

Article

Research on Factor Coupling of Industrialization of Oil and Gas Scientific and Technological Achievements

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Abstract: This paper presents the relationship between the factors of the industrialization of oil and gas scientific and technological achievements. These have established the internal coupling model and the external coupling model among the factors of the industrialization of oil and gas scientific and technological achievements. As revealed in the process of the industrialization of oil and gas scientific and technological achievements, there is a mutual influence between the factors. The actual data is used to simulate the internal coupling and the coupling between the factors of the industrialization of oil and gas scientific and technological achievements. The results show that the degree of the internal coupling and the coupling between the factors changes from coupling dissonance to a coordination state, indicating that the coupling of the factors of the industrialization of oil and gas scientific and technological achievements are enhanced. Results are presented the degree of internal coupling and coupling coordination of each factor basically changed from coupling dissonance to coordination state, indicating that the coupling of the elements in the industrialization of oil and gas scientific and technological achievements is synergistic. In conclusion, attention was drawn to strengthen the interaction between the subject of the industrialization of oil and gas scientific and technological achievements, integrate the industrialization resources of oil and gas scientific and technological achievements, improve the environment for the industrialization of oil and gas scientific and technological achievements, and improve the management system for the industrialization of oil and gas scientific and technological achievements, which can promote the development of the industrialization of oil and gas scientific and technological achievements.



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Keywords: scientific and technological achievements; industrialization of oil and gas scientific and technological achievements; factors coupling

1. Introduction

The industrialization of scientific and technological achievements is the hub connecting scientific and technological achievements and industrial innovation, and it is the product of perfecting scientific and technological management system and building an innovation-oriented country. The purpose of this study is to promote the management of oil and gas science and technology achievements, realize the rapid development of oil and gas science and technology achievements, improve the application level of oil and gas science and technology achievements, and provide an important theoretical basis and method support for the development of oil and gas science and technology achievements industrialization. At the same time, it aims to improve the industrialization performance of oil and gas scientific and technological achievements, promote the development of science and technology oil and gas enterprises, promote the transformation and upgrade of the oil and gas industry and high-quality development, improve the quality and efficiency of oil and gas enterprises, and explore a more suitable path for the industrialization of oil and gas scientific and technological achievements in China.

Coupling comes from physics. It is defined as a network consisting of two or more circuits. If the change of current or voltage in one circuit can affect a similar change in other

circuits, this kind of network is called a coupling circuit. The function of a coupling is to transfer (or convert) energy from one circuit to another [1]. Carl Wicker (1976) introduced the theory of loose coupling into the field of organized management. In management science, post-coupling refers to the relationship between two or more factors or systems, which is manifested as interaction, compatibility, and mutual movement. The coupling of factors refers to the interaction, compatibility, and coordination among factors within a system. The coupling results of the factors will promote the next stage of coupling, mainly in the form of synergies, to improve the sustainable operation of the system.

In foreign countries, the main method of technology transfer factor coupling research on the industrialization of scientific and technological achievements is to build a theoretical model and analyze it by structural equation model fitting [2]. Sandeep Singhai et al. (2021) conceptualized the input factors, that is, the significant correlation between micro, meso, and macro factors, and used the structural equation model based on covariance to extensively analyze and test the contribution of input factors to the successful technology transfer. The research results show that communication, innovation, knowledge, product quality and motivation are the five most important factors for successful technology transfer [3]. Alana Corsi et al. (2021) systematically reviewed the literature on technology transfer models and found possible obstacles and opportunities in the process of sustainable technology transfer. On this basis, a theoretical model of sustainable development with “obstacles and opportunities” as the core is put forward, which can predict and solve possible obstacles and take “opportunities” as the promoting factor of technology transfer [4].

Kaiyun Zhang et al. (2022) explored the mechanism by which policy perception obtains technical resources needed for enterprise development through cross-border behaviors and the moderating effect of inter-organizational trust and technological potential gap. The result shows that the usefulness and availability of policy perception significantly promote technology transfer performance, and cross-border behavior performs an intermediary role between the two. From the perspective of influencing factors of technology transfer, the technology potential gap significantly moderates the relationship between cross-border behavior and technology transfer performance, and inter-organizational trust positively moderates the relationship between cross-border behavior and technology transfer performance [5]. Haining Fang et al. (2021) analyzed technology transfer in universities (TTU) and high-tech industries development, HTID) and found that technological innovation, technological absorption capacity, development level of high-tech industry, industry-learns-research cooperation, and technological and financial development have significant promoting effects on their coupling coordination [6].

When studying the coupling of multi-agent cooperation in innovation, Klessova, Engell et al. (2022) found that the publicly funded multi-actor research, development, and innovation project is a temporary consortium formed by a network of multiple organized actors to jointly create new knowledge and market upstream innovation. The coupling between the organized actors and groups of these actors represents the joint work that leads to the flow of knowledge and the flow of activities [7].

Huang, L et al. (2022) built a theoretical framework for the influence of knowledge base dynamic changes on green innovation from the perspective of technological knowledge coupling, and studied and revealed the nonlinear relationship mechanism between different technological knowledge coupling and green innovation. The inverse U-shaped nonlinear relationship between existing technology knowledge coupling and green innovation, between new and existing technology knowledge coupling and green innovation of manufacturing firms [8].

Cheng, M. L et al. (2023) analyzed the coupling coordination degree of driving factors of innovation network and ecological efficiency and found that the comprehensive efficiency of innovation network was lower than the efficiency of scientific and technological innovation and the efficiency of scientific and technological achievement transformation, and the ecological efficiency of scientific and technological innovation and coupling coordination degree was higher than that of technological achievement and coupling coordination

degree of transformation. Information and communication technologies perform an important role in promoting the integrated efficiency and eco-efficiency of innovation networks in different system [9].

Yanming Sun (2019) studied the coupling mechanism of factors in the industrialization of scientific and technological achievements in China and conducted an empirical analysis of the relationship among factor coupling, system transformation, and performance output in the industrialization of scientific and technological achievements [10]. Jinfu Wang and Jing Qiu et al. (2023) used the TOE (technology–organize–environment) theoretical framework and fsQCA (fuzzy set qualitative comparative analysis) to study the coupling coordination degree of regional innovation chain driven by multiple factors. The research results showed that there were two key factors to effectively improve the coupling coordination degree of the regional innovation chain, namely, the level of digital technology and marketization [11,12].

The structural equation model is often used in the research of factor coupling of industrialization of scientific and technological achievements in foreign countries. In addition to using the structural equation model, qualitative comparison analysis of fuzzy sets is also combined in China. The research of factor coupling is an important part of revealing the internal activities of the industrialization of scientific and technological achievements. The foreign research on the factors of the industrialization of scientific and technological achievements mainly focuses on the loose coupling theory, the coupling of factors affecting innovation, and the coupling of subject, knowledge and technology. The domestic research on the classification and specific factors of the industrialization of scientific and technological achievements has certain limitations. The motion process and realization of factor coupling have not been deeply studied, and the combination of qualitative analysis and quantitative analysis of factor coupling is lacking.

This study analyzes the coupling of the subject factor, resource factor, environment factor, management factor, and overall factor of the industrialization of oil and gas scientific and technological achievements through empirical research and constructs the coupling model of each factor and the overall factor coupling model, and further analyzes the coupling mechanism of the factors of the industrialization of oil and gas scientific and technological achievements. The degree of coupling coordination within and among the elements of the industrialization of oil and gas scientific and technological achievements is analyzed.

2. Materials and Methods

According to the self-organize theory, the fundamental mechanism of the orderly evolution of a system is a nonlinear interaction between various factors or subsystems in the system. Under this nonlinear interaction, the system generates holistic behavior.

The non-linear interaction of the internal coupling of the factors of the industrialization of oil and gas scientific and technological achievements is mainly embodied in the internal coupling of the subject factor, the internal coupling of the resource factor, the internal coupling of the environment factor, and the internal coupling of the management factor. In the internal coupling of factors, the coupling is not only the coupling between two indicators but also the simultaneous coupling between several indicators.

To measure factor coupling, it is necessary to refer to the coupling coordination degree model. The coordination degree is derived from the volumetric coupling coefficient model in physics. The following steps are used to calculate the coupling coordination degree:

The first step is to process the data. The different data obtained are processed into unified data that can be used for coupling research. The processing method is usually standardized or normalized so as to eliminate the dimensional and order of magnitude effects. During the analysis, the analysis item is first treated with an Interval, and the interval processing formula is as follows [13]:

$$a + (b - a) \times (X - Min) \div (Max - Min) \quad (1)$$

In the preceding formula, a is the lower limit 0.01, b is the upper limit 0.99, X is the actual value, Max is the maximum value of an item, and Min is the minimum value of an item. After the interval processing, all the data were between 0 and 1, then the processed data was used for a formal coupling coordination degree study.

The second step is to calculate the coupling degree C , the coordination index T , and the coupling coordination degree D [14]. U_1 and U_2 are the composite indices of system 1 and system 2, respectively. The composite index is derived from the original data through statistical analysis: First, the original data with different units of data interval processing, combined with their respective weights to calculate the composite index.

Calculation formula of coupling degree:

$$C = 2 \times \sqrt{(U_1 \times U_2) / (U_1 + U_2)^2} \quad (2)$$

The value of coupling degree C is $[0, 1]$. The larger the value of C is, the better the coupling state of the two systems involved in coupling degree calculation is, and each parameter develops towards the direction of order. The smaller the C value is, the worse the coupling state of the two systems involved in the calculation of coupling degree is, and each parameter develops towards the direction of disorder.

The calculation formula of the coupling coordination index is as follows:

$$T = a \times U_1 + b \times U_2 \quad (3)$$

Here, a and b are the weights of system 1 and system 2, respectively. T is the coupling coordination index. In the calculation of multi-system and multi-factor coupling coordination index, the weight $c, d, \dots$, can increase the system or factor composite index $U_3, U_4, \dots$, extending to the coupling of multiple systems or multiple elements. In the calculation of this study, considering that the purpose of the coupling study is to see whether the synergies in the same direction can be formed after the coupling of factors and whether they can be coordinated, the weight of each system is assumed to be equal by default.

Calculation formula of coupling coordination degree:

$$D = \text{Sqrt}(C \times T) = \sqrt{C \times T} \quad (4)$$

D is the degree of coupling coordination and value ranges from 0 to 1. The larger the value of D , the more coordinated the development level of the two systems involved in the calculation of the coupling degree. The smaller the D value is, the more uncoordinated the development level of the two systems involved in the calculation of coupling degree is, that is to say, the lower the degree of collaboration between the two systems.

The third step is to use the calculated coupling coordination degree index D , corresponding to the classification index of coupling coordination degree, to obtain the coupling coordination degree. Coupling coordination levels 1–10 correspond to the coupling coordination degree of extreme disorder quality coordination. The classification standards of coupling coordination degree are shown in Table 1.

When the coupling coordination degree is greater than 0.0 and less than 0.1, the coordination level is 1, and the coupling coordination degree is an extremely disorder. When the coupling coordination degree is greater than or equal to 0.1 and less than 0.2, the coordination level is 2, and the coupling coordination degree is a severe disorder. When the coupling coordination degree is greater than or equal to 0.2 and less than 0.3, the coordination level is 3, and the coupling coordination degree is a moderate disorder. When the coupling coordination degree is greater than or equal to 0.3, and less than 0.4, the coordination level is 4, and the coupling coordination degree is a mild disorder. When the coupling coordination degree is greater than or equal to 0.4, and less than 0.5, the coordination level is 5, and the coupling coordination degree is a borderline disorder. When the coupling coordination degree is greater than or equal to 0.5 and less than 0.6, the coordination level is 6, and the coupling coordination degree is a forced coordination. When the coupling coordination

degree is greater than or equal to 0.6 and less than 0.7, the coordination level is 7, and the coupling coordination degree is a primary coordination. When the coupling coordination degree is greater than or equal to 0.7 and less than 0.8, the coordination level is 8, and the coupling coordination degree is an intermediate coordination. When the coupling coordination degree is greater than or equal to 0.8, and less than 0.9, the coordination level is 9, and the coupling coordination degree is a good coordination. When the coupling coordination degree is greater than or equal to 0.9 and less than 1, the coordination level is 10, and the coupling coordination degree is a quality coordination.

Table 1. Classification criteria of coupling coordination degree.

Coupling Coordination Degree D Value Interval	Coordination Level	Degree of Coupling Coordination
(0.0–0.1)	1	Extreme disorder
[0.1–0.2)	2	Severe disorder
[0.2–0.3)	3	Moderate disorder
[0.3–0.4)	4	Mild disorder
[0.4–0.5)	5	Borderline disorder
[0.5–0.6)	6	Forced coordination
[0.6–0.7)	7	Primary coordination
[0.7–0.8)	8	Intermediate coordination
[0.8–0.9)	9	Good coordination
[0.9–1.0)	10	Quality coordination

3. Data Analysis and Validation

3.1. Internal Coupling of Subject Factors

The subject factor of oil and gas scientific and technological achievements can be divided into the public service subject factor and behavior subject factor. The subject factors of public service include government, economic management institutions, intermediary organizations, etc., while the subject factors of behavior include oil and gas enterprises, oil and gas industry colleges and universities offering oil and gas-related majors, and oil and gas research institutes, etc. [15].

The government performs a macroscopic role in the industrialization of oil and gas scientific and technological achievements [16]. As the subject of public service, the government is the organization that provides assistance to various problems in the process of industrialization of oil and gas scientific and technological achievements by cooperating with economic management agencies and intermediary organizations. Economic management agencies cooperate with the government to conduct science and technology management in the industrialization of oil and gas scientific and technological achievements, and intermediary organizations perform a linkage role in the industrialization of oil and gas scientific and technological achievements.

The coupling of the subject factors of the industrialization of oil and gas scientific and technological achievements includes the interaction between the public service subject and the behavior subject, which can be manifested in the communication, cooperative relationship, cooperation degree, and cognitive concept among the subjects. The coupling model of oil and gas scientific and technological achievements in industrialization is shown in Figure 1.

The public service subject and the behavior subject interact in the industrialization of oil and gas scientific and technological achievements. The public service subject provides services for the behavior subject and participates in the industrialization process of scientific and technological achievements. Behavioral subjects dominate the industrialization of oil and gas scientific and technological achievements, propose possible problems in the industrialization process, and provide a reference for public service subjects to formulate policies, norms, and industry standards for the industrialization of oil and gas scientific and technological achievements.

According to the relevant connotation of the subject factors of the industrialization of oil and gas scientific and technological achievements, the coupling index of the subject factors is established, as shown in Table A1.

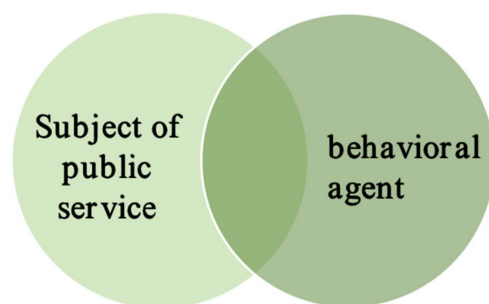


Figure 1. Coupling model of subject factors of the industrialization of oil and gas scientific and technological achievements.

When conducting the coupling study of the subject factors, the relevant data of China National Petroleum Corporation from 2016 to 2020 are selected to represent the subject factors of the industrialization of oil and gas science and technology achievements during the “13th Five-Year Plan” period, and the coupling of the subject factors of the industrialization of oil and gas science and technology is calculated. The calculation results are shown in Table A2. In terms of the coupling and coordination degree of the subject factors of the industrialization of oil and gas scientific and technological achievements of PetroChina, it has progressed from the verge of imbalance in 2016 to high-quality coordination in 2020.

3.2. Internal Coupling of Resources Factors

Oil and gas science and technology achievement resources mainly include human resources, data resources, information resources, and knowledge resources.

Talents are workers with higher quality in human resources. Talent has strong business ability, can be creative labor, and is our economic and social development of important resources. Talents for the industrialization of oil and gas scientific and technological achievements are those who can closely combine science and technology with the industry, create new products or technologies through scientific and technological innovation, and promote the continuous development and expansion of the oil and gas industry. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the number of scientific research personnel.

Data, an intuitive reflection of things, is the most core factor of production in the era of the digital economy. Data are objective, unprocessed raw resources. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the number of patent applications and authorized patents.

Information is an intangible resource that can create value and be exchanged. Information, as meaningful data, can reflect the degree of development and change. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the number of national science and technology awards.

Knowledge refers to the knowledge of facts, principles, and skill management required for R&D and innovation in the industrialization of oil and gas scientific and technological achievements. Knowledge is the result of data and information processing, analysis, extraction, and evaluation [17]. It is the reflection of higher-level data and information and can reflect the laws of motion and state changes of things. It is mainly reflected in the contribution rate of scientific and technological progress in the industrialization of oil and gas scientific and technological achievements.

The resource factor coupling of oil and gas scientific and technological achievements mainly includes the coupling of talents and data, the coupling of talents and information, the coupling of talents and knowledge, the coupling of data and infor-

mation, and the coupling of information and knowledge. Talent–data–information coupling, talent–information–knowledge coupling, talent–data–knowledge coupling, data–information–knowledge coupling, talent–data–information–knowledge coupling, talent–data–information–knowledge coupling, and talent–data–information–knowledge coupling. Figure 2 shows the resource factor coupling model of oil and gas scientific and technological achievements.

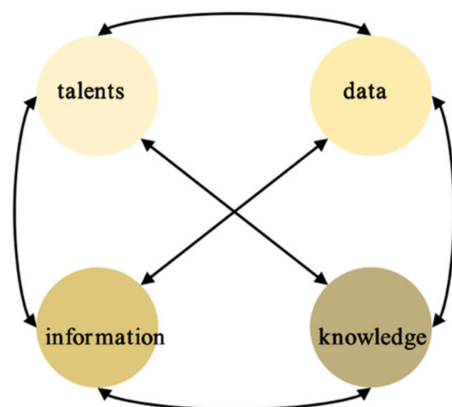


Figure 2. Coupling model of resource factors in the industrialization of oil and gas scientific and technological achievements.

Talents in the industrialization of oil and gas scientific and technological achievements interact with data, information, and knowledge. Talents obtain data by sorting out and analyzing specific and intuitive numbers, obtain information by using data, and form knowledge by understanding, transforming, and processing information more deeply. Knowledge is a higher level of data and information obtained through induction, deduction, and other methods. Data, information, and knowledge are the reflection of talents' mastery and application of various materials.

According to the relevant connotation of resource factors in the industrialization of oil and gas scientific and technological achievements, the coupling index of resource factors in the industrialization of oil and gas scientific and technological achievements is established, as shown in Table A3.

The relevant data of China National Petroleum Corporation from 2016 to 2020 are selected to represent the resource factors of the industrialization of scientific and technological achievements in the 13th Five-Year Plan period and the coupling of resource factors of the industrialization of oil and gas science and technology is calculated. The calculation results are shown in Table A4. The coupling and coordination degree of resource factors in the industrialization of oil and gas scientific and technological achievements of PetroChina Group has progressed from moderate imbalance in 2016 to primary coordination in 2020.

3.3. Internal Coupling of Environment Factors

The environmental factors of oil and gas scientific and technological achievements mainly include internal environment factors, external environment factors, and oil and gas geo-environment factors [18].

The internal environment mainly includes the internal environment in the industrialization system of scientific and technological achievements of oil and gas, which is manifested as the internal environment of the organization of oil and gas enterprises or colleges and universities in the oil and gas industry in the process of industrialization of scientific and technological achievements, such as the allocation of scientific and technological achievements research and development funds [19,20]. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the organization of internal research and development expenses.

The external environment mainly includes social, economic environment, technology market environment, policies, and regulations. Zheng Jixing et al. (2016) believe that the dissemination and promotion of technological innovation achievements is a complex and organic technology diffusion system. The external environment of this system includes the market environment, policy environment, and social environment [21]. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the total domestic industrial added value and domestic research and development (R&D) funds for industrial enterprises above the designated size of oil and gas.

Oil and gas geo-environment mainly refer to the tension of political patterns, conflicts, territorial sovereignty disputes, and security between countries and regions caused by oil and gas resources. The change in oil and gas geography is due to the continuous growth of oil consumption in the world, while the increase in proved oil reserves is decreasing. Additionally, although natural gas reserves are abundant, the transportation means are complex, and the cost is high. The contradiction between the emerging oil and gas consumption areas and the traditional oil and gas consumption areas affects the trade process of oil and gas in the whole country.

The Organize of the Petroleum Exporting Countries (OPEC) is committed to maintaining oil market stability and promoting oil market prosperity. OPEC implements the oil production quota system to protect the interests of oil producers and oil consumers. If the demand for oil and gas rises or some oil and gas-producing countries reduce the production of oil and gas, OPEC will increase its oil and gas production to stabilize the oil price. If demand for oil and gas falls, OPEC will reduce oil and gas production to stabilize oil prices. Some countries with large oil and gas consumption, such as the United States, encourage non-OPEC countries to vigorously produce oil and gas, which leads to conflicts between OPEC members and other oil and gas producers, causing changes in the oil and gas geographical environment [22]. The environmental factors of industrialization of oil and gas scientific and technological achievements are mainly reflected in overseas crude oil equity production, overseas natural gas equity production, lead system, and revision of international standards.

The coupling of environmental factors of the industrialization of oil and gas scientific and technological achievements includes the coupling of the internal environment and external environment, the coupling of the external environment and oil and gas geo-environment, and the coupling of the internal environment and oil and gas geo-environment. The coupling of internal environment, external environment, and oil and gas geo-environment.

The coupling model of environmental factors for the industrialization of oil and gas scientific and technological achievements is shown in Figure 3.

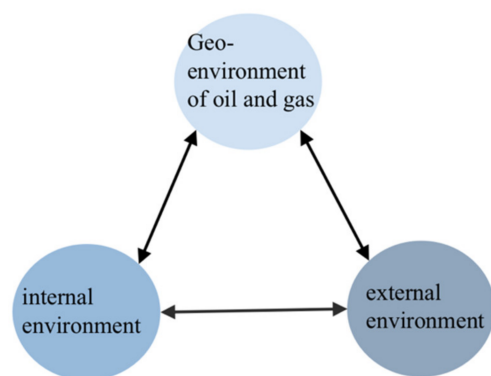


Figure 3. Coupling model of environment factors for industrialization of oil and gas scientific and technological achievements.

The internal environment, external environment, and geo-environment of the industrialization of oil and gas scientific and technological achievements interact with each other,

forming the exchange of material, energy, and environment resources within and outside the organization, exchanging information domestically and internationally, and winning the right to speak [23]. The internal environment is the microenvironment of the industrialization of oil and gas science and technology achievements, the external environment is the macro environment of the industrialization of oil and gas science and technology achievements, and the geographical environment of oil and gas is the special environment of the industrialization of oil and gas science and technology achievements. The interaction among the three has a positive impact and reaches a harmonious degree, which makes the environment of the industrialization of oil and gas science and technology achievements sustainable development.

According to the relevant connotation of environment factors of oil and gas scientific and technological achievements, the coupling index of environment factors of oil and gas scientific and technological achievements industrialization is established, as shown in Table A5.

The relevant data of China National Petroleum Corporation in 2016 and 2020 are selected to represent the environmental factors of the industrialization of scientific and technological achievements in the “13th Five-Year Plan” period and the coupling of environmental factors of the industrialization of oil and gas science and technology is calculated. The calculation results are shown in Table A6. In terms of coupling and coordination degree of environmental factor in the industrialization of oil and gas scientific and technological achievements, China National Petroleum Group has progressed from serious imbalance in 2016 to primary coordination in 2020.

3.4. Internal Coupling of Management Factors

The management factors of the industrialization of oil and gas scientific and technological achievements are mainly to plan, organize, lead, coordination, and control. In the process of industrialization of oil and gas scientific and technological achievements, plan refers to comprehensive and long-term plan for the development of achievements. Organize means that the industrialization of achievements is organized in a purposeful and systematic way. Lead means that the process of industrialization of results is goal-oriented and runs under the lead of leaders. Coordination refers to the coordinated development of various activities and human resources in the process of industrialization of achievements. Control means that each process in the industrialization of results can be effectively controlled. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the master plan of scientific and technological innovation, the key point of scientific and technological innovation construction, the national skill master studio, the important scientific and technological cooperation, and the major scientific and technological research and development progress.

The management factors of the industrialization of oil and gas scientific and technological achievements are mainly plan, organize, lead, coordination, and control. In the process of industrialization of oil and gas scientific and technological achievements, plan refers to comprehensive and long-term plan for the development of achievements. Organize means that the industrialization of achievements is organized in a purposeful and systematic way. Lead means that the process of industrialization of results is goal-oriented and run under the lead of leaders. Coordination refers to the coordinated development of various activities and human resources in the process of industrialization of achievements. Control means that each process in the industrialization of results can be effectively controlled. The industrialization of oil and gas scientific and technological achievements is mainly reflected in the master plan of scientific and technological innovation, the key point of scientific and technological innovation construction, the national skill master studio, the important scientific and technological cooperation, and the major scientific and technological research and development progress. The coupling factors of the industrial management of oil and gas scientific and technological achievements include plan–organize coupling, plan–lead coupling, plan–coordination

coupling, plan–control coupling, organize–lead coupling, organize–coordination coupling, organize–control coupling, leader–coordination coupling, leader–control coupling, coordination–control coupling; plan–organize–lead coupling, plan–organize–coordination coupling, plan–organize–control coupling, plan–lead–coordination coupling, plan–lead–control coupling, plan–lead–control coupling, organize–lead–control coupling, organize–lead–coordination coupling, organize–lead–control coupling, organize–lead–control coupling, organize–control–coordination coupling, lead–coordination coupling; plan–organize–leader–coordination coupling, plan–organize–coordination–control coupling, plan–leader–coordination–control coupling, organize–leader–coordination–control coupling; and Plan–organize–lead–coordination–control coupling. Figure 4 shows the coupling model of the industrial management of oil and gas scientific and technological achievements.

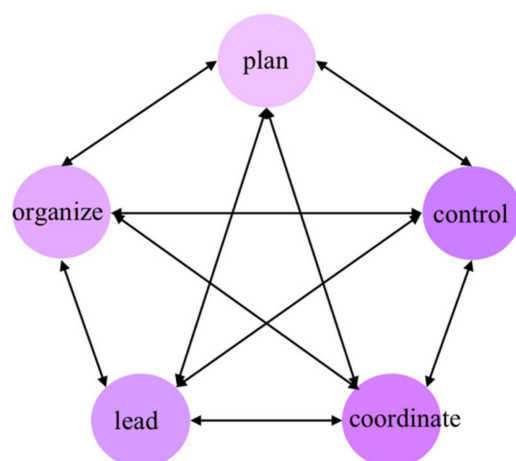


Figure 4. Factor coupling model of industrialization management of oil and gas scientific and technological achievements.

The plan, organize, lead, coordination, and control of the industrialization of oil and gas scientific and technological achievements affect each other. As management factors, they are inseparable, including and interacting with each other. In the plan, you need to organize through lead to coordinate the process and control the process. In organize, it needs to be carried out by leaders according to plans. Organize is also a process of continuous coordination and control. In lead, the premise is plan, action is organize, function is coordination, and specific operation is control. In coordination, according to the plan, lead, organize, and finally control the existing activities, then carry out coordination. In control, the leader organizes the activities according to the plan and achieves the purpose of control by making everything in balance and following the established process.

According to the relevant connotation of the factors of the industrialization management of oil and gas scientific and technological achievements, the coupling indicators of the factors of the industrialization management of oil and gas scientific and technological achievements are established, as shown in Table A7.

The relevant data of China National Petroleum Corporation from 2016 to 2020 are selected to represent the factors of industrialization management of oil and gas scientific and technological achievements during the “13th Five-Year Plan” period, and relevant calculations are carried out on the coupling of the factors of industrialization management of oil and gas scientific and technological achievements. The calculation results are shown in Table A8. In terms of coupling coordination degree of oil and gas scientific and technological achievements industrialization management, CNPC has progressed from moderate imbalance in 2016 to high-quality coordination in 2020.

3.5. *Coupling between the Factors of Industrialization of Oil and Gas Scientific and Technological Achievements*

In the process of industrialization of oil and gas scientific and technological achievements, there is a coupling relationship among the subject factors, resource factors, environmental factors, and management factors. All factors interact with each other under the condition of unbalanced development of industry and space, exchange material and energy, and through energy dissipation and internal nonlinear dynamic mechanism, the original chaotic and disordered state is transformed into an orderly state in time, space, and function. In the factor structure of the industrialization of oil and gas scientific and technological achievements, the subject factor is the main force, the resource factor is the important guarantee, the management factor is the measure, and the environment factor is an important support.

The relevant data of China National Petroleum Corporation from 2016 to 2020 are selected to represent the relevant situation of the subject factors, resource factors, environmental factors, and management factors of the industrialization of scientific and technological achievements of oil and gas during the 13th Five-Year Plan period, including the index system of the industrialization of scientific and technological achievements of oil and gas established in Tables A1, A3, A5 and A7. The coupling among the factors (subject, resources, environment, and management) of the industrialization of oil and gas technology is calculated, and the calculation results are shown in Table A9. In terms of factor coupling coordination degree, China National Petroleum Group has progressed from a moderate imbalance in 2016 to good coordination in 2020.

3.6. *Coupling Model of Industrial Factors of Oil and Gas Scientific and Technological Achievements*

Through the research on the internal coupling and inter-factor coupling of the oil and gas scientific and technological achievements, it is found that the different factors of the industrialization of oil and gas scientific and technological achievements have mutual influence and interaction, which is an organic and unified whole, and constitute the basic structure of the coupling of the factors of the industrialization of oil and gas scientific and technological achievements.

The factor coupling of the industrialization of oil and gas scientific and technological achievements includes the coupling of subject factor–resource factor, subject factor–environment factor, subject factor–management factor, resource factor–environment factor, environment factor–management factor, and resource factor–management factor. The coupling of subject factor–resource factor–environment factor, coupling of subject factor–resource factor–management factor, coupling of subject factor–environment factor–management factor, coupling of resource factor–environment factor–management factor; and the coupling of subject factor–resource factor–environment factor–management factor.

4. Discussion

4.1. *Conclusions*

By analyzing the internal coupling of the factors of the industrialization of oil and gas science and technology achievements, namely, the coupling of the subject factors of the industrialization of oil and gas science and technology achievements, the coupling of resource factors, the coupling of environmental factors, and the coupling of management factors of the industrialization of oil and gas science and technology achievements, the coupling model of each factor is constructed, and the coupling degree of each factor is calculated. On this basis, the coupling coordination degree among the oil and gas scientific and technological achievements is calculated, and it is found that the coupling degree of the internal coupling and the coupling coordination degree of each factor is basically changed from coupling dissonance to coordination state, indicating that the coupling of the oil and gas scientific and technological achievements in industrialization is synergic, and performs a role in promoting the development of the oil and gas scientific and technological achievements in industrialization. The subject factor is the main implementer of oil and

gas science and technology achievements industrialization activities, the resource factor is the material of oil and gas science and technology achievements industrialization activities, the environment factor is the space of oil and gas science and technology achievements industrialization activities, and the management factor provides measures for the oil and gas science and technology achievements industrialization activities.

4.2. Policy Suggestion

Strengthen the interaction between the subject of the industrialization of oil and gas scientific and technological achievements. Oil and gas enterprises, oil and gas industry colleges, other colleges and universities offering oil and gas related majors, and oil and gas research institutes should strengthen the interaction among the subject and strengthen the construction of the collaborative innovation system of production, study, and research [24]. The government should strengthen the connection with oil and gas enterprises, oil and gas industry colleges, other colleges and universities offering oil and gas related majors, and oil and gas research institutes, and more importantly, establish contact with scientific and technological economic management institutions and intermediary organizations, so as to provide help for the industrialization of oil and gas scientific and technological achievements [25]. Scientific and technological economic management agencies, the government, and intermediary organizations should perform their respective functions in accordance with the principle of “joint construction, sharing and sharing” to achieve interconnection and build an innovation platform conducive to the industrialization of oil and gas scientific and technological achievements.

Integrate the industrialization resources of oil and gas scientific and technological achievements. In order to promote the industrialization of oil and gas scientific and technological achievements, resources, such as talents, data, information, and knowledge, need to be effectively integrated and rationally allocated. The complementary resources of talents, data, information, and knowledge can enrich the lack of resources for the industrialization of oil and gas scientific and technological achievements. The increasing availability of information and knowledge will enhance the social and collaborative innovation capabilities of the entire oil and gas industry [26]. Through resource sharing, the subject of the industrialization of oil and gas scientific and technological achievements take the initiative to provide technical equipment, test materials, scientific, and technological information, etc., to provide hardware and software support for the industrialization of oil and gas scientific and technological achievements.

Improve the environment for the industrialization of oil and gas scientific and technological achievements. We should build a favorable environment for innovation, promote the deep integration of scientific and technological innovation with the economy and society, and effectively connect innovation achievements with market demands [27]. To improve the internal environment for the industrialization of oil and gas scientific and technological achievements, increase the scientific research funds that can be given within the organization and the corresponding supporting funds for the industrialization of oil and gas scientific and technological achievements. To increase financial support for oil and gas scientific and technological achievements, establish a guiding fund for the industrialization of oil and gas scientific and technological achievements, and encourage and support the raising of funds for the industrialization of oil and gas scientific and technological achievements through multi-level capital markets. On the one hand, the industrialization of scientific achievements of oil and gas should adapt to the changes in the geo-environment, and on the other hand, we need to improve our power of discourse in the international community in the field of oil and gas.

Improve the management system for the industrialization of oil and gas scientific and technological achievements. The industrialization of oil and gas scientific and technological achievements involves many subjects, resources, and environmental factors. In order to make the industrialization of oil and gas scientific and technological achievements smooth, management work needs to be planned in advance. When organizing the industrialization

activities of oil and gas scientific and technological achievements, it is necessary to have a clear understanding of the overall goal of the industrialization of oil and gas scientific and technological achievements and carry out a systematic analysis so as to rationally arrange and arrange the industrialization activities of oil and gas scientific and technological achievements. No matter in the initial research and development or in the final promotion into the market, oil and gas scientific and technological achievements need a subject who can lead the entire organization to complete the industrialization task. In the industrialization process, various elements and processes should be coordinated and effectively controlled.

5. Limitations

Based on the above analysis results, it can be concluded that different factors of the industrialization of oil and gas scientific and technological achievements interact with each other, interact with each other and organically unify, which together constitute the basic structure of the coupling of factors of the industrialization of scientific and technological achievements. Figure 5 shows the coupling model of the factors of the industrialization of oil and gas scientific and technological achievements, which is the overall coupling model of the coupling of subject factors, resource factors, environmental factors, and management factors of the industrialization of oil and gas scientific and technological achievements. Each specific factor of the four factors influences each other. This kind of influence not only includes the influence between two concrete factors but also includes the influence between several concrete factors [28]. Moreover, it is manifested as the influence of a specific factor on other factors through indirect factors. By analyzing the degree of coupling coordination among the factors of oil and gas science and technology achievements, it is found that the coupling within and between the factors basically changes from coupling dissonance to a coordination state, indicating that the coupling of the factors is synergistic. The subject factor, resource factor, environmental factor, and management factor of the industrialization of oil and gas scientific and technological achievements influence each other. The subject factor is the main implementer of the industrialization activities, the resource factor is the material of the industrialization activities, the environmental factor is the space of the industrialization activities, and the management factor provides a guarantee for the industrialization activities.

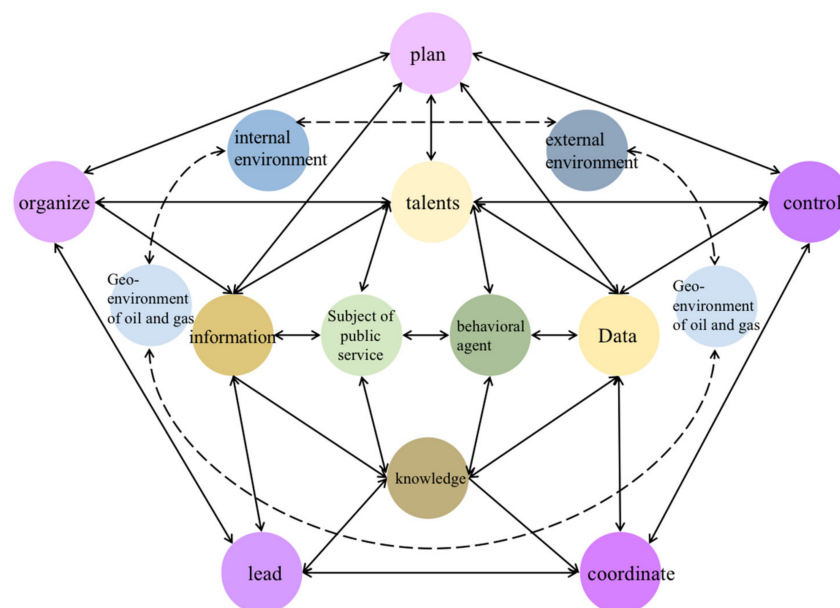


Figure 5. Factor coupling model of industrialization of oil and gas scientific and technological achievements.

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Appendix A

Table A1. Coupling index of subject factor of the industrialization of oil and gas scientific and technological achievements.

Factor	Indicator	Units	Attribute
Subject of public service	Government subsidy	Ten thousand yuan	+
Behavioral agent	Key laboratories and experimental bases	Each	+
	Scientific research institutions	Each	+

Table A2. Calculation results of coupling coordination degree of subject factor in industrialization of oil and gas scientific and technological achievements.

Year	Coupling Degree C Value	Coordinate Index T Value	Coupling Coordination Degree D Value	Coordination Level	Degree of Coupling Coordination
2016	0.341	0.490	0.409	5	Borderline disorder
2017	0.137	0.337	0.215	3	Moderate disorder
2018	0.975	0.672	0.809	9	Good coordination
2019	0.341	0.497	0.411	5	Borderline disorder
2020	0.998	0.949	0.973	10	Quality coordination

Table A3. Resource factor coupling index of oil and gas science and technology achievements industrialization.

Factor	Indicator	Units	Attribute
Talents	Researcher	Each	+
Data	Apply for a patent	Item	+
	Obtain an authorized patent	Item	+
Information	National science and technology award	Item	+
Knowledge	Contributing rate of technology advancement	%	+

Table A4. Calculation result of resource coupling coordination degree of oil and gas science and technology achievements industrialization.

Year	Coupling Degree C Value	Coordinate Index T Value	Coupling Coordination Degree D Value	Coordination Level	Degree of Coupling Coordination
2016	0.223	0.384	0.293	3	Moderate disorder
2017	0.633	0.637	0.635	7	Primary coordination
2018	0.846	0.279	0.486	5	Borderline disorder
2019	0.390	0.324	0.355	4	Mild disorder
2020	0.559	0.786	0.663	7	Primary coordination

Table A5. Coupling index of environment factors in the industrialization of oil and gas scientific and technological achievements.

Factor	Indicator	Units	Attribute
Internal environment	Organize internal research and development expenses	Ten thousand yuan	+
External environment	Total domestic industrial added value	Billion	+
	Domestic funds for research, experimental development (R&D) of industrial enterprises above designated size of oil and natural gas	Billion	+
Geo-environment of oil and gas	Overseas equity production of crude oil	Ten thousand tons	+
	Overseas natural gas equity production	Ten thousand tons	+
	Leading system to revise international standards	Item	+

Table A6. Calculation result of environment coupling coordination degree of oil and gas science and technology achievements industrialization.

Year	Coupling Degree C Value	Coordinate Index T Value	Coupling Coordination Degree D Value	Coordination Level	Degree of Coupling Coordination
2016	0.230	0.150	0.186	2	Severe disorder
2017	0.296	0.216	0.253	3	Moderate disorder
2018	0.824	0.502	0.643	7	Primary coordination
2019	0.999	0.973	0.986	10	Quality coordination
2020	0.982	0.853	0.915	10	Primary coordination

Table A7. Factor coupling index of industrialization management of oil and gas scientific and technological achievements.

Factor	Indicator	Units	Attribute
Plan	Master plan for scientific and technological innovation	Item	+
Organize	Focus on scientific and technological innovation	Each	+
Lead	National skill master studio	Each	+
Coordinate	Major scientific and technological cooperation	Each	+
Control	Major scientific and technological development progress	Item	+

Table A8. Calculation result of coupling coordination degree of industrial management elements of oil and gas scientific and technological achievements.

Year	Coupling Degree C Value	Coordinate Index T Value	Coupling Coordination Degree D Value	Coordination Level	Degree of Coupling Coordination
2016	0.180	0.304	0.234	3	Moderate disorder
2017	0.351	0.234	0.287	3	Moderate disorder
2018	0.472	0.654	0.556	6	Forced coordination
2019	0.297	0.066	0.140	2	Severe disorder
2020	0.968	0.892	0.929	10	Quality coordination

Table A9. Calculation results of coupling coordination degree of oil and gas scientific and technological achievements in industrialization.

Year	Coupling Degree C Value	Coordinate Index T Value	Coupling Coordination Degree D Value	Coordination Level	Degree of Coupling Coordination
2016	0.208	0.310	0.254	3	Moderate disorder
2017	0.309	0.365	0.336	4	Mild disorder
2018	0.698	0.498	0.590	6	Forced coordination
2019	0.318	0.480	0.391	4	Mild disorder
2020	0.826	0.857	0.842	9	Good coordination

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