An Analysis of Factors Influencing the Development of Chinese Coalbed Methane Industry

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Abstract—**On the basis of the Delphi method, the indicators / variables that impacted system, were inquired and analyzed by using principal component analyses and factor analysis techniques; the factor equations were exploring utilized: comprehensive latent factors was acquired by solving overdetermined equations, thereby, the sequencing of all the variables affecting the system could be realized, finally the purpose of "seizing the key variables" to find countermeasures was achieved.**

Keywords-coalbed methane; constraining factors; delphi method; principal component analysis; factors analysis

I. INTRODUCTION

Coalbed gas, also called coal bed methane, is a kind of natural gas stored in the coal bed and the surrounding rock. If coalbed gas can be exploited and applied appropriately, it can serve as a kind of unconventional source of energy and also a clean energy, otherwise, it will cause even worse greenhouse effect, almost 22 times worse than CO_2. China is rich in coalbed gas reserves and about $36.81 \times 10^{12} m^3$ coalbed gas is buried underground above 2000 meter, which makes China take up the third place in the world [1] and be provided with great potential for exploitation. The exploitation of coalbed gas is very meaningful to implement strategies of " thrift, cleanness and security " and facilitate the construction of modern energy system which is clean, efficient, secure and sustainable. The twelfth 5-year-project on energy industry emphasizes that we should make great efforts to the prospect and exploit coalbed gas according to resource prospect and previous development [2]. Also it puts forward several goals for coalbed gas industry: till 2015, the production of coalbed gas should reach $300 \times 10^8 m^3$, among which, $160 \times 10^8 m^3$ should be from surface exploitation with a 100% utilization rate and $140 \times 10^8 m^3$ should be from coal mine exploitation with a 60% utilization rate [3]. However, in 2013, the whole nation only produced $29.26 \times 10^8 m^3$. Now, the twelfth 5-year-project is due, and our country has revised goals for coalbed industry in strategic plans on energy development (2014-2020) that till 2020, the production of coalbed gas should try to surpass $300 \times 10^8 m^3$.

This thesis will apply Delphi method, principal components analysis (P.C.A.) as well as factor analysis (F.A.) to analyze influence factors of the development of coalbed gas industry in China to facilitate its future development.

II. A BRIEF INTRODUCTION OF RELEVANT STUDIES

The history of coalbed gas industry is far shorter than that of petroleum and natural gas industry. The oil crisis in 1970s started to make the USA think about the exploitation of coalbed gas industry. Now, America, Australia, China and India all devote to produce and sell coalbes gas as a kind of pipeline natural gas. America has the largest production of coalbed gas [4], and in 2009, it sold over $538 \times 10^8 m^3$. Many scholars have done studies about coalbed gas industry mainly in these following aspects.

- The study of the accumulation of calbed gas. Shengwei Wang [5], Yong Qin [6] and al have analyzed geological conditions and its fundamentals about the accumulation of calbed gas to present its accumulation mechanism and recognize its inner features in detail.

- The study of technologies of coalbed gad exploitation. Wuzhong Li [7], Tiancai He [8], Huifang Yao [9] and al have studied the geological features, major prospection technics, processing and utilizing technology of coalbed gas, coal mine gas drainage technology and exploitation technologies on the ground, etc. from the technological view.

- The economic evaluation of coalbed gas technology. Wuzhong Li [7], Wenliang Wang [10] and al have made evaluations for the development prospect and economic benefit of coalbed gas.

- The study of present situation and problems&measures of coalbed gas exploitation. Shengyou Zhang [11], Ton-g Niu [12] and al have analyzed the current situation of coalbed gas development and located those problems from the aspects of regional differences, enterprise differences and mine right management, and proposed several countermeasures and suggestions.

- The study of the comprehensive utilization of coalbed gas. Qincai Yin [13], Yigang Wang [14] and al have studied the comprehensive utilization of coalbed gas in industry and life, and analyzed its major problems and proposed solutions.

From the above studies, we can easily find that there are already many studies based on the micro-technology but rare based on the macroscope. Therefore, both micro and macro analyses are needed. Based on the current situation of study, the authors use those first-hand materials to analyze those

factors that influence the development of coalbed gas industry with the hope that it can serve as a kind of inspiration for the future development.

III. THE CURRENT SITUATION OF THE DEVELOPMENT OF CHINESE COALBED GAS INDUSTRY

The total amount of caolbed gas resource is $36.81 \times 10^{12} m^3$, with $7.8 \times 10^{12} m^3$ from high rank coal, $14.3 \times 10^{12} m^3$ from middle rank coal and $14.7 \times 10^{12} m^3$ from low rank coal, and the total amount of producible caolbed gas is $10.87 \times 10^{12} m^3$. The amount of resource in Erdos, Qinshui, Turpan-Hami, Dzungaria, Yili,, western Henan, Liupanshui and southern Sichuan-northern Guizhou those 8 coal bearing areas reaches $26.34 \times 10^{12} m^3$, accounting for 72% of the total amount in the country. Those eight areas undoubtedly constitute a resource base for coalbed methane industrialization.

The Chinese government attaches great importance to the development of CBM industry. The target of CBM vertical well demonstration project in southern Qinshui Basin in Shanxi is to build a coalbed gas demonstration base with a production of $3.5 \times 10^{10} m^3$ per year. Currently we have drilled 600 wells, fractured 600 wells, drained 491 wells, built well site around 491 wells, laid 535km gas producing pipeline and 142.3km gas gathering pipeline for those 491 wells, and built 38 valve groups and 1 gas gathering station while 2 another are still under the construction. New technology research and experiment to improve the basic condition have shown preliminary results.

Although the demonstration area has made a series of achievements, the whole development of CBM industry is still just passable. In 2012, the production of a single CBM well around the country is only 1090 ~ 1700 m³ per day on average, and the annual output of coalbed gas is only $26.6 \times 10^8 m^3$. Table 1 is the statistics of Chinese CBM production in 2012. By the day of June 30th, 2014, 67.86% of CBM vertical wells in the southern Qinshui Basin produce less than 500m³ of gas per day, 90.66% less than 1000m³. Only 34 wells accounting for 9.34% produce more than 1000m³ of coalbed gas. Thus, targets of the development of CBM industry in our country fail frequency.

TABLE I. PRODUCTION OF COALBED METHANE IN 2012

Unit	The Number of Producible Wells after Drainage	Average Yield of Single Well (m³/d)	Total Annual Output (10⁸m³)	Target of 2015 (10⁸m³)
PetroChina CBM Company	1423	1090	2.2	26
Shanxi Jincheng Mining Group	3000	1350	14.4	55
China United CBM, Ltd.	801	1700	4.5	40
PetroChina North China CBM Company	1009	1650	5.5	40
Total	6223	1386	26.6	161

IV. ANALYSIS OF FACTORS INFLUENCING THE DEVELOPMENT OF CHINESE CBM INDUSTRY

A. Determination of Influencing Factors

Currently, Chinese CBM industry is faced with a dilemma for many reasons. Basic theory of CBM reservoir, CBM reservoir technology, development and manufacturing of CBM professional equipment, personnel, experience, policy and business environment, as well as many other factors all have influence on the current situation. After the communication with major CBM enterprises, references to the development of foreign CBM industry, and consulting relevant documents, the author identifies 29 influencing factors of CBM industry.

B. Analyses of Influencing Factors

1) Sources of Data The data used in this thesis come from PetroChina CBM company and China United CBM, Ltd. By Delphi method, several specialists have measured those factors (indexes) anonymously. After four rounds of opinions collection and feedback, those specialists confirmed their opinions and index weights are set. Based on that, we resort to the following processes to colligate those opinions.

2) Principal Component Analysis Principal Component Analysis uses mathematical statistic methods to find out main factors of the system and the relationship between these factors [16]. PCA can reduce many variables to a few indexes, thus it simplifies the high dimensional space with many variables into a low dimensional one with a few indexes. The comprehensive index which carries with the largest amount of information is the first principal component. We standardize those data collected through Delphi method and get the sample matrix $\mathbf{x}$; we calculate the correlation matrix R of $\mathbf{x}$ and use the feature vector of R as orthogonal basis L to make the calculation: $\mathbf{y} = \mathbf{Lx}$. And then $\lambda_j \quad j = 1, 2, \cdots, p$ is the characteristic value of R and it also represent variance in j axis after orthogonal transformation.

Thus, PCA usually uses λ_j to determine the sequence of principal components, and we pick first m principal components from the sequence according to the principle

$$\left(\lambda_1 + \lambda_2 + \cdots + \lambda_m \right) \Big/ p = 0.6 \sim 0.85$$

$$
\begin{aligned}
F_1 &= l_{11} x_1 + l_{12} x_2 + \cdots + l_{1p} x_p \\
F_2 &= l_{21} x_1 + l_{22} x_2 + \cdots + l_{2p} x_p \\
&\vdots \\
F_m &= l_{m1} x_1 + l_{m2} x_2 + \cdots + l_{mp} x_p
\end{aligned}
\quad (1)
$$

The principal components of this research are calculated, from which we can see that four principal components carry all the information of indexes.

3) Factor Analysis Factor Analysis is used to analyze a set of relevant variables and uses several crytic and unobservable random variables (factor) to explain the relationship between original variables [17].

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Following PCA stated above, m(m<p) principal components are picked and then the factor model can be written as:

$$x_1 = a_{11}f_1 + a_{12}f_2 + \cdots + a_{1m}f_m + e_1$$
$$x_2 = a_{21}f_1 + a_{22}f_2 + \cdots + a_{2m}f_m + e_2$$
$$\vdots \qquad\qquad (2)$$
$$x_p = a_{p1}f_1 + a_{p2}f_2 + \cdots + a_{pm}f_m + e_p$$

Matrix form: $\mathbf{x} = \mathbf{Af} + \mathbf{e}$

In (2), f_j is the common factor of observed variables, and e is the specific factor of x. f_j and e are independent to each other.

Also:
$$\mathbf{E(x)} = \mathbf{0} \quad \mathbf{Var(x)} = \mathbf{E}$$
$$\mathbf{E(f)} = \mathbf{0} \quad \mathbf{Var(f)} = \mathbf{I_m} \qquad (3)$$
$$\mathbf{E(e)} = \mathbf{0} \quad \mathbf{Var(e)} \text{ is limit}$$

When the column vector of A in (2) is mutually orthogonal, (2) is also called orthogonal factor model and its covariance structure is:

$$\mathbf{Var(x)} = \mathbf{Var(Af + e)} = \mathbf{A^2 Var(f)} + \mathbf{Var(e)}$$
$$\mathbf{Cov(x,f)} = \mathbf{E}\{[\mathbf{x} - \mathbf{E(x)}][\mathbf{f} - \mathbf{E(f)}]\} = \mathbf{A} \qquad (4)$$

Thus, $A = \left(a_{ij}\right)_{p \times m}$ is called factor loading matrix. In Factor Analysis, the feature vector of R also serves as orthogonal matrix. After we have chosen several principal factors and omitted specific factors and residual errors, the expression of orthogonal factor model can be written as:

$$x_1 = u_{11}f_1 + u_{12}f_2 + \cdots + u_{1m}f_m$$
$$x_2 = u_{21}f_1 + u_{22}f_2 + \cdots + u_{2m}f_m$$
$$\vdots \qquad\qquad (5)$$
$$x_p = u_{p1}f_1 + u_{p2}f_2 + \cdots + u_{pm}f_m$$
$$\mathbf{x} = \mathbf{uf}$$

The document [17] puts forward the orthogonal rotation of factor: if f is a common factor vector of orthogonal factor model, then for any orthogonal matrix O (z=O), f is also its common factor vector, and u.O is the factor loading matrix of z. In the actual calculation of Factor Analysis, after we get the initial factor loading matrix u, we repeatedly multiply it by the orthogonal matrix O until u.O obviously shows practical significance. This method is called the orthogonal rotation of factor. After orthogonal rotation, the contribution of common factors to xi does not change, but the common factor itself may not be the same. From the mathematical view, the factor loading a_{ij} is the covariance of x_i and f_j, i.e. $Cov(x_i, f_j)$. If the variable x_i is a standardized variable, a_{ij} is also the correlation coefficient of x_i and f_j. From the view of " systematic theory ", the essence of orthogonal factor model is that for the observed system, there are many observable variables that influence the system, and these variables can be summarized into m crytic and unobservable comprehensive variables, namely factors. The factor loading a_{ij} represents the relative importance of i variable to j common factor, and it also shows how well those factors can explain the influence of observable variables on the system.

By the method in document [17], we use the software SPASS to do the varimax rotation, and then the factor model is presented in Table 2.

TABLE II. THE KAISER ROTATED FACTORS MODEL AFFECTING CBM DEVELOPMENT INTRODUCTION

	f₁	f₂	f₃	f₄
X1	-0.898	-0.034	0.254	0.359
X2	-0.395	-0.199	0.718	-0.538
X3	0.394	-0.194	-0.898	-0.021
X4	0.514	-0.321	0.72	-0.339
X5	0.595	0.233	-0.428	0.639
X6	-0.221	0.466	0.15	-0.844
X7	0.089	0.224	0.405	-0.882
X8	-0.203	0.886	0.28	-0.309
X9	0.508	0.845	-0.111	0.128
X10	0.966	-0.253	-0.043	0.035
X11	0.992	0.072	-0.074	0.073
X12	0.888	-0.396	-0.12	-0.199
X13	0.794	-0.039	-0.126	0.594
X14	0.785	0.507	0.012	0.356
X15	0.733	0.452	0.509	-0.017
X16	0.921	0.272	0.261	0.1
X17	0.527	0.424	0.733	-0.074
X18	-0.085	0.99	0.106	-0.033
X19	0.419	-0.059	-0.887	0.187
X20	0.258	0.94	0.222	-0.029
X21	0.631	0.232	-0.511	0.536
X22	0.895	-0.046	-0.287	0.338
X23	0.346	0.452	0.254	0.782
X24	0.571	-0.141	-0.076	0.805
X25	0.032	0.978	-0.182	-0.092
X26	-0.394	0.194	0.898	0.021
X27	0.383	-0.919	0.057	-0.078
X28	-0.793	-0.139	0.585	-0.096
X29	0.966	-0.253	-0.043	0.035

4) Analysis of Factors Influencing Chinese CBM Industry

a) Factor Identification From Table 2 we can see, knowledge background of CBM personnel, personnel with professional technique and CBM expert are more important for factor f1, so f1 can be regarded as " human capital ". Similarly, the second factor f2 can be regarded as " enterprise strength "; f3 " industrial environment " and f4 the " internet+ " b ase of CBM industry.

b) The whole Sequence of Influencing Variables on Different Factors From Table 2, we can see that orthogonal factor model is indeed an overdetermined set:

$$x_{p\times 1} = A_{p\times m} \cdot f_{m\times 1} \qquad (6)$$

Because there is no solution of the overdetermined set in (6), we have to find its least square solution: $f \in R^m$, and make $\|r\|^2 = \|x - Af\|^2 = \min_{R^m}$. And usually we get $f_j \quad j = 1,2,\cdots,m$ by solving the set $A^T A f = A^T x$.

Considering that a_{ij} is the weight of i variable to j common factor, when we standardize a_{ij} as:

$$a'_{ij} = \left. a_{ij} \middle/ \sum_{i=1}^{p} a_{ij} \right. \qquad i = 1,2,\cdots,p, \quad j = 1,2,\cdots,m \qquad , \qquad a'_{ij} \times f_j$$

becomes the score x_i gets on the factor f_j , namely the importance of x_i to f_j . Also $w_i = \sum_{j=1}^{m} a'_{ij} f_j \quad i = 1,2,\cdots,p$ is the quantified representation of the importance of influencing variables to those common factors, such as " human capital " and " enterprise strength ", or it can show how greatly they influence " the system " and thus we can put variables in order, as shown in Table 3.

In Table 3, if we make 0.5 as the threshold, those main factors that influence the development of Chinese CBM industry are obviously found, which show that the incompetence of expenditure of R&D from governmental special funds and enterprises as well as in cooperation of production, learning and research leads to the deficiency of patents of CBM exploitation technology, technological system of CBM prospection and exploitation and standards system of CBM exploitation technics, and causes the failure of Farm-out of CBM industry chain; when encountering price fluctuation of international oil and gas, the main part of CBM exploitation market will lose its competence in capital.

V. SUGGESTIONS FOR THE DEVELOPMENT OF CBM INDUSTRY

a) To Put Basic Science in the Prerequisite Place To Confirm the Foundation of CBM Industry A lot of natural vertical and horizontal primary fractures (cleat) and larger secondary cracks in coal beds are main channels for gas seepage and migration. Different from natural gas, coalbed gas is stored in coal beds mainly in states of dissociation, adsorption and dissolution. Free gas only accounts for 10% to 20%, while adsorbed gas is of 80% to 95%, and the amount of dissolved gas is very small. 80% to 90% of adsorbed methane in most coal beds is absorbed on the surface of coal's dense micro pores. When the pressure of coal bed decreases to the critical desorption pressure, adsorbed methane begins to desorb and becomes free gas which is mainly distributed in the coal cleats and nano micropores. The formation water is mainly stored in the cleats and cracks of coal (usually not to enter into micropores). After the formation of wellbore, the coalbed water and free gas in cracks will move to the wellbore due to pressure difference and thus water and gas are produced (the yield which is decided by the amount of free gas is very low); at first, what is drained out is mainly water, then water and gas and finally mainly gas; with the decrease of pressure (fluid pressure in cracks in fact), the free gas in pores starts to diffuse to cracks, which reduces pore pressure, and when the pressure drops to the critical pressure of desorption, desorption occurs; The whole process is desorption→diffusion→seepage →production. It must be pointed out that, the daily production of single well is not mainly depends on reserves and abundance, but mainly on the state of coalbed gas and the dynamic process mentioned above. The general process of CBM mining is usually as follows: drilling→fracturing→drainage→gas→production. The mechanism of storage and exploitation of CBM is different from that of conventional natural gas, as document [4] said: " so it is not surprising that their productions are different ". But surprisingly, the exploitation of CBM in our country is almost the same as that of natural gas in aspects of equipment, technics and materials of drilling, cementation, completion and fracturing, as well as equipment of drainage and production. As " Several Opinions of CPC Central Committee and State Council for Deepening Institutional Reform and Accelerating the Implementation of the Strategy: Innovation Drives Development " on March 13th, 2015 pointed out: to accelerate the implementation of the strategy that innovation drives development is to make the market play the decisive role in resource allocation and to make government play its role better ... . We should adhere to laws and take characteristics of scientific and technological activities into consideration to master laws of scientific discovery and research and create a favorable environment for scientific researches, inventions, and technological breakthroughs. The national planning of science and technology should focus on strategic requirements and key research areas where the market fails to allocate resources effectively. Our national Research Institute will complete the analysis of dynamic system of each link in the process of CBM desorption, diffusion, seepage and production as soon as possible to find out features of CBM bedrocks and the mechanism of fracturing and drainage, and construct the theoretical foundation for technology system of CBM exploration and standard system of subsequent development of CBM industry.

b) Innovation of Enterprises to Form Technological System of CBM Industry After the construction of basic science of CBM industry. Technological problems will be solved. " Several Opinions of CPC Central Committee and State Council for Deepening Institutional Reform and Accelerating the Implementation of the Strategy: Innovation Drives Development " pointed out that we should grasp the market rules of technological innovation to make market the main means of innovative resource allocation, to make enterprises the main force of technological innovation, and to make intellectual property system the basic guarantee for

innovation. As Wu Jinglian, a famous economist said: the nature of science and technology is very different. Scientific innovation and incentives should be undertaken by society (including government). While technological innovation and incentives should be mainly undertaken by market. With correct theoretical basis, huge market demand, ample resource reserves and " internet+ " economic model, as well as the construction of technology patent, technology system and standard system of CBM exploration and development, under the policy of speeding up the implementation of strategical innovation, market will play a decisive role in resource allocation. In an innovative environment, the creative vitality creative potential of the whole society are much inspired. Due to dockings of science and technology, innovation achievements and industry, innovative projects and productivity, as well as innovative work and economic interest, it's inevitable that the efficiency and effectiveness of labor, information, knowledge, technology, management, and capital will be much improved.

c) To Improve the Strength of CBM Enterprises and Make Accumulation for Industry Development The strength of CBM enterprises is undoubtedly an important factor that influences the development of CBM industry, while most of them are in a rather difficult situation due to low profitability, and poor financing ability. Beside capital strength, their incompetence in integration of production, study and research, mining capabilities of demonstration base data, technical strength and coping with the impact of alternative products shows that the strength of CBM enterprises is particularly important for industry development. Therefore, CBM enterprises should take measures to enhance their strength, including paying more attention to technology and capital application and increasing their profitability; also the financing capacity and capital strength of CBM market players need to be further enhanced; they should also strengthen exchanges and contacts with universities and scientific research institutes to achieve high-degree integration of production, study and research; besides they should see their own advantages, and find ways to resistant the impact of alternative products, and increase their ability of data mining.

d) To Create a Favorable Industrial Environment for the Development of CBM Industry In the development of CBM industry, industrial environment plays an important role. Equipments of CBM mining, transportation and application influence the development of the whole industry greatly. The deficit and immatureness of technology and government's fiscal policy all have an impact on industrial development. In the big environment, including policy environment and business environment, industrial organization, market structure, and price are all important factors. Thus, we should put emphasis on the R&D and manufacturing of CBM equipment to step out of the small circle inside the industry, and pay attention to external exchanges to introduce external technology for technological innovation and mining requirements. As for government, it should enact some preferential industrial policies and tax policies to make its

macro-control more favorable for the development of CBM industry. Therefore, with various efforts, an agreeable industrial environment can be built.

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TABLE III. THE SEQUENCE OF FACTORS AFFECTING THE DEVELOPMENT OF COALBED METHANE INDUSTRY

	Component score				
	f1	*f2*	*f3*	*f4*	*Sequence*
	3.4718	*2.0500*	*2.3888*	*-0.1013*	
patents of CBM exploitation technology	0.1791	0.1680	0.7370	0.0052	1.0892
expenditure of R&D from governmental special funds	0.2490	0.1790	0.5114	0.0012	0.9407
influence of international price of oil and gas	-0.1339	0.0769	0.9030	-0.0015	0.8446
standards system of CBM exploitation technics	0.1745	-0.1271	0.7241	0.0239	0.7954
cooperation of production、learning and research in CBM exploitation	0.0875	0.3725	0.2230	0.0020	0.6850
expenditure of R&D from enterprises	0.3129	0.1079	0.2623	-0.0071	0.6761
farm-out degree of CBM industry chain	0.0302	0.0889	0.4074	0.0621	0.5887
capital strength of CBM market players	-0.0689	0.3511	0.2812	0.0218	0.5852
technological system of the prospection and exploitation of CBM	-0.1343	-0.0787	0.7220	0.0379	0.5469
environmental protection of CBM products	0.1176	0.1791	0.2556	-0.0551	0.4973
data mining of CBM demonstration base	-0.0288	0.3924	0.1068	0.0023	0.4726
profitability of CBM enterprises	0.2668	0.2008	0.0119	-0.0251	0.4545
financing ability of CBM market players	0.1726	0.3347	-0.1121	-0.0090	0.3862
specialization degree of CBM industry chain	-0.0750	0.1847	0.1506	0.0594	0.3197
personnel with professional technique	0.3371	0.0284	-0.0748	-0.0051	0.2856
distribution of CBM resource	-0.2696	-0.0552	0.5879	0.0068	0.2698
influence of CBM substitutes	0.0107	0.3877	-0.1834	0.0065	0.2215
national macroeconomic policies	0.3282	-0.1004	-0.0433	-0.0024	0.1821
knowledge background of CBM personnel	0.3282	-0.1004	-0.0433	-0.0024	0.1821
price of CBM	0.2697	-0.0155	-0.1267	-0.0419	0.0857
CBM expert	0.3019	-0.1569	-0.1211	0.0140	0.0379
market demand of CBM	0.1941	-0.0560	-0.0762	-0.0567	0.0051
industrial organization and market structure	0.3042	-0.0182	-0.2887	-0.0238	-0.0265
basic theory of CBM reservoir	-0.3050	-0.0136	0.2555	-0.0253	-0.0884
social cognition of CBM	0.1302	-0.3640	0.0576	0.0055	-0.1708
policy and business environment	0.2023	0.0922	-0.4307	-0.0450	-0.1812
government's fiscal policy of CBM exploitation and application	0.2144	0.0918	-0.5139	-0.0378	-0.2455
import of external technology	0.1424	-0.0234	-0.8914	-0.0132	-0.7855
research and manufacturing of CBM equipment	0.1339	-0.0769	-0.9030	0.0015	-0.8446

TABLE IV. PRINCIPAL COMPONENTS INFLUENCING CBM DEVELOPMENT

Total Variance Explained

Components	Eigenvalue and Variance		
	eigenvalue	Variance (%)	Comulative (%)
1	13.133	45.288	45.288
2	7.560	26.068	71.356
3	5.190	17.895	89.251
4	3.117	10.749	100.000

Principal components

	Basic theory of CBM reservoir	Technological system of the prospection and exploitation of CBM	Research and manufacturing of CBM demonstration base	Standards system of CBM exploitation technics	Policy and business environment	Specialization degree of CBM industry chain	Farm-out degree of CBM industry chain	capital strength of CBM market players	financing ability of CBM market players	Knowledge background of CBM personnel	Personnel with professional technique	CBM expert	Price of CBM	Profitability of CBM enterprises	Expenditure of R&D from government mental special funds
F1	-0.7523	-0.7638	0.6089	0.1040	0.8887	-0.5100	-0.3380	-0.3319	0.5662	0.8701	0.9306	0.7387	0.9443	0.8374	0.5082
F2	-0.1033	0.1390	-0.4920	0.1447	0.0322	0.5483	0.4958	0.9097	0.7589	-0.0999	0.1728	-0.2410	-0.0428	0.5265	0.7290
F3	-0.3664	0.6290	-0.3115	0.9771	-0.4212	0.1829	0.6026	-0.1606	-0.2938	0.4775	0.3055	0.5668	-0.0020	-0.0519	0.4404
F4	0.5378	0.0395	-0.5386	0.1166	0.1780	-0.6370	-0.5262	-0.1913	-0.1313	-0.0696	-0.1036	-0.2738	0.3262	0.1375	0.1279

Principal Components (continue)

	Expenditure of R&D from enterprises	Patents of CBM exploitation technology	data mining of CBM demonstration base	Import of external technology	Cooperation of production, learning and research in CBM exploitation	government's fiscal policy of CBM exploitation and application	Industrial organization and market structure	environmental protection of CBM products	Market demand of CBM	Influence of CBM substitutes	Influence of international price of oil and gas	Social cognition of CBM	Distribution of CBM resource	National macroeconomic policies
F1	0.7831	0.2363	-0.0748	0.7050	0.1928	0.9103	0.9956	0.5173	0.7994	0.0964	-0.6089	0.2543	-0.9220	0.8701
F2	0.4787	0.7760	0.9106	-0.3903	0.9670	0.0143	-0.0699	0.4612	-0.1722	0.8022	0.4920	-0.7185	0.0183	-0.0999
F3	0.3873	0.5356	-0.3957	-0.4500	-0.1571	-0.4113	0.0588	-0.2540	-0.1152	-0.4990	0.3115	0.6453	0.1455	0.4775
F4	0.0875	0.2349	-0.0928	-0.3850	-0.0556	0.0445	0.0185	0.6746	0.5639	-0.3134	0.5386	0.0517	0.3583	-0.0696