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Based-estimated volatility Real Option evaluation method in drilling exploration and development

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Abstract. Oil and gas field development are characterized by high risks and uncertainties, thus making relevant risk evaluation is an essential decision to reduce development losses. On the basis of comprehensive analysis of traditional evaluation methods, combined with a gas field development example, the Real Option method is used to break through the “static” evaluation of the Net Present Value of traditional assessment, and the uncertainty factor is taken as an active impact factor, which the bigger to may excavate greater result. The benefits are calculated by numerical simulation using Monte Carlo Simulation method to establish a Real Option model based on volatility estimation. The evaluation results show that the Monte Carlo Simulation uses the correlation between the indicators to establish a Net Present Value model, which can comprehensively consider a variety of factors, and can also obtain the corresponding cumulative probability. The results are more objective and more realistic, and more reasonable evaluation.

1. Introduction

There are great risks and uncertainties in oil and gas field development, thereby making evaluations and strengthening risk analysis are prerequisites for avoiding risks and reducing losses [1]. The traditional Discounted Cash Flow (CFD) economic evaluation method is applicable to drilling project evaluation with less uncertainty factors and shorter production period. When it is used to evaluate projects with large strategic risks, it is likely that the value of the project will be underestimated. Insufficient investment in the long run will damage the long-term competitiveness of enterprises [2]. The real option method breaks through the static evaluation of traditional economic evaluation methods, and is suitable for project investment decisions with long cycle and high risk. At present, real option theory has been widely used in investment development. However, the determination of volatility in the conventional method is mainly based on historical oil price data, and the inaccuracy of volatility estimation has great influence on the evaluation of options, which makes the calculation of Option value have certain error, thereby restricts the application of Real Option method.

The Monte Carlo method can solve the above problems well. This paper uses Monte Carlo numerical simulation method to estimate the volatility, and through statistical test analysis of multiple random variables, random simulation, according to the probability distribution of Net Present Value, to get the random number which used to calculate the sampled value of Net Present Values. Finally, the approximate solution of the volatility is solved by the large number theorem, which accurately reflects the characteristics of the volatility, and the obtained result is more scientific and reliable.



The rest of this paper is organized as follows: In Section 2, the related information of traditional economic evaluation methods is proposed and the determine of volatility by Monte Carlo simulation is reviewed. In Section 3, the implementation using the proposed method is presented on the case study of a gas field, the results show that this gas field is suitable for exploration and development. Section 4 gives conclusion of the whole work.

2. Traditional economic evaluation method

The Discounted Cash Flow method (DCF) is one of the most commonly used methods in traditional economic evaluation. It is a method to considers all income and expenditure during the life of the project, and consider the time value of funds. The economic evaluation using DCF is a method of discounting the income and expenditure of different time periods to the same time point and then comparing. The most common methods in the DCF method include: Net Present Value method, Investment Payback Period method, Benefit Cost Ratio method, and Internal Rate of Return method.

2.1. Net present value method

The Net Present Value (NPV) method is to calculate the Net Present Value of the income and expenditure incurred during the life of the project (according to the same discount rate), and then compare and draw conclusions. The calculation method is as shown in (1).

$$NPV = \sum_{t=0}^N (CI - CO)_t (1+i)^{-t} \quad (1)$$

Among them: NPV is the Net Present Value of the project; CI is the cash inflow, which mainly includes sales income, government subsidies, and assets recovery; CO is cash outflow, which mainly includes investment, working capital outflow, operating costs and taxes; $(CI - CO)_t$ is the NPV for year t ; i is the financial benchmark rate of return; N is the life of the project. Judging basis, when $NPV > 0$, the project can be developed.

2.2. Investment Recovery Period method

The Investment Payback Period method is the time required for the total investment of the project to be fully recovered from the depreciation, amortization amount and income under normal production and operation conditions after the project is put into production, and is recorded as P_t . The basic calculation is as follows (2).

$$\sum_{t=1}^{P_t} (CI_t - CO_t) = 0 \quad (2)$$

Among them: P_t is the investment recovery period, other symbols are the same as above.

Judging basis: when $T_p > T_b$, the project can be developed (where T_b is the industry standard investment payback period).

2.3. Internal Rate of Return Method

The Internal Rate of Return (IRR) method can reflect the profitability that the project can provide for its funds. It is the discount rate that the sum of the present value of the Net cash flow of each year from the beginning to the end of the life (calculation period) is equal to zero. The specific mathematical manifestation is shown in the following formula (3).

$$\sum_{t=0}^N (CI - CO)_t (1+i)^{-t} = 0 \quad (3)$$

3. Real Option evaluation based-estimated volatility

3.1. Uncertainty analysis

3.1.1. Monte Carlo simulation. In the economic evaluation of oil and gas exploration and development programs, the basic data used in traditional economic evaluation methods (such as oil and gas production, investment, cost, product sales price, etc.) have great ambiguity and high degree of uncertainty because of its large Partly from prediction or estimation, and because the results of traditional method evaluation can provide a certain internal rate of return or net present value, the reliability of the value cannot be quantified, and the economic evaluation decision maker is judged to a certain extent. Bring risks.

The Monte Carlo method is a branch of experimental mathematics. It uses random numbers for statistical experiments. It can randomly simulate the dynamic relationship between variables, obtain a large number of analog measurement results and analyze them, and solve some complex uncertainties or risk problems. [1]. Based on the analysis of the probability distributions obeyed by various uncertain factors, it makes sensitivity analysis on the main uncertain factors, determines the main risk factors and considers the correlation between the factors in combination with the model, and uses Monte Carlo simulation. Uncertain factors of the economic evaluation model are fully considered by Monte Carlo, therefore it is useful to avoid the possible losses caused by the unexpected emergence of uncertain factors[3]. Besides, in the economic evaluation risk analysis, it not only allows people to know the range of risk factors, but also quantitatively describes its impact on major economic indicators, which makes the results of its evaluation more realistic, and the economic evaluation is more scientific and objectively reasonable.

3.1.2. Real Option method. The Real Option method is to evaluate the investment value of the project based on the concept of options. It is a dynamic evaluation method that fully considers the value of uncertainty and investment decision flexibility. From the perspective of option investment, the fluctuation of oil and gas prices and the uncertainty of oil and gas reserves give typical option characteristics, and the uncertainty is regarded as a positive factor of venture capital projects. The more uncertainties, the more options options may be included. It is also bigger.

The Real Option method can be used to solve the economic evaluation and investment decision-making problems of high-risk, multi-uncertainty and multi-stage investment projects. The exploration and development characteristics of oil and gas field projects are characterized by large risks and uncertainties, and the investment is generally Multi-stage investment[3-5]. Generally, the whole development process is divided into pre-exploration exploration stage, evaluation exploration stage and development stage. The Real Option method considers each stage of the oil and gas exploration and development project as a whole, and after each stage, through stage evaluation, the oil company can decide whether to continue the next investment in final. Due to space limitations, this paper only studies and develops the real option B-S model formula adopted by its oil and gas field project as follows:

$$NPV_T = NPV + C \quad (4)$$

$$C = AN(d_1) - Xe^{-rt}N(d_2) \quad (5)$$

$$d_1 = \frac{\ln(A/X) + (r + \sigma^2/2)t}{\sigma\sqrt{t}} \quad d_2 = d_1 - \sigma\sqrt{t} \quad (6)$$

Where: C is the Real Option value of the undeveloped reserves; N(x) is the cumulative probability distribution function of the standard normal distribution; A is Cash flow of the block to be developed, A=Total output×Oil price×Parities×Tons of barrel than; X is Development investment and cost, X=Investment volume×Fixed cost×10; r is the risk rate, and σ is the volatility.

3.2. Volatility based on Monte Carlo simulation

In economic evaluation, volatility is the standard deviation of assets. Then the general article only examines the volatility by using historical oil prices, which ignores the impact of the market environment and causes unreasonable results. The calculation of the volatility of this paper is based on the method in Zhou's article[2], and the annual net present value is used as the basis for the calculation of the volatility, so that the time value of the project is fully reflected, and the standard deviation of the Net Present Value and the Net Present Value of the mathematical expectation value ENPV are utilized. The ratio represents the volatility, which reflects the volatility of the Net Present Value and reflects the volatility of the asset.

In order to obtain more accurate volatility, this paper uses Monte Carlo simulation to enhance the economic parameters such as total output, investment amount, cost and oil price, which affect the cash flow, and analyze the probability of uncertain factors changing at different amplitudes and distribution, and the impact on the Net Present Value of the project, the volatility of real options is measured.

3.3. Measurement steps of Real Option evaluation method based-estimated volatility

The basic steps are as follows:

(1) Determine the uncertainty parameters of economic evaluation of oil and gas field development, based on the law of exploration and development and the characteristics of each factor, study its probability distribution and find out the relationship function between random variables and Net Present Value.

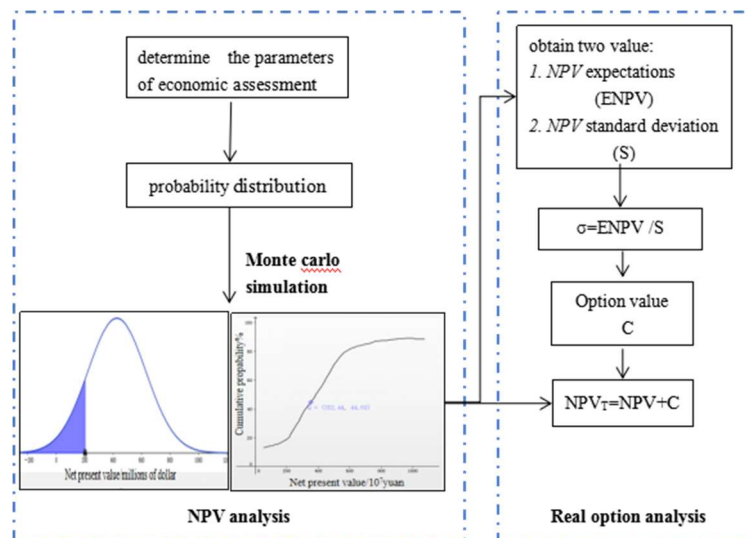


Fig. 1 Volatility based on simulation results - real option idea

(2) Using Excel and @Risk software to establish Monte Carlo simulation model, for the factors affecting the Net Present Value such as total output, investment, cost and oil price, numerical simulation based on its distribution function, using Colmogo Rolf's law of increasing numbers, after 5000 random sampling and operations, yielded a series of financial Net Present Value.

(3) Analyze the expected value[2], standard deviation, probability distribution and cumulative probability distribution obtained from the simulation results of the financial Net Present Value.

Calculate the volatility of the development of the oil and gas field project, and then calculate the option value C, and finally obtain the comprehensive Net Present Value of the Real Option.

4. Case analysis

The data in this paper is from Zhang's article[3] in 2012. Based on the sensitivity analysis of the project, Zhang determined that the three factors of oil and gas price, load factor and operating cost have a strong relationship with internal rate of return. For the product sales and price in the analysis, Together, it

reflects oil and gas production. However, the uncertainty analysis in the project is not limited to the above indicators. Based on the research purpose of this paper, the Net cash flow indicators affecting each year include: annual construction investment amount, oil sales volume, sales price, etc. The specific parameter values are shown in Table 1. These factors are random variables with great uncertainty, so the Net cash flow of each year becomes an uncontrollable random variable. The Monte Carlo simulation of the economic evaluation of oil and gas field development in this paper is to make a probability analysis of each economic evaluation index, obtain the probability distribution of each economic evaluation index, and build a Monte Carlo simulation model of the cash flow of the development project. The mean and standard deviation of the net present value NPV, using the formula to calculate the volatility of the project.

Tab.1 Project Development Economic Evaluation Parameter Table

Parameters	Number	Parameters	Number
Total output/10 ⁴ t	50.218	Investment horizon	5
Investment volume/10 ⁷ yuan	191.802	Productive life	25
Fixed cost/10 ⁷ yuan	36.050	Oil price/(dollar*barrel ⁻¹)	70
Parities/(dollar*yuan ⁻¹)	6.92	Tons of barrel than/(barrel*t ⁻¹)	7.428
Benchmark yield%	12.0		

4.1. Net Present Value simulation and determination of volatility

According to the regular characteristics and probability distribution of oil and gas field development projects, using the principle that the data obeys the central limit theorem[6], the normal distribution is used to give the probability distribution function of each parameter and the Net Present Value, the Figure. 2 as follow.

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{1}{2}\left(\frac{X-\mu}{\sigma}\right)^2\right] \quad (7)$$

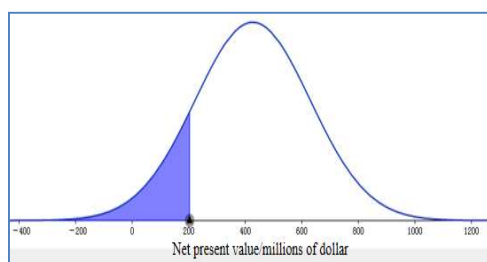


Fig. 2 NPV standard normal distribution

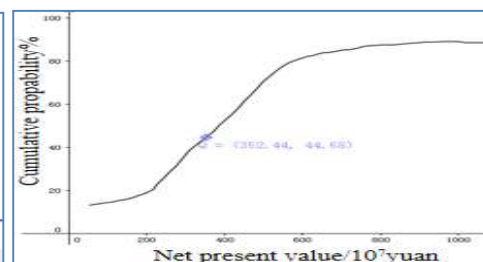


Fig. 3 NPV cumulative probability

Using the Monte Carlo method to perform 5000 simulations[4], the model results calculated ENPV=458.76×10⁷yuan, and the standard deviation S=203.56×10⁷yuan, which is different from the one in Zhang's article because of the uncertain factors considered in this paper. It also includes other indicators, which make the result larger. The FIG.3 shows that the meaning of Q point is: the cumulative probability that the Net Present Value is not more than 352.44×10⁷yuan is 44.68%. Finally, the paper determines the volatility of the exploration and development of the gas field project $\sigma = S / |ENPV| = 44.4\%$.

4.2. Real Option evaluation results

The Option value impact parameters are: risk-free interest rate r is calculated by 8%, volatility σ is 44.4%, investment period t is 5 years, and the project temporarily does not consider dividends.

The Net Present Value $NPV=359.36 \times 10^7$ yuan is calculated by Monte Carlo simulation to determine the intermediate variable d_1 , d_2 of the distribution function, where $d_1=-1.09$, $d_2=-2.083$.

Find the cumulative probability distribution function of the standard normal distribution by looking up the standard normal distribution function table

$$N(d_1)=1-N(1.09)=0.1379; N(d_2)=1-N(2.083)=0.0188$$

The option value calculation result is $C=180.691 \times 0.1379 - 552.295 \times e^{-8\% \times 5} \times 0.0188 = 36.21 \times 10^7$ yuan.

Therefore, the oil and gas field project contains a comprehensive Net Present Value of the Option value, $NPV_T = NPV + C = 359.36 \times 10^7 + 36.21 \times 10^7 = 395.57 \times 10^7 > 0$. Therefore, the oilfield project can be explored and developed.

5. Conclusion

(1) Due to the characteristics of high risk and high uncertainty, oil and gas field projects are particularly important for risk analysis before project exploration and development. In this paper, uncertainty is regarded as a positive factor. The larger the value, the more potential value exists, which shows the characteristics of financial options for the development process. The method based on Real Option evaluation can more accurately evaluate the value of project development and determine the importance and significance of its exploration.

(2) The volatility estimation method established by Monte Carlo simulation method avoids the objectivity determined by historical oil price data in the conventional method, solves the problem of volatility in Real Option evaluation, and improves the accuracy of measurement.

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