Method for Determining Lowest Oil Price Limit by Developing Tight Peripheral Oil in Daqing

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Abstract. The outer oil field of Daqing is a low-permeability oil field, which has a large proportion of the tight oil reserves. Due to the high development costs of the tight oils, many fields are difficult to reach the standard of economic evaluation. It increases the difficulty in optimizing reserves and use of reserves. In the process of the development of the tight oil field, it is important to determine the limit of starting oil price. It is also an important basis for determining the launch of the oil field development project. The evaluation of present value method does not consider the change process of external conditions and has certain limitations. However, the introduction of investment option value method for evaluation can fully consider changes in oil prices and other external factors, and provide a more realistic assessment of the oilfield development process. In the case of low oil prices, some tight oil fields can also be used effectively, which improves the efficiency of resource utilization, increases the scale of reserves utilization, and solves the problem of optimization and evaluation of reserves.

Keywords: Oilfield development, tight oil, oil price boundary, option evaluation method.

1. Introduction

With the increasing demand for oil resources, tight oil has become a hot spot in oilfield development in recent years. In China, tight oil was only used to describe low-permeability sandstone oilfields, and then it was strictly limited. The peripheral oilfields of Daqing placanticline are Low-permeability Oilfields with strong reservoir heterogeneity, small natural energy and low single well production. The reserves of tight oil account for a large proportion. There are many uncertain factors in the development process, which make it difficult to develop and have high development costs. Therefore, it is necessary to strengthen core area optimization and economic evaluation. Determining the initial oil price limit of oilfield development is an important content in the development process. The traditional internal rate of return method and net present value method are usually used for economic evaluation of oil fields. Under the current situation of relatively low oil price, many tight oil blocks are difficult to be effectively utilized.
2. Comparison between option evaluation method and traditional evaluation method

The option is actually a kind of option right, the holder can take some action in the future or not. It can be said that it is the holder's right to buy the underlying assets at a certain price within a specified period of time. During this period of time, the holder can exercise this right or give up this right. The characteristic of option is that it can make investors pay less cost and enlarge profit space on the basis of controlling loss. In this way, the greater the volatility of the underlying asset value, the greater the uncertainty, and the greater the value of the option.

The traditional economic evaluation method is to use the net present value method to judge the initial oil price limit of tight oil field development. At present, this method is used to determine the limit of tight oil in Daqing peripheral oilfields. It is to discount the future cash flow of investment scheme at a specific discount rate, and calculate the oil price when the net present value is zero, so as to determine the initial oil price limit of oilfield development.

\[ \eta_{NPV} = \sum_{t=1}^{n} \frac{c_t}{(1 + R)^t} - \sum_{t=1}^{n} \frac{l_t}{(1 + R)^t} \]  

(1)

The traditional net present value method used in economic evaluation cannot consider the information of future changes, which is a static and rigid evaluation \[9\], and assumes that the investment is completely reversible and has certain limitations \[10\]. In the theory of real option, the uncertain factors in the future are fully considered. According to the different situations of oilfield development, the project can be invested, postponed or abandoned, and the value of the project can be evaluated more truly.

Tight oil fields in peripheral oilfields of Daqing placantcline have low reserve grade, low abundance and rapid decline, and the project development has the characteristics of real option \[10\]. First of all, there are many uncertain factors in the development process. Secondly, the development investment is irreversible. Once the investment cost is invested, there will be accidents. For example, if there is no industrial oil flow in drilling, the capital will become the sunk cost. In addition, the development investment is flexible. The oilfield developers can flexibly choose to expand, reduce or postpone the development process according to the actual situation.

3. The process of investment option evaluation method

Stochastic process is a process that describes the change of variables under uncertain constraints. Because the change of asset price is uncertain, it is suitable to analyze the future change of asset price. This is the formula of the differential equation of random motion: \( \frac{dx}{dt} = a(x, t)dt + \sigma(x, t)dz \), where \( a(x, t) dt \) is the drift rate and \( \sigma(x, t) \) is the interference intensity.

According to the stochastic motion differential equation, the partial differential equation model of investment options can be derived:

\[ \frac{1}{2} \sigma^2 x^2 T_x(x, t) + (r - \delta)x T(x, t) + T_t(x, t) - rT(x, t) = 0 \]  

(2)

For the oilfield development with no fixed period, the only factor influencing the investment decision is the single variable oil price \( y \), and the investment option partial differential equation 1 becomes the differential equation about oil price \( y \):

\[ \frac{1}{2} \sigma^2 Y^2 T_{yy}(Y) + (r - \delta)YT_{y}(Y) - rT(Y) = 0 \]  

(3)

This differential equation of investment option value is a second order homogeneous differential equation. The solution of this differential equation is

\[ T(Y) = aY^{a_2} + \frac{N}{D + \delta}Y - \frac{NC}{D + \tau} \]  

(4)

When \( T(Y) - l = 0 \), At this time, the oil price is the threshold oil price for tight oil development

\[ aY^{a_2} + \frac{N}{D + \delta}Y - \frac{NC}{D + \tau} - 1 = 0 \]  

(5)

Among

\[ a = \frac{NC^{1-a_2}}{a_1-a_2} \left( \frac{a_1}{D + \tau} + \frac{1-a_1}{D + \delta} \right) \]  

(6)
\[ \alpha_1 = \frac{1}{2} \left( \frac{r-\delta}{\sigma^2} + \sqrt{\left( \frac{r-\delta}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2}} \right) \]  
(7)

\[ \alpha_2 = \frac{1}{2} \left( \frac{r-\delta}{\sigma^2} - \sqrt{\left( \frac{r-\delta}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2}} \right) \]  
(8)

4. Determination of key parameters of investment option evaluation method

D is the decline rate of production, \( \sigma \) is the volatility of oil price, R is the risk-free interest rate, 5% of the interest rate of short-term treasury bonds is selected as the risk-free interest rate, and \( \delta \) is the convenience yield.

\[ \delta = \frac{D}{j} \]  
(9)

L is the after tax profit, \( j \) is the value of the developed oil reserves, where \( j \) should be about 30% of the oil price, \( l \) is 40% of the oil price, and the decline rate of production is \( d = 12\% \). Then the convenience rate of return can be expressed as

\[ \delta = \frac{12\% \times (40\% - 30\%) Y}{30\% Y} = 0.04 \]  
(10)

Calculation of oil price volatility

\[ X_i = \frac{(Y_{i+1} - Y_i)}{Y_i} \]  
(11)

\( X_i \) is the logarithm of the price ratio, \( y \) is the price, and the price volatility is the mean square deviation.

\[ \sigma = \sqrt{\frac{\sum_{i=1}^{n-1} (X_i - \bar{X})^2}{n-1}} \]  
(12)

The crude oil prices from 1987 to 2016 were counted, and the oil price volatility was calculated as \( \sigma = 0.255 \).

5. Application examples

The g58 block of Daqing placanticline peripheral oilfield is an undeveloped tight oil block. There are 25 planned wells and 25 infrastructure projects. The annual production capacity is 95826.5 barrels. The total investment is 17282608.7 dollars, the total cost is 60.93 dollars per barrel, and the production decline rate is 12%.

\[ a_1 = 1.65, a_2 = -0.97, a = "677034644.8" \]

By substituting the parameters into the oil price equation 5 which is the initial limit of tight oil development, we can get the result

\[ 677034644.8Y^{-0.97} + 598915.6 Y - 51629624.89 = 0 \]  
(13)

By using the univariate solution function of simulation analysis, the iterative solution is obtained, and \( P = 67.0 \) USD / barrel. Using the conventional NPV method, \( R \) is the discount rate. Currently, the peripheral oilfields are taken as 6%, \( n = 15 \). Each parameter is substituted into the equation. When the NPV is zero, the single variable solution function is also used for iterative solution. The calculated initial oil price \( P = 79.2 \) USD / barrel.

To sum up, the initial oil price of g58 block obtained by differential equation of investment option value is 67.0 US dollars, while the initial oil price calculated by conventional net present value method is 79.2 dollars. The evaluation result is lower than that of conventional method, which increases the scale of reserve production and solves the problem of reserve block selection and evaluation.

6. Conclusion

(1) The result of calculating the oil price limit of undeveloped tight oil field by differential equation method of investment option value is lower than that of traditional net present value method, because the traditional net present value method underestimates the value of undeveloped tight oil field, which is more helpful to the development and development of oil field in the period of relatively low oil price.
(2) The differential equation method of investment option value does not negate the original NPV method, but considers the fluctuation law of oil price and other external factors in the original method, so as to evaluate the value of tight oil field more comprehensively.

(3) The traditional NPV method is suitable for the development of conventional oilfields with small uncertainty, while for tight oil fields around Daqing placantcline, there are many uncertain factors in the development process, so it is more suitable to use the investment option value method to evaluate.

7. Explanation of symbols

\( \eta_{NPV} \) — Net present value, 10000 yuan

\( C_t \) — Cash inflow at time t, 10000 yuan

\( I_t \) — Cash outflow at time t: 10000 yuan

\( R \) — Discount rate

\( T \) — Investment option value, USD

\( Y \) — Oil price, USD / barrel

\( C \) — Total cost, USD / barrel

\( I \) — Total investment, USD

\( r \) — Risk free interest rate

\( \delta \) — Convenience rate of return

\( N \) — Annual production capacity, barrels

\( D \) — Decline rate

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