2022). Other studies on institutional support for unconventional gas have mostly focused on shale gas, and some scholars have proposed policy recommendations in terms of exploring geological resources, sound market mechanisms, environmental protection, etc. Yu et al. (2018) proposed macro-level recommendations for coping with environmental protection by comparing shale gas policy systems. Wu et al. simulated competition in the shale gas industry under scenarios of technology, cost, and subsidies (Yunna et al., 2015). Most relevant research focuses on enterprises, macro theory, and qualitative research. However, when it comes to industry, it is only studied as an environmental component, and there is a lack of targeted in-depth analysis in the industrial field.

The theoretical study of institutional support affecting the coalbed methane industry is insufficient. According to the results of in-depth interviews, we construct a conceptual model based on grounded theory. Grounded theory is a qualitative study based on inductive data. Its core is to collect and analyze data using scientific and standardized operational procedures, which is suitable for theoretical construction (Glaser, 2004; Wang et al., 2020). Based on the conceptual model, we applied the system dynamics method to construct an institutional support system model for the coalbed methane industry. There is a non-linear feedback relationship between institutional support and the coalbed methane industry, which constitutes a complex system. The system involves various of influencing elements, some of which are difficult to quantify. System dynamics can better solve this problem by examining the role of decision-making and feedback relationships in the system through computer simulation (Forrester, 1958; Ross and Chang, 2021; Shal and Laberiano, 2021). Finally, we used the goodness of fit method to investigate the fitting degree of the simulation data and the actual value and verified the validity of the system model (Pinto and Sooriyarachchi, 2021; Shalabh, 2021). Through the combination of qualitative and quantitative research, we discussed the internal influence of institutional support on the coalbed methane industry. We conducted simulations with the aim of expanding the scope and methods of institutional support research, optimizing the combination of institutional supports to promote the development of the coalbed methane industry, and providing a reference for developing new energy.

2 Theoretical analysis

2.1 Institutional support

As an important part of institutional theory, institutional support has received much attention from scholars. Xin and Pearce (1996) defined institutional support as an important resource that the government provides to firms and classified institutional support into two dimensions: formal institutional support and informal institutional support . Formal institutional support refers to the various types of formal support provided by a state administration to enterprises to reduce the negative effects of imperfect market mechanisms. These support policies are regulatory institutional support, including government subsidies, tax breaks, support for building alliances, intellectual property protection, etc., which some scholars also refer to as government institutional support (Shu et al., 2015). Informal institutional support refers to the support provided by institutional agents such as the government through a firm's efforts to establish political ties and, thus, the relationship between the firm and the government. Similarly to most scholars, we support this view. Li and Atuahene-Gima (2001a) studied the impacts of political connections between organizations and governments on organizations by comparing formal and informal institutional support. Tellis et al. (2009) suggested that governments should provide innovative firms with certain tax breaks, R&D subsidies, etc. to avoid unreasonable costs and risks in promoting the development of firms. Peng argued that institutional support promotes business development but is often arbitrary and artificially manipulable, triggering political behavior or unhealthy competition among firms (Peng et al., 2009).

Most current institutional-support-related research highlights the role of external institutional support from the government and its impact on firm structure, strategy, and behavior and less frequently examines the impact of institutional support on the industry. Focusing on the government as a non-market force, we looked at the impacts of formal and informal institutional support on the development of the coalbed methane industry.

2.2 Coalbed methane industry

An industry is a collection of enterprises or organizations with similar attributes, and this paper defines the coalbed methane industry as a collection of enterprises engaged in coalbed methane exploration, development, and production. China is rich in coalbed methane resources. According to a government work report, there are 114 gas-bearing zones in the country. The coalbed gas area that is <2,000 m is 415,000 square kilometers. The prospective resources make up 36.81 trillion cubic meters, equivalent to the conventional natural gas resources on land and ranking among the top three in the world. More than 100 favorable exploration target areas have been evaluated at present, and more than 10 rich target areas with resources of 1,000 × 10^8–7,000 × 10^8 m^3 have been selected. Some authors predict that the surface production of coalbed methane in China will increase steadily and annually (Bo and Hui, 2021), providing a solid foundation for industrializing coalbed methane in China.

Demand is the fundamental driving force behind the industrialization of coalbed methane. China has been a net importer of crude oil since 1993 and a net importer of natural gas since 2007, and its imports of natural gas are rising rapidly. With the rapid development of the national economy, the energy supply situation has become increasingly tight, with oil and natural gas being particularly prominent. From the perspective of energy demand and energy security, China must develop and utilize new energy sources to continue its rapid economic growth, and the coalbed methane industry is one of the best choices.

2.3 Institutional support and the coalbed methane industry

2.3.1 Research design

The United States was the first country to develop and utilize coalbed methane, providing much experience in policy support, key technology breakthroughs, and infrastructure construction for coalbed methane development. Australia, Canada, the United Kingdom, and Germany have all introduced legal and fiscal incentives for developing and utilizing coalbed methane resources and have regulated the management of coalbed methane exploitation. To solve energy supply problems and ensure coal mine safety, China attaches great importance to coalbed methane development and utilization and has provided institutional support in various ways.

Grounded theory summarizes concepts from the original data and generates theories through step-by-step coding. The concepts are interrelated to form a unified, intrinsically linked whole (Critical, 2019). This method can overcome the shortcomings of the lack of a normative process of other qualitative methods, so it is widely used (Estrada et al., 2021; Xie et al., 2021). The existing theoretical framework in related research is still not perfect, and the grounded theory has a scientific and standardized operation process. The generation of the theory is rooted in real data, which helps produce a realistic and robust theory (Strauss and Corbin, 1990). Therefore, this study uses grounded theory for its analysis. Through in-depth interviews, the institutional support affecting the development of the coalbed methane industry was investigated. The respondents included relevant practitioners and researchers in the coalbed methane industry. According to Fassinger's study, a sample size of 20–30 is appropriate (Fassinger, 2005). This study draws on the experience of research in grounded theory, and 30 people were selected as the survey objects to ensure the theoretical saturation of the sample. The questions are based on the questionnaires of Li and Atuahene-Gima (2001b) and Peng and Luo (2000). These included the following: "What do you think of the policies and projects provided by the government that are conducive to the development of companies or industries? What do you think of the technical information and technical support provided by the government? What do you think of the current fiscal policy in favor of the company or industry development? Do you think a good relationship between the company and the government is beneficial to the development of the company or industry?". In order to ensure the reliability of the database, a sample return visit was conducted based on a preliminary collation of the collected data, and the required data were supplemented in a targeted manner according to the literature. Twenty-five interview records were randomly selected for coding analysis, and the remaining five were used for testing. Finally, data analysis was conducted by using open coding, spindle coding, and selective coding.

2.3.2 Data analysis

2.3.2.1 Open coding

Open coding is the initial step in theory formation through the examination of data row by row and the definition of events. Based on an analysis of sentences or paragraphs, the collected interview materials are initially processed to carry out conceptualization and categorization. Conceptualization refers to selecting or creating concepts that best reflect the nature of the original material. Categorization refers to abstract concepts that are higher than general concepts in a hierarchical structure. By excavating and collating in-depth interview records and literature, the initial concepts with less than two occurrences were eliminated, and finally, 13 concepts and 13 categories were abstracted, as shown in Table 1.

2.3.2.2 Axial coding

Spindle coding is a process of linking the categories obtained in open coding by using a coding model, that is, "causality → phenomenon → context → condition → strategy → result". In order to ensure comprehensive coding, through cluster analysis, we divided our study into the open coding data and the associated category in order to establish more general categories. Six main categories were summarized according to the relationships between the different categories: formal institutional support, informal institutional support, disposable funds, profits, fair competition, and the coalbed methane industry. The canonical model is shown in Figure 1.

2.3.2.3 Selective decoding

Selective coding involves selecting core categories and establishing connections based on the concepts and categories that already exist in a system analysis. Incomplete categories in the conceptualization are supplemented by verifying the relationships between the core category and the other categories. All of the categories in this study were derived from China's 13th Five-Year Plan and in-depth interview reports. The relationships are shown in Figure 2, with the coalbed methane industry as the core category. On the one hand, the government provides formal institutional support for the development of the coalbed methane industry in five ways: priority, financial subsidies, cost reduction, tax incentives, and property rights protection. They increase the disposable funds of enterprises, which is conducive to the expansion of reproduction and an increase in profits. Property rights protection promotes the innovation of coalbed methane technology, reduces enterprise costs, and expands profit margins. On the other hand, the government provides informal institutional support for the coalbed methane industry. A good corporate political relationship between enterprises and the government will promote more policy tilt, accelerate technological innovation, reduce costs,

TABLE 1 Axial coding of institutional support for the coalbed methane industry.

Scope	Initial concept
Priority	The priority of coalbed methane enterprises in the process of exploration, development, extraction, and utilization
Financial subsidies	Government financial subsidies for the coalbed methane industry, including civil subsidies, development and utilization subsidies, and central financial funds, are used to promote the development and utilization of coalbed methane and the transformation of safety technology
Cost relief	The cost of coalbed methane in the process of exploration and development is reduced or exempted
Tax incentives	Coalbed methane enterprises' tax incentives, including tariffs, value-added tax, corporate income tax, and resource tax
Property rights protection	Improvement of the industrial intellectual property protection system, building R&D innovation centers, increasing the transfer of scientific and technological achievements, and demonstration of industrial applications
Corporate political relations	Support for and tilting of industrial policy, resource allocation, government orders, and other aspects
Coalbed methane production	The amount of coalbed methane extraction includes surface drilling and underground gas drainage
Coalbed methane utilization	The quantitative value of coalbed methane use includes pipeline gas, compressed natural gas (CNG), liquefied natural gas (LNG), low-concentration gas, and wind power generation
Disposable capital	Funds available for profit distribution, technical research, and expanded reproduction of coalbed methane enterprises
Technological innovation	The innovation of technical means in each link of coalbed methane exploration, development, storage, transportation, and final utilization can maximize the economic, social, and environmental benefits of the industry
Fair competition	Coalbed methane enterprises jointly accept the role and evaluation of the law of value and survival of the fittest under the same market conditions and realize the specialized production and enterprise management of coalbed methane
Cost	The average cost of mining per cubic meter of coalbed methane
Coalbed methane sales price	The average price of selling coalbed methane is determined by the negotiation between the supply and demand sides or by maintaining a reasonable ratio of the equivalent calorific value of alternative fuels

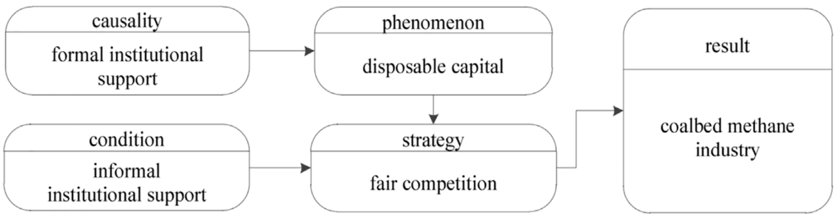

FIGURE 1
Canonical model of institutional support for the coalbed methane industry.

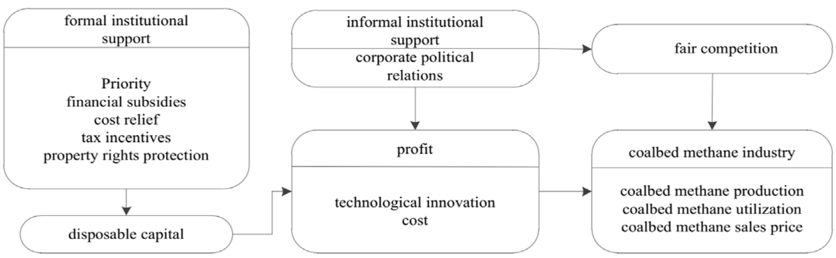

FIGURE 2
Initial model of institutional support for the coalbed methane industry.

and enable enterprises to obtain more profits, affecting fair competition. Increased profit will attract more enterprises to enter the coalbed methane industry, promote the increase in coalbed methane production and utilization, reduce the sales price, and promote the development of the coalbed methane industry. Fair competition will play a negative role in industrial development.

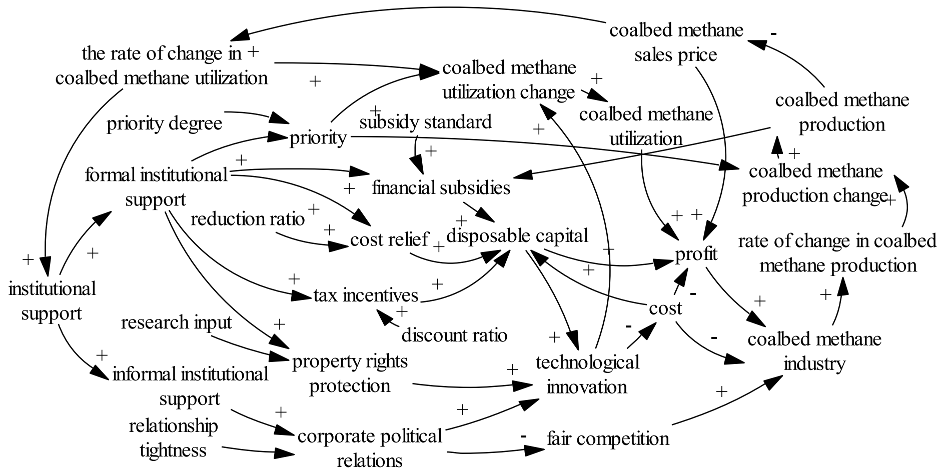

FIGURE 3
Systematic causality analysis.

3 System model construction

3.1 Basic system assumptions

Based on the theory of system feedback control, system dynamics is an applied discipline that uses computer simulation technology to study the dynamic behavior of system development qualitatively and quantitatively (Forrester, 1958). It is an effective method for analyzing complex systems (Morales and Andrade-Arenas, 2021). There is an information feedback relationship between institutional support and the coalbed methane industry that conforms to the modeling conditions of system dynamics. Moreover, using the system dynamics method to study system structure and behavior helps in thoroughly analyzing the dynamic evolutionary relationships between the internal mechanisms of the system. Therefore, the system dynamics method is suitable for analyzing the relationship between institutional support and the development of the coalbed methane industry. The influencing factors involved in the system and their correlations are complex. Therefore, we simplified the system and determined three basic assumptions.

H1. *The system model only considers the impacts of major variables on the coalbed methane industry.*

H2. *The relationships between some system variables and other system variables arenot significant and are set as constants.*

H3. *Each variable of the system is non-negative.*

3.2 Causality analysis

We analyzed the causal relationships in the system based on the above theoretical analysis and the initial model. The system's causality and the main loop relationships are shown in Figure 3.

Institutional support includes formal institutional support and informal institutional support. Formal system support includes five dimensions: priority, financial subsidies, cost relief, tax incentives, and property rights protection. Priority can solve the problem of overlapping mining rights, promote the priority for use of coalbed methane, increase the amount of coalbed methane utilization, and reduce emptying. Financial subsidies, fee reductions, and tax incentives increase the disposable capital of enterprises, which is conducive to the expansion of reproduction and increase in profits. Property rights protection promotes technological innovation for coalbed methane and reduces the costs of enterprises. Enterprises gain more profits from increases in customers and disposable funds and reduce their costs, thus promoting the development of the coalbed methane industry. Informal institutional support refers to the political relationship between an enterprise and the government. Good corporate political relations will promote technological innovation, reduce costs, and promote industrial development, but may affect fair competition. From this perspective, they will play a negative role in industrial development.

The development of coalbed methane will increase production, reduce the sales price, stimulate the rate of change in utilization, and promote greater institutional support.

3.3 System model construction

Based on the diagram of the system's causality, the symbol for the flow is introduced into the diagram of the system dynamics, and a matching variable for the unit demand is added to obtain the diagram of the system flow, as shown in Figure 3.

There are twenty-seven variables in the system, including two state variables (coalbed methane production, coalbed methane utilization), five rate variables (coalbed methane utilization change, coalbed methane production change, financial subsidies, cost relief, tax incentives), fifteen auxiliary variables (institutional support, formal institutional support, informal institutional support, priority, property rights protection, corporate political relations, technological innovation, fair competition, rate of change in coalbed methane utilization, disposable capital, profit, cost, coalbed methane sales price, coalbed methane industry, rate of change in coalbed methane production), and six constants (priority degree, reduction ratio, discount ratio, subsidy standard, relationship tightness, research input). The unit- and time-matching coefficients are hidden in

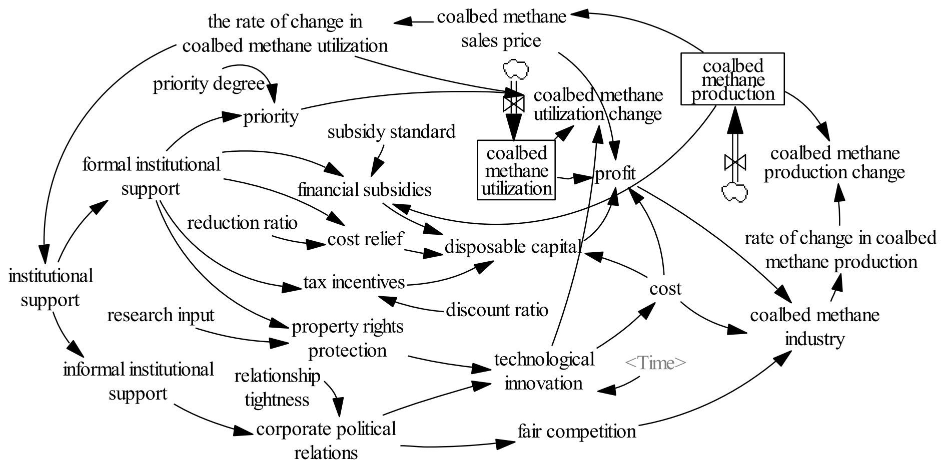

FIGURE 4
Analysis of the system flow diagram.

TABLE 2 The main equations of the system.

Equation design	Unit	Basis
coalbed methane production = INTEG(coalbed methane production change/(35 × unit matching coefficient),92)	billion cubic meters	data research collation
coalbed methane utilization = INTEG(coalbed methane utilization change/(160 × unit matching coefficient),37)	billion cubic meters	data research collation
coalbed methane utilization change = coalbed methane utilization × rate of change in coalbed methane utilization × (1 + priority) × (1 + technological innovation)	billion cubic meters	causality analysis
rate of change in coalbed methane production = coalbed methane production × rate of change in coalbed methane production × priority	billion cubic meters	causality analysis
financial subsidies = (1 + formal institutional support) + subsidy standard × coalbed methane production/(unit matching coefficient ×10)	dmnl	data research collation
cost relief = reduction ratio × formal institutional support ×100	dmnl	initial model
tax incentives = formal institutional support × (1 + discount ratio)	dmnl	initial model
institutional support = rate of change in coalbed methane utilization × 0.9	dmnl	causality analysis
coalbed methane sales price = WITH LOOKUP (2000 × unit matching coefficient/coalbed methane production),([(0,0)-(120,3.51)],(0,2.1),(120,3.51)))	yuan	data research collation
profit = (1 + disposable capital) × (1 + coalbed methane utilization/unit matching coefficient ×100) × (coalbed methane sales price/unit matching coefficient −cost/unit matching coefficient)	dmnl	causality analysis
disposable capital = tax incentives + financial subsidies + cost relief −cost/2	dmnl	causality analysis
cost = 1.5-technological innovation/2	yuan	data research collation
technological innovation = WITH LOOKUP(Time × (1 + property rights protection) × (1 + corporate political relations)/(2 × time matching coefficient),([(0,0)-(120,1)],(0,0.3),(120,1)))	dmnl	causality analysis
coalbed methane industry = (1 + fair competition) + (1 + profit) −(1 + cost/unit matching coefficient)	dmnl	causality analysis

Figure 4 to make the relationships between variables in the system flow diagram appear more intuitive.

3.4 Design of the main equations

Vensim PLE was used to simulate the system model based on the system flow diagram. This paper's simulation period was set from 2010 to 2020, with a duration of 120 months. The model involved three types of equations, and the main equations were designed as shown in Table 2.

3.4.1 Constant equation

The variables of priority, reduction ratio, subsidy standard, preference ratio, relationship tightness, and research input were set as constants with values between 0 and 1.

TABLE 3 Test of the fit of the simulated and real values of the system model.

Variable	Coalbed methane production	Coalbed methane utilization
R^2	.92	.95

3.4.2 Table function equation

The variables of financial subsidies, cost relief, and tax incentives were expressed in the table function, and the initial values were set according to the "13th Five-Year Plan" of the National Energy Administration for coalbed methane development and utilization. Due to the slightly different policies for each province and city, the system simulation data were based on central financial support.

3.4.3 Auxiliary equation

The auxiliary equation was set according to the relationships between the variables, where the initial values of the coalbed methane production, coalbed methane utilization, and cost were obtained from coalbed methane research reports and China's energy bureau.

4 Simulation and analysis of the system model

4.1 Initial value selection and parameter settings

Vensim PLE was used to simulate the system model based on the system flow diagram. The simulation period was 120 months, from 2010 to 2020. According to the data from the National Energy Administration, the initial value of coalbed methane production in the model was set to 9.2 billion cubic meters, and the initial value of coalbed methane utilization was set to 3.7 billion cubic meters. According to the coalbed methane research report and the Twelfth and Thirteenth Five-Year Plans, the coalbed methane sales price was set between 2.1 and 3.51 yuan. The initial cost was 1.5 yuan, the subsidy standard was .2–.3 yuan/m^3, and the tax preference was the preferential tax rate. The values of the time- and unit-matching coefficients were both 1.

4.2 Tests of the system model's validity

The system model was shown to be consistent with the real system structure by testing the causality diagram, system flow diagram, variable sources, and equation design. The main units of the system model variables were a billion cubic meters, yuan, dmnl, etc. The model ran normally, the dimensions were consistent, and the unit conformance test was passed.

In order to further test the validity of the model, the goodness-of-fit formula (Eq. 1) was used to test the simulated and historical data. The closer the R^2 value of the goodness of fit is to 1, the more effective the system model is (Strauss and Corbin, 1990).

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (y_i - y_i')^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \quad (1)$$

where y_i is the simulated value of the relevant variable in the ith year of the experimental period. y_i' is the true value for year I, and $\bar{y}$ is the average. The test results are shown in Table 3. The degree of fit of the simulated and real values of the main elements in the model was >.9, and the fitting effect was good (Anna and Tamás, 2022). The model was able to reflect the actual situation well.

The simulation model shows that, under the support of the current system, the coalbed methane industry shows an upward trend (as shown in Figure 5). The production and utilization of coalbed methane continue to increase. With the development of the coalbed methane industry, the utilization rate increases, thus further promoting institutional support.

4.3 Sensitivity analysis

The developmental prospects of the coalbed methane industry are broad, and the output and utilization of coalbed methane are increasing annually. However, due to the large proportion of difficult-to-recover resources, limited technological development, weak market competitiveness, and other reasons, there is still a gap between the production and utilization of coalbed methane and the goals of the 12th and 13th Five-Year Plans. It is necessary to strengthen institutional support for the coalbed methane industry.

According to the results of the initial model and system simulation, the institutional support for the coalbed methane industry can be improved in six dimensions: priority, financial subsidies, cost relief, tax incentives, property rights protection, and corporate political relations. Among them, cost relief and tax incentives have received greater support. According to the simulation results, exemption from all user fees and taxes on the existing basis has little impact on the coalbed methane industry. The priority of gas extraction has been established; however, coalbed methane utilization must be further strengthened. Financial subsidies have been reduced since 2019, and property rights protection and corporate political relations must be strengthened. Therefore, in the sensitivity analysis, the reduction ratio and the discount ratio remained unchanged. In Current1, the priority degree, subsidy standard, research input, and relationship tightness must increase to obtain Current2. These changes significantly increase coalbed methane production and utilization (as shown in Figure 6) in comparison with Current1. The subsidy standard will be restored to .3 yuan, and coalbed methane planning objectives can be achieved. At the same time, increasing research input and relationship closeness can promote technological innovation and enhance the development of the coalbed methane industry.

Increasing the priority increases the production and utilization of coalbed methane. By raising the subsidy standard, enterprises receive more financial subsidies. Increasing disposable capital is conducive to expanding coalbed methane reproduction, increases profits, attracts enterprise investment and development, promotes the development of the coalbed methane industry, and improves coalbed methane production and utilization. Increasing research input and enhancing property rights protection can stimulate technological innovation. At the same time, the relationships are closer, and

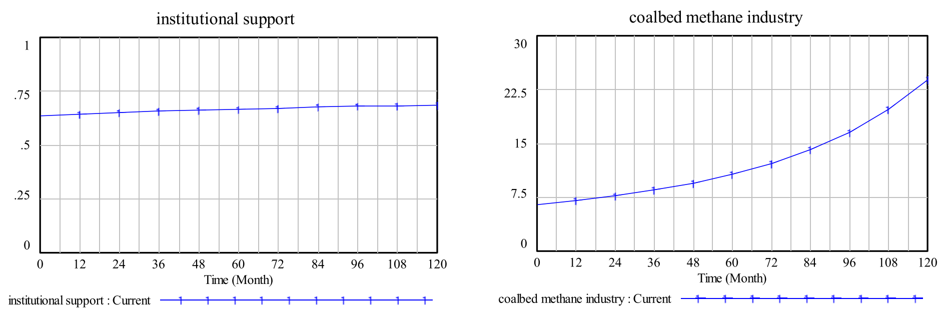

FIGURE 5
Simulation results.

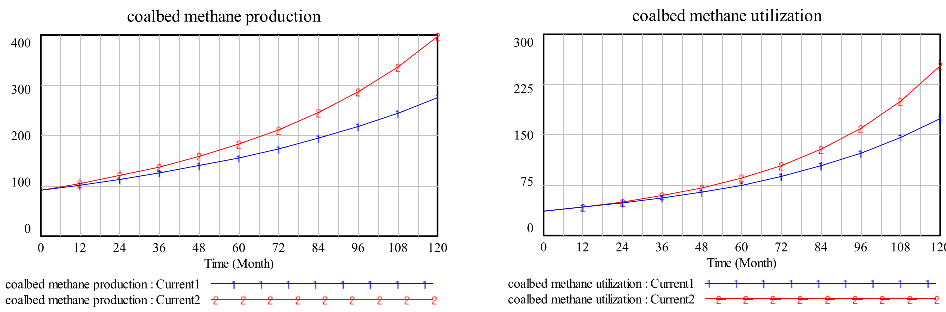

FIGURE 6
Changes in coalbed methane production and utilization.

good corporate political relations promote technological innovation. Improving technological innovation can increase the use of coalbed methane, increase profits, promote the development of the coalbed methane industry, and increase coalbed methane production.

5 Conclusion and management inspiration

5.1 Research conclusion

Unlike in previous studies, we examined policies concerning the coalbed methane industry through in-depth interviews and grounded theory from the perspective of institutional support. In combination with the collection of survey data, we constructed and simulated a dynamic model of the institutional support system for the coalbed methane industry. Suggestions for the sustainable development of the coalbed methane industry were obtained.

(1) The interaction between institutional support and the coalbed methane industry constitutes a dynamic system. Formal institutional support includes the five areas of priority, financial subsidies, cost relief, tax incentives, and property rights protection, and informal institutional support corresponds to corporate political relations.
(2) Institutional support promotes the development of the coalbed methane industry. Combinations of increases in the priority degree, subsidy standards, research input, and relationship tightness are effective means of institutional support for the promotion of the development of the coalbed methane industry.

5.2 Management insights

(1) The management of coalbed methane mining rights should be supervised and the scale of use should be strengthened. The implementation of gas mining priority mechanisms and the prioritization of the allocation of mining rights by coalbed methane enterprises should be ensured. Coalbed methane priority self-use, priority sales, the strengthening of the facilities of the gas pipeline network, the establishment of efficient innovative marketing systems, and an increase in the scale of use for coalbed methane should be considered.
(2) The central financial subsidy standards should be improved and local government subsidies should be encouraged. The recovery of the central financial subsidy standard of .3 yuan/cubic meter will help the production and utilization of coalbed methane meet the planning objectives. Local governments can set up special funds to increase incentives and subsidies, constantly improve the management system, and mobilize the enthusiasm of enterprises.
(3) The level of technological innovation should be improved and fair competition should be ensured. R&D investment in the basic theory of coalbed methane should be increased, and key technologies and equipment should be developed and utilized.

Intelligent information technology should be developed, importance should be attached to intellectual property protection, and the intelligence level of the coalbed methane industry should be improved. A "government–industry–university–research" collaborative innovation platform should be built, the training of coalbed methane professionals and technical personnel should be strengthened, and innovation capabilities should be enhanced. Coalbed methane enterprises should consider their political relations and encourage the government to increase policy support. At the same time, the government will guarantee fair competition through bidding and other means.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization, JW and C-HN; Methodology, JW; Software, JW; Validation, JW; Writing—original draft preparation, JW; Writing—review and editing, C-HN; Supervision, C-HN; Funding acquisition, C-HN. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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