Analysis and Quantitative Study of China’s Oil and Gas Uncertainties during the “14th Five-Year Plan”

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Abstract: As a mining industry which is vital to the national economy, the oil and gas industry is faced with various uncertainties from the exploration and development at the upstream, refining and production at the midstream to the transportation and sale at the downstream. With the implementation of the “Go Global” strategy of the oil and gas industry and the steady progress of the Belt and Road Initiative, a more comprehensive and accurate identification, classification and quantification of the uncertain factors facing the oil and gas industry is required by the “14th Five-Year Plan”. This paper first identifies and classifies the uncertain factors of the oil and gas industry and then analyzes the difference between those uncertain factors from the domestic and overseas perspectives. Different methods of quantifying the uncertainties are also designed from the three dimensions of resource, technology and economy. Based on the development trend of various factors during the “14th Five-Year Plan” period, this paper predicts the quantitative results of uncertainties in the following 10 years.

1. Introduction

In recent years, China’s oil and gas output has been fluctuating around 190 million tons, but the consumption of oil and gas has gradually increased, leading to an increasing dependence on imported oil and gas. In 2019, the dependence on imported oil and gas reached 72%. With the continuously deepening of the “Go Global” strategy and the steady progress of the Belt and Road Initiative, the overseas equity of oil and gas production equivalent has steadily increased and reached around 100 million tons in 2019[1], although the domestic output basically remained unchanged. Due to the increasing difficulty of domestic oil and gas development and the rise in the equivalent of overseas oil and gas equity, there is a higher requirement for the uncertainty facing the oil and gas industry.

During the “14th Five-Year Plan” period, the oil and gas development at home and abroad will face new situations, which makes it necessary to further analyze the uncertain factors. On the one hand, uncertain factors need to be correctly identified and classified. The uncertainty may not only cause losses but also bring benefits, such as technical risk and technological progress. On the other hand, uncertain factors, including resource quality, overseas tax laws and policy environment, need to be accurately quantified at the current stage, considering the domestic and international environment. Therefore, a comprehensive analysis of the domestic and international uncertainties related to the development of China's oil and gas industry in the next 5 to 10 years is of great research value and practical significance.
2. Current Status of Identification and Quantitative Study of Uncertain Factors of the Oil and Gas Industry

As to the identification of uncertain factors, most scholars [2-4] focused their researches on the risks existing in the exploration and development, including exploration risk, geological risk, reserve risk, technical risk, project risk and contract risk. Some scholars [5-7] also concerned themselves with macro-environmental risks, such as political and economic environment, sovereign credit and international oil price, but failed to make a detailed summary of all the uncertainties facing the oil and gas industry. Their researches focused on analyzing the impact of risk factors. For the few researchers conducting comprehensive analysis, they carried out the weighted ordering of uncertain factors to evaluate oil and gas resources but failed to explain the path and degree of risk quantification.

As to the quantitative evaluation of uncertain factors, most researchers focused on analyzing the degree to which these factors are important to each other. However, scholars have not yet reached an agreement on the method of determining the index weights. On the one hand, some scholars devoted to applied research are more inclined to adopt subjective judgment methods, such as expert scoring, analytic hierarchy process and hierarchical optimization of key elements. On the other hand, some scholars focusing on theoretical research prefer objective weight-determining methods, such as principal component analysis [8,9], grey relational analysis and catastrophe evaluation. Considering that each method has its scope of application and limitations, some scholars have tried to combine various methods to determine the weights with their own limitations.

3. Identification and Transmission of Uncertain Factors of China’s Oil and Gas Industry

From a macro perspective, many factors, such as fluctuation in international oil prices, change in deposit and loan interest rates and competitors’ ability, will affect the development of the domestic oil and gas industry. From a micro perspective, the implementation effect of the development plan will be affected by the quality of resources, hydrogeology level as well as roof and floor lithologic conditions, which means that they must also be considered as uncertainty. From the perspective of oil and gas production, there are some differences in the technologies and processes such as drilling, fracturing, gas production, gathering, transportation and sale, which implies that technical uncertainty needs to be considered. In summary, based on the identification and classification of uncertain factors in the oil and gas industry at home and abroad from existing literatures, this paper presents the identification and classification results of uncertain factors of China’s oil and gas industry in Table 1 below. The influence paths of uncertain factors are also shown in Figure 1 below.

| Dimension                  | Category                          | Uncertain factor                                                                 |
|----------------------------|-----------------------------------|----------------------------------------------------------------------------------|
| Resource uncertainty       | Resource quality                  | Sulfur content, volumetric weight, porosity, permeability, gas saturation, etc. |
|                            | Resource characteristics          | Depth of burial, gas-bearing area, hydrocarbon-generating layer thickness, gas content, reservoir pressure and critical desorption pressure |
|                            | Resource location                 | Climate type, geographic location, infrastructure condition and natural disaster |
| Technical uncertainty      | Exploration technology            | Seismic technology, well appraisal technology and exploration result              |
|                            | Drilling and well completion      | Pre-drilling control, drilling and well completion design and operation, equipment operation and drilling accident |
|                            | Fracturing technology             | Plan design and operation, raw material and equipment and fracturing accident     |
|                            | Ground construction level         | Design level, material and structure, design change, construction condition and material |
|                            | Production technology             | Production technology risk, production system and backup plan                     |
|                            | Gathering and transportation      | Construction level, storage and transportation media, pipeline network design, corrosion, operation and leakage |

Table 1 Identification and Classification of Uncertain Factors of China’s Oil and Gas Industry
Economic uncertainty

| Economic policy | Taxation policy, subsidy policy, mineral rights policy and environmental protection policy |
|----------------|----------------------------------------------------------------------------------|
| Oil and gas market | Market competition, market demand, market size and market price |
| Investment and financing environment | Deposit and loan interest rate, exchange rate and inflation level |
| Financial status | Fundraising, investment, cash flow and income distribution |
| Others | Enterprise interior factors Marketing level, management system, decision-making mechanism, emergency response mechanism and human resource mechanism |

Figure 1 Influence Path of Uncertain Factors on the Development of the Oil and Gas Industry

4. Research on Quantitative Methods of Uncertain Factors

The main risk factors faced by the oil and gas industry include resource factor, economic factor and enterprise interior factor. During the “14th Five-Year Plan” period, great attention must be paid to the uncertainty of existing oil and gas resources at home and abroad, the technological uncertainty in the future development and the macro-economic uncertainty in the future economic situation.

4.1. Quantitative Analysis of Resource Uncertainty

As to resource uncertainty, Guo [10] quantified this category of uncertainty into workable reserves and believed that resource uncertainty should be quantified by modified reserves. This paper shares and adopts his viewpoint. The modified reserve model is shown in Equation 1:

$$N^* = N \cdot (1 - S_{depth} - S_g) \cdot S_p \cdot IOC\%$$  \hspace{1cm} (1)

In the equation above, $N^*$ means adjusted reserves; $N$ means original workable reserves; IOC% means investor’s proportion; $S_{depth}$ means the adjustment factors for different resource burial depths; $S_g$ means the adjustment factors under different geographic conditions; $S_p$ means the adjustment factors for different resource quality.

Liu Jianye [11] predicted and analyzed the future trend of subsidy based on different situational
assumptions. According to the risk identification during the whole life cycle of coalbed methane development, he designed different compensation mechanisms for resource risk, technical risk and economic risk. The resource risk was compensated through the quantity of resources. The technical risk was compensated through various investment costs. The economic risk was compensated through the discount rate. In this way, all risks could be converted into the benefit evaluation process by means of compensation and a comprehensive evaluation model was also built for risk compensation. Finally, based on the distribution type of development parameters, this model was utilized to carry out the break-even analysis through probability density function.

4.2. Quantitative Analysis of Technical Uncertainty

As to technical uncertainty, considering the short period of exploration and production capacity construction, it is believed that other technical factors, such as exploration, drilling and fracturing, can affect the relevant investment apart from production technology. Technical uncertainty is believed to bring about changes in the related investment. Therefore, technical uncertainty is modified as follows:

\[ I_i^* = I_i \cdot (1 + S_{tec-i}) \]  \hspace{1cm} (2)

In the Equation 2, \( I_i^* \) is the investment amount after the compensation for the \( i^{th} \) technical uncertain factor. \( I_i \) is the theoretical investment amount under the condition that the \( i^{th} \) technical uncertain factor does not occur. \( S_{tec-i} \) is the adjustment factor of the \( i^{th} \) technical uncertain factor. Regarding the adjustment factor, it is believed that technological progress and learning effect will gradually decrease the investment. Therefore, the influence of learning effect needs to be removed and quantified, as shown in the Equation 3:

\[ S_{tec-i} = \frac{1}{n} \sum_{j=1}^{n} \left( \frac{I_{ij-act} - I_{ij-exp}}{I_{ij-exp}} \right) + S_{study} \]  \hspace{1cm} (3)

It is assumed that the construction party has carried out a total of \( n \) similar projects. \( I_{ij-act} \) is the actual amount of the \( i^{th} \) investment of the \( j^{th} \) project under the influence of previous risks. \( I_{ij-exp} \) is the designed amount of the \( i^{th} \) investment of the \( j^{th} \) project in the past. \( S_{study} \) is the adjustment coefficient of the learning effect during the \( i^{th} \) investment.

When trying to quantify technological progress, Ted mcCallister \([11]\) used the National Energy Modeling System (NEMS) to quantify the degree of technological progress in the American oil and gas industry. This method can also be utilized to quantify technological progress in China’s oil and gas industry. As shown by calculation results, the annual output without the technological progress for exploration, drilling and well completion as well as exploitation will decrease by about 0.68%, 0.84% and 0.55% respectively.

4.3. Quantitative Analysis of Economic Uncertainty

The transmission mechanism of the impact of international oil price fluctuations on the shale gas development benefits was studied\([13]\). Through trend analysis, correlation analysis, co-integration test and regression analysis, the researchers also quantified the effect of oil price on key evaluation parameters for development benefits of the factors, such as shale gas price, market size, investment and related operating costs. It is believed that this method can be applied to the whole oil and gas industry and the transmission path is shown in Figure 2 below.
It is believed that uncertain factors, such as economic policy, market, investment, financing and enterprise interior factors, will prolong the oil and gas development cycle. A method of quantifying the uncertainty by adjusting the discount rate is designed. Combined with risk identification, the adjusted discount rate with uncertainty quantification is calculated as follows.

\[ i_d = i_{NR} + i_{inf} + i_R + i_{pro} + i_{inv} \]  

(4)

In the Equation 4, \( i_d \) is the adjusted discount rate of coalbed methane projects under the compensation of economic uncertainty. \( i_{NR} \) is the risk-free rate of return in the country where the resource is located. \( i_{inf} \) is the inflation rate in the country where the resource is located. \( i_R \) is the overall uncertainty compensation in the domestic or overseas oil and gas industry. \( i_{pro} \) is the uncertainty compensation of the project. \( i_{inv} \) is the compensation for investment and financing risk and it can be ignored when there is no investment and financing activities.

The risk-free rate of return is measured by the long-term treasury interest rate. The inflation rate is measured by the CPI. The industrial risk is measured by the average return on net assets of the industry. The project risk is measured by the company’s average return on net assets for this type of project. The investment and financing risks are measured by the change of the historical investment and financing interest rates, with the specific method omitted.

5. Analysis of Difference in Oil and Gas Development at Home and Abroad

Although China’s oil and gas industry has basically the same types of uncertainties for oil and gas development as those of its foreign counterparts (See 2.1), there are great differences in the magnitude of the uncertainties. This chapter will analyze the main differences in the uncertainties of the oil and gas development both at home and abroad.

5.1. Impact of oil price uncertainty

Oil price is the main factor affecting the economic benefits of overseas oil and gas projects. Domestic oil prices influence the domestic projects while international oil prices affect international projects. Obviously, domestic oil prices are relatively stable while international oil prices fluctuate greatly.

5.2. Impact of exchange rate uncertainty

The exchange rate risk of overseas oil and gas projects is affected by various factors, including the exchange rate system of the invested country and the proportion of foreign currency in investment and financing of projects. Countries with more stable exchange rates will have a smaller risk for exchange.
rate.

5.3. **Impact of political uncertainty**
Most of China’s overseas investments in oil and gas projects are located in developing countries, leading to greater political risks.

5.4. **Impact of macro-economic uncertainty**
There is a growing demand for energy in those countries with a fast economic growth, which can secure the profitability of oil and gas projects.

5.5. **Impact of business environment uncertainty**
The business environment of the invested country will also have an impact on the benefits of overseas oil and gas projects, including whether the tax system of the country is stable, whether the infrastructure is in place and whether the investment environment is convenient for investors.

5.6. **Impact of legal uncertainty**
The legal system of the invested country will affect the benefits of oil and gas projects. A perfect, consistent and effective legal environment is conducive to the operation and management of petroleum companies besides reducing operating costs and increasing project benefits.

5.7. **Impact of contract uncertainty**
Contract terms have a considerable influence on the benefit of the contractor engaged in overseas oil and gas projects. There are great differences between technical service contracts, product sharing contracts and mineral taxation contracts in terms of fiscal and taxation terms and cost recovery. Moreover, the benefits gained by the contractors will be also different.

6. **Conclusions**
This paper first identifies, summarizes and classifies the uncertain factors of the oil and gas industry. The differences between the uncertain factors are analyzed from domestic and overseas perspectives. Some methods of quantifying different types of uncertain factors are also designed from the dimensions of resource, technology and economy.

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