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Risk Analysis of Exploration and Development in Oil and Gas Enrichment Area Based on Economic Benefit Analysis

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As everyone knows, oil and gas exploration and development process are rather complex. Effective risk management and reasonable avoidance of losses caused therefrom means so much to healthy and sustainable development of China's oil and gas industry. This paper analyzes the oil and gas exploration and development risks from the perspective of economic benefit, for example, in North China. Eventually, it turns out that the oil and gas resource extent in North China is richer and takes up a great portion. Among the eight areas where oil and gas reserves are distributed, K1 and K5 belong to the low-risk and high-yield areas with highest exploration value. A case study conducted on an oil and gas exploration and development project in the region K2 shows that the cost has the highest impact on the return on oil and gas exploration and development. Therefore, we should endeavor to reduce the discovery cost and thus increase the yield rate. The findings provide important clues to the exploration and development of oil and gas resources in other areas of China.

1. Introduction

As the most important strategic resources in China, oil &gas exploration and development is the core and the leader of the whole petroleum industry. It features high investment, high risk and high profit, and relatively complex as it is, its economic benefit will be subjected to a number of uncertain factors such as geological, technical and economic conditions, etc. It is precisely because of these uncertain factors that there is a big risk in the oil and gas exploration and development process (Zhang and Kang, 2012). China's oil and gas resources are more abundant, but enough attention was never paid to risk awareness and prevention during oil and gas exploration and development (Klaiber et al., 2016). Effective risk management and reasonable avoidance of losses caused therefrom in this process make sense of the healthy and sustainable development of China's oil and gas industry (Jenden et al., 2015).
By far, many scholars at home and abroad have conducted a lot of surveys on the oil and gas exploration and development, and these efforts have borne fruits. Some scholars have evaluated the risks of oil and gas exploration and development (Nelson, 1988; Vengosh et al., 2014; Sun et al., 2015); some made extensive studies on the risk management for oil and gas exploration and development (Yadav and Avadich, 2010; Copping et al., 2015); some have also studied the economic benefits of oil and gas exploration and development (Osofsky, 2012; Chen et al., 2015). As north China reserves abundant oil and gas resources, now taking it as an example, this paper analyzes the oil and gas exploration and development risks from the perspective of economic benefits, thus making much sense in theories and practices.

2. Establishment of risk analysis model

The ultimate purpose of oil and gas exploration and development is to obtain oil and gas reserves and thus access to resources. However, due to many uncertainties such as risks in the oil and gas exploration and development process, it is usually impossible to obtain the expected reserves for oil and gas and realize economic benefits (Feng et al., 2014). Therefore, it is not enough to identify the risks. It is also necessary to judge the impact degree of risks and the economic benefits that oil companies can obtain. Now, the net present value (NPV) is an important indicator for measuring economic benefits. The specific formula is:

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$$\mathrm{NPV}=\sum_{t=1}^{n}(CI-CO)_t(1+i_0)^{-t} \quad (1)$$

The specific indicators for evaluation system are shown in Table 1.

Table 1: Evaluation system of cash flow method

	Evaluating indicator	Evaluating indicator
Reserves	Reserve parameters	Crude oil density 、oil area
	Reserve index	Oil reserves 、 recoverable reserves 、 reserves abundance
	Reserve cost	Proven reserves cost and discovery cost
Development class	Development parameters	Oil production rate and decline factor
	Production parameters	productive power
	Investment indicators	Total development investment
Sales category	Sales parameters	Crude oil price and crude oil commodity rate
	Sales Index	Total profit and after tax profit
Cost class	Cost change rate	Management fee and operation fee
	Total cost	Financial expenses, management costs and operating costs
	Unit cost	Cost and total cost

Up till now, there are many models for calculating the degree of impact of the risks on revenue. Common risk assessment methods are: Monte Carlo simulation (MCS), Delphi method and sensitivity analysis (Wu, D. D., et al. 2010). Among them, the MCS is mainly used to calculate the oil & gas resources, but cannot reflect the economic benefits; Delphi method is cumbersome to operate; the sensitivity analysis can use the degree of risk change to analyze its economic benefits for oil & gas exploration and exploitation, but it will be unable to judge the possibility of the project operation.

Based on the net present value formula, the MCS method is introduced to calculate the probability of scale return by relevant method, and the risk indicators is set up to reflect the risk level (Kruizinga et al., 2008). According to the central limit theorem, no matter what distribution the random variable X_k (k=1，2…) is subject to, if only they are independent of each other, the mathematical expectation and variance can be expressed as:

$$\mathrm{E}(X_k)=\mu_k,\ \mathrm{D}(X_k)=\sigma_k^2>0,\ \mathrm{k}=1, \quad (2)$$

If *n* is greater, it means to be approximately subject to the normal distribution. For X～N(μ，σ2), it can be transformed into a standard normal distribution by linear transformation, that is, $\mathrm{Z}=\frac{X-\mu}{\sigma}\sim\mathrm{N}(0,1)$, and the conversion into a distribution function F(x) can be expressed as :

$$\mathrm{F(x)}=\mathrm{P}\{X\le x\}=P\left\{\frac{X-\mu}{\sigma}\le\frac{x-\mu}{\sigma}\right\}=\Phi\left(\frac{x-\mu}{\sigma}\right) \quad (3)$$

In formula (3), a risk indicator can be set up, and expressed as:

$$\sigma_{risk}=P\{NPV\le NPV_{fix}\}=P\left\{\frac{NPV-\mu}{\sigma}\le\frac{NPV_{fix}-\mu}{\sigma}\right\}=\Phi\left(\frac{x-\mu}{\sigma}\right) \quad (4)$$

Where, NPV_{fix} represents the NPV available from the conventional economic evaluation on oil and gas exploration and development; σ_{risk} represents risk indicator, which shows that the economic benefit from oil and gas exploration and development under the risk impact is less than the probability of NPV_{fix}. The higher the value σ_{risk}, the greater the probability that the current economic return is less than the ideal economic benefit, and the greater the risk (ÖnderÖkmen and Ahmet Öztaş. 2008).

For some different parameters, different impacts will be produced on the economic evaluation indicators of oil and gas exploration and development, such as investment, cost, finance, price, etc. (Patil and Frey, 2010). The contribution of the evaluation parameter *X* to the evaluation indicator *Y* can be expressed as:

$$\mathrm{R}=\frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sum_{i=1}^{n}(x_i-\bar{x})^2} \quad (5)$$

Where, *R* is the contribution rate; $\bar{x}$ and $\bar{y}$ are expressed as the mean values of X and Y, respectively.

3. Risk Analysis of Oil and Gas Exploration and Development in North China

3.1 Current situation of oil and gas resources in North China

China's oil and gas resources are rather abundant in reserves, especially in recent years, with the relentless advancement of the exploration and mining technologies, China's oil and gas production has shown an increasing trend year by year. In particular, China's petroleum outputs increase progressively every year. As of 2016, China's petroleum reserves have reached 235.4 million tons, ranking third in the world, as shown in Fig. 1.

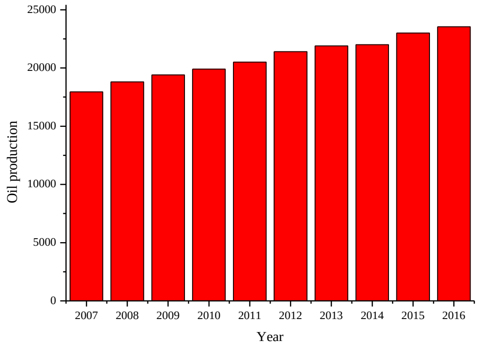

Figure 1: Changes in China's Oil Production from 2007 to 2016

North China, as the largest and the most vigorous area in China, is endowed with much more abundant oil and gas resources than other areas. There are considerable oil and gas outputs as shown in Fig. 2.

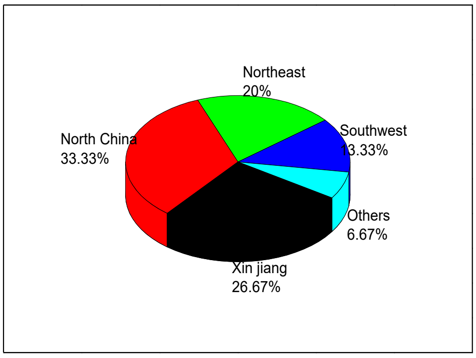

Figure 2: Changes in China's Oil Production from 2007 to 2016

Now, this paper analyzes the oil and gas exploration and development risk in North China with rich oil and gas resources. The oil and gas exploration and development in North China mainly concentrate in 8 regions. Given the above, the risk assessment is performed on these 8 regions in North China, and the risk indicator can be available. The specific calculation results are shown in Table 2.

Table 2: Risk indicator of 8 regions in North China

Region	Risk index	NPV_{fix}
K1	0.1658	12.35
K2	0.1405	0.45
K3	0.3546	12.05
K4	0.3123	1.8312
K5	0.1634	37.65
K6	0.4812	0.1345
K7	0.1104	0.5621
K8	0.2121	0.034

Based on data in Table 2, the relationship between NPV_{fix} and risk in different regions can be studied, where, there are four different regions: A, B, C, and D, as shown in Fig. 3.

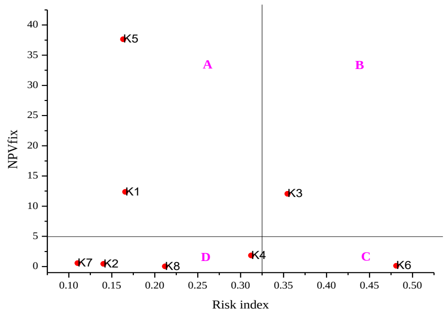

Figure 3: Risk - Benefit Analysis Map of Eight Regions in North China

From Fig. 3, we can find that, among the eight regions in North China, K2, K4, K7, and K8 pertain to the low-risk and low-yield regions (Region D), and K1 and K5 are the low-risk and high-yield areas (Region A). These are the regions with the highest development value. Therefore, most investors will choose to explore and develop oil and gas resources in these two regions. K3 is a high-risk and high-yield region (Region B), where, only those companies who have strong capitals and are capable of bearing certain risks will conduct exploration and development. K6 is a high-risk, low-yield region (Region C), which investors generally do not choose for oil and gas exploration and development since there is a high risk but the final rate of return is not high, unless the government will take some measures to give preferential policies or compensation. In general, companies will not participate in exploration and development in such region. Therefore, from the general view, the oil and gas resources in most regions of North China are worthy of exploration and development.

3.2 Specific case analysis

This paper performs a specific case analysis on an oil and gas exploration and development project in the region K2 of North China. Key parameters are as follows: the construction period lasts for 2 years; the production period lasts for 15 years; the crude oil commodity rate is 96%; the profit margin is 13%; the depreciation time of fixed assets is 6 years; the residual rate is 6%. The cost is shown in Table 3. The rate of change in the any of development costs such as operation expenses is 0.

Table 3: Main cost details

Parameter	Cost	Parameter	Cost
Raw materials and main materials cost for oil wells	8	Annual downhole operation cost of production well	6
Annual fuel cost of production well	4	Annual repair fee	4
Annual direct wages and benefits of oil wells	10	Paid royalty of reserves	1
Transportation cost of production well	5	Oilfield maintenance expenses	45
Unit water injection fee	9	Development well drilling cost	30

Table 4: Distribution characteristics of reserves parameters and recovery factor

Parameter	Distribution characteristics	Maximum	Minimum	Most likely value	Value 1	Value 2	Fixed value
Oil-bearing area	Triangle	5.3	2.4	4			
Oil saturation	Triangle	49	38	45			
Porosity	Normal state	32	24	28			
Effective thickness	Uniformity				11.35	14.95	
Density of crude oil	Uniformity				0.92	0.94	
Volume coefficient	Fixed value						1

Table 5: Distribution characteristics of development parameters

Parameter	Distribution characteristics	Value 1	Value 2	Parameter	Distribution characteristics	Fixed value
recovery ratio	Uniformity	25	32	Steady production years	Fixed value	4.5
Oil recovery speed	Uniformity	2.2	2.8	Single well daily production	Fixed value	15
Drilling success rate	Uniformity	96	100	Average depth of well	Fixed value	3500
Crude oil price	Uniformity	1200	1400	Injection production ratio	Fixed value	2.5
Single well diurnal injection	Uniformity	15	19	Well distribution coefficient	Fixed value	1.1

The candidates and predictions of the parameters for reserves and development parameters of oil and gas resources are shown in Tables 4 and 5.
From data in Table 4 and Table 5, it can be found that the yield rate of oil and gas exploration and development project in the region K2 of North China ranges from -3.54% ~13.96%, and the maximum probability of yield range is 3.96% ~ 5.03%, as high as 30%. The contribution rate of crude oil price return is 12.35%, which shows that, if the price of crude oil rises by RMB 1/ton, the yield will increase by 0.1235%. It is found from the analysis of other factors that the contribution rate of cost to the rate of return is the maximum, indicating that the cost has the highest impact on the return. Therefore, great efforts should be made to reduce the discovery cost and thus increase the rate of return.

4. Conclusion

This paper analyzes the risks of oil and gas exploration and development from the perspective of economic benefits in some areas of China, for example, in North China, and it is found that:
(1) China's oil and gas resource reserves are more abundant. With the continuous advancement of exploration and mining technology, oil and gas yield more year by year. The oil and gas resources in North China are relatively abundant, and take up a great portion. Among reserve areas, K1 and K5 are low-risk and high-yield areas with the highest development value.
(2) A case study made on an oil and gas exploration and development project in the K2 area shows that the cost has the highest impact on the return on oil and gas exploration and development. Therefore, we should endeavor to reduce the discovery cost and thus increase the yield rate.

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