An Application of Expanded Real Option in Investment Decision-making of Iron Ore Resources in Chinese Steel Enterprises

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Abstract. Due to the huge fluctuation of iron ore prices and the excessive dependence on overseas iron ore, Chinese steel enterprises have a greater risk of raw material supply. Based on the theory of financial options, this paper expounds the pricing method of real options, and analyses the value composition of real options in iron ore investment projects. Based on Black-Scholes option pricing model and taking the fluctuation of iron ore price as a virtual variable, a decision-making model of iron ore resources investment with expanded real options is constructed. This not only improves the traditional NPV investment decision-making methods, but also improves the efficiency of foreign investment of Chinese steel enterprises.

Introduction

China is the world's iron and steel production and consumption center. In 2015, China produced 540 million tons of iron ore and consumed 1.11 billion tons of iron ore, accounting for 60% of the world's iron ore consumption. At the same time, for the first time, the external dependence of iron ore imports has exceeded 80%, and the proportion of iron ore imports from Australia and Brazil has reached 83.8% of China's total imports[1]. In 2016, China's crude steel output was 808 million tons, accounting for more than 50% of the world's total, steel consumption was 681 million tons, accounting for nearly 45% of the world's total, even the growth of domestic iron ore production could not meet the rapidly growing demand for iron ore. Despite China's large demand, the rising international iron ore prices over the past decade have had a huge negative impact on China's iron and steel industry. Therefore, China's steel industry production is still facing a high degree of dependence on foreign iron ore and price uncertainty risk.

In view of the situation of iron ore price and safety, many scholars put forward their own reasons and countermeasures. Caldentey R and Haugh M (2006) studied the dynamic hedging of corporate profits in financial markets, and discussed how different information conditions can lead to different types of hedging and better operational solutions [2]. He Weida and Wan Xuejun (2008), Chen Yushan (2015) mainly used game tools to study the pricing rights and pricing mechanism of iron ore and put forward corresponding countermeasures[3]-[4]. Fan Songmei et al. (2018) comprehensively evaluated the supply risk of iron ore resources in China from five aspects: market risk, resource risk, political risk and market power. It was found that the supply risk of iron ore resources in China mainly existed in resources and political risk, and the risk level was higher[5]. Based on previous studies, this paper constructs an investment decision-making model of iron ore project based on Black-Scholes theory of options, which takes advantage of the uncertain impact of iron ore prices. This model better copes with the investment behavior with price risk in the market, and provides decision theory for steel enterprises to obtain more competitive raw material supply.

Pricing Method and Value Composition of Real Options in Iron Ore Resources Investment

Options is a financial derivative instrument, which is the option holder's right to choose in the future. Real options are the extension and extension of option pricing theory in real assets. There are many ways to invest in iron ore resources projects, such as traditional net present value (NPV), Black-Scholes option pricing, and real option pricing, etc.
Traditional Pricing and Real Option Pricing of Iron Ore Resources Project Investment

Traditional Investment Pricing Methods. Traditional investment pricing methods include NPV, PI, IRR and payback period. The net present value method (NPV) is a commonly used method because it is easy to calculate and is expressed by formula.

\[ NPV = \sum_{t=0}^{T} \frac{(CI - CO_t)}{(1+i)^t} - CO_0 \]  

(1)

When \( NPV > 0 \), it means that the net benefit of the investment project is equivalent to the interest calculated by the benchmark rate of return, and still has surplus, so it can be invested in the project. When \( NPV < 0 \), it means that the net benefit of the investment project does not meet the requisite rate of return, and the project cannot be invested.

B-S Option Pricing Model. On the basis of the above assumptions, Black and Scholes solved their differential equations and obtained the pricing formula of European call options[6].

\[ \frac{\partial f}{\partial t} + rS \frac{\partial f}{\partial S} + \frac{1}{2} \sigma^2 S^2 \frac{\partial^2 f}{\partial S^2} = rf \]  

(2)

Formula (2) is B-S differential equation, where \( f \): option price and \( r \) is risk-free interest rate.

In risk neutrality, \( E(\text{Max}(S - X),0) \) is the expected value of the maturity date of European call options paid for no dividend. Among them, \( S \) is the stock price at the expiration of the right, \( X \) is the executive price of the right, \( E \) is the expected value in the risk neutrality, \( T \) is the expiration time of the right, \( t \) is the current time of the right, \( r \) is the risk-free interest rate, and \( \sigma \) is the stock volatility estimated for historical data. Because of risk neutrality, and assuming the price of European call option is \( c \), then:

\[ c = e^{-r(T-t)}E(\text{Max}(S - X),0) \]  

(3)

The right-hand evaluation of formula (3) is an integral process. Based on this, we can get the pricing formula (4) of European call options for assets without dividend payment, where \( d_1 \) and \( d_2 \) are cumulative probabilities.

\[ c = SN(d_1) - Xe^{-(T-t)}N(d_2) \]  

(4)

Pricing Method of Real Options. Real option pricing method is to find the corresponding underlying financial assets in the financial market through the corresponding relationship with financial options and calculate them. Usually, the Black-Scholes option pricing model (hereinafter referred to as the B-S option pricing model). In the B-S option pricing model, investors' risk preference has no effect on option pricing, and the factors affecting option price include: the market price of underlying assets, the execution price of options, the risk-free interest rate, the variance of return and the maturity time of options[7].

Value Composition of Real Options for Iron Ore Resources Projects

Sources of Expanded Real Options in Iron Ore Resources Investment Projects. The value of real options in iron ore projects is closely related to the uncertainties in the future, when the uncertainties are small and small, the value of real options is small. And the value of real options varies with the types of real options. Amram and Kulatilada (1998) believe that non-financial options such as expansion, postponement, conversion and closure of investments may be used in the project process [8], i.e. there are four kinds of real options included in the investment project.

In iron ore resources investment projects, the value of expanded real options is larger due to the current fluctuation of iron ore prices, while the value of other real options is smaller, even neglected.

Value Composition of Expanded Real Options in Iron Ore Resources Investment Projects. When iron and steel enterprises invest in iron ore projects and carry out mining, iron ore transaction prices in the market continue to rise in a certain period of time. For iron ore projects, there is an opportunity to expand production (real options). At this time, iron and steel enterprises will decide
to increase investment and expand production scale during the period of rising iron ore prices, in order to increase profits, or choose project investment. Therefore, when calculating the value of real options in an iron ore investment project, it is necessary to analyze the factors affecting capital gains, which can be divided into two categories.

The first category includes certainty factors such as investment duration and project management cost, which are inherent values in iron ore investment projects. The other is the uncertainty factors of iron ore investment project, which is the medium-term right value of iron ore investment project. The uncertainties of investment projects mainly come from the external uncertainties of iron ore investment projects caused by the rising price of iron ore market, interest rate and geological environmental factors of the project. One of the most important uncertainties is the rise in iron ore market prices. These uncertainties, steel enterprises through additional investment to increase production capacity decision to obtain the value of extended real options in the project.

**Decision-making Model of Iron Ore Resources Investment Based on Expanded Real Options**

**Establishment of Real Option Decision Model in Iron Ore Resources Investment Project**

Because the price of iron ore market fluctuates greatly, there is great uncertainty. When the price rises, an iron ore investment project contains expanded real options. Therefore, the total value of the iron ore investment project \( V_T \) can be constructed as the sum of the net present value of a fixed investment project and the value of an expanded real option that can increase production capacity by additional investment in the future. As long as the intrinsic net present value and the expanded real option value of iron ore projects are calculated separately, the total value of iron ore investment projects can be obtained.

Total value of iron ore investment projects are equal to internal net present value of iron ore investment projects + European expansion real option value of projects, namely:

\[
V_T = NPV_I + D_1 C_E
\]

In the formula, \( V_T \) represents the total value of iron ore investment projects by steel enterprises. \( NPV_I \) represents the original net present value of iron ore investment projects. \( C_E \) indicates that the project calculated by B-S model contains the value of extended real options. \( D_1 \) dummy variable indicates that \( D_1 \) is 1 when iron ore price rises, and is 0 when iron ore price falls or remains unchanged.

According to the value composition of real options of iron ore resources, the total value of iron ore investment projects \( V_T \) can be calculated by the formula. When \( V_T > 0 \), steel enterprises can invest in iron ore projects. When \( V_T < 0 \), steel enterprises should abandon investment in iron ore projects.

**Real Option Value Calculation of Iron Ore Resources Investment Projects**

The intrinsic \( NPV \) of iron ore project can be calculated by traditional \( NPV \) method. As long as the intrinsic net present value of iron ore project and the expansion or delay real option value of iron ore project are calculated respectively, then the total value of iron ore investment project can be obtained by summing up.

**The Basis for Calculating the Price of Expanded Real Options in Iron Ore Investment Projects.** Expanded real option in iron ore investment project is a kind of non-tradable real option. There are essential differences between the calculation of the value of real option and that of financial option. But Cox, Ingersoll and Ross (1985) point out that the pricing of real options in the project can be calculated by deriving B-S model[9].

**Expanded Real Option Pricing Formula in Iron Ore Investment Projects.** According to the option pricing principle of B-S model and assuming that the value of iron ore assets in iron ore investment projects of steel enterprises obey the general Wiener process, we can see from Ito theorem that the differential equation shown in the B-S option pricing model of extended real option value \( C_E \) satisfies formula.
\[ rC_{E,t} = \frac{dC_{E,t}}{dt} + (\mu - \varepsilon)V_i \frac{dC_{E,t}}{dV_i} + \frac{1}{2} \sigma^2 V_i^2 \frac{d^2C_{E,t}}{dV_i^2} \] (6)

In the formula: \( V_i \) indicates the value of iron ore assets in iron ore investment projects at time \( t \), \( \mu \) indicates the expected value of value growth rate per unit time, \( C_{E,t} \) indicates the value of real options for expansion of iron ore investment projects at time \( t \), \( \sigma \) indicates the standard deviation of asset value growth per unit time of iron ore investment projects (fluctuation rate of value), and \( r \) represents risk-free interest rates.

The above extended real option pricing formula has the following boundary conditions:

\[ C_{E,t,T} = e^{-r(T-t)} \max((S-I),0) \] (7)

In the formula: \( T \) indicates the final time for iron ore investment projects to expand investment, \( t \) indicates the start time of iron ore investment project expansion investment, \( S \) expresses the present value of net cash flow of iron ore investment project value at the end of expansion period, \( I \) expresses the present value of cost expenditure funds for iron ore investment projects at the end of the expansion period, \( r \) represents a risk-free interest rate.

According to the B-S option formula, the integral derivation is carried out, and it is concluded that:

\[
\begin{align*}
   C_{E,t} &= S \cdot N(d_1) - I \cdot e^{-r(T-t)} \cdot N(d_2) \\
   d_1 &= \left[ \ln(S/I) + (r - \varepsilon + 1/2\sigma^2) \right]/(\sigma \sqrt{T}) \\
   d_2 &= d_1 - (\sigma \sqrt{T})
\end{align*}
\] (8)

In the Formula (8), \( N(d_{1,2}) \) is the cumulative probability expressed as a normal distribution variable. The (8) calculation of the value of expanded real options in the iron ore investment strategy model of steel enterprises is constituted.

Therefore, based on B-S option model, Formula (9) constitutes a decision-making model of iron ore investment for steel enterprises based on extended real option method.

\[
\begin{align*}
   V_t &= NPV_t + D_t C_E \\
   C_{E,t} &= S \cdot N(d_1) - I \cdot e^{-r(T-t)} \cdot N(d_2)
\end{align*}
\] (9)

### Decision-making Application of Expanded Real Options in Iron Ore Investment Projects

Taking an iron ore resource investment project of a steel enterprise as an example, it is analyzed the application of extended real option.

### Basic Data

A steel enterprise invests in the mining right of a metro resource project. The maximum duration of the continuous mining of the iron ore resource project is about 8 years, and the investment and development of the iron ore resource can be divided into two stages: early stage and late stage. In the early stage of investment, the exploration of iron ore resources to obtain geological data and medium-scale development are carried out at the same time. The estimated investment is $56.0 million, and the discount rate of the project is 8%. In the later stage of investment, two years after the iron ore project was carried out, a steel enterprise chose to expand and develop the iron ore project, and continued to make additional investment with US$38.0 million. Assuming that there is no dividend in the process of project investment and production, the risk-free interest rate of funds in the project is 8%; the price fluctuation rate of iron ore is 30% observed by steel enterprises based on historical data; assuming that the specific data of investment and expected cash flow of the company in the two stages of investment are shown in the following table:
<table>
<thead>
<tr>
<th>Years</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
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<tbody>
<tr>
<td>previous investment</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net cash flow</td>
<td>-</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Discount rate</td>
<td>8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expansion of investment</td>
<td>-</td>
<td>-</td>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase cash flow</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cumulative cash flow</td>
<td>-</td>
<td>8</td>
<td>10</td>
<td>17</td>
<td>20</td>
<td>18</td>
<td>15</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

**Calculation and Analysis of NPV**

Firstly, the net present value (NPV) method is used to analyze the decision-making of iron ore investment projects by steel enterprises. When NPV method is used for analysis, the expected total investment and return of the iron ore project will be obtained. The net present value (NPV) of the iron ore investment project is calculated as follows:

\[
NPV_I = \sum_{t=1}^{8} A_t (1 + r)^{-t} - 38(1 + r)^{-2} - 56 = -0.74
\]  

(10)

In the above calculation, because \( NPV_I < 0 \), the conclusion of the investment project of the iron ore must be rejected according to the traditional method, so the investment and development of the iron ore resources is not advisable. However, the NPV method does not consider the value of expanded real options in iron ore investment projects mentioned at the beginning.

**Calculating the Value of the Expanded Real Options of the Iron Ore Investment Project CE**

According to historical data, steel enterprises have observed that the price fluctuation rate of iron ore is 30%. Assuming that all the fluctuations of project income of iron ore are affected by price fluctuations, the future net cash flow fluctuation is 30%. According to the data in the table, the expiration time of expansion options is 2 years.

Calculate the net present value \( S \) of cash inflows in the second year, i.e. the initial value of expansion options:

\[
S = \sum_{t=3}^{8} A_t (1 + r)^{-t} = 37.72
\]  

(11)

**Calculate Value of Real Option.** At the end of the second year, the executive price of the expanded real option of the assets of the iron ore investment project was US$37.72 million, and the annual income fluctuated was \( \varepsilon = 30\% \).

\[d1 = 0.5722, \quad N(d1) = 0.7157(\text{look-up table});\]
\[d2 = 0.1480, \quad N(d2) = 0.5596(\text{look-up table});\]

Thus, the value of expansion option \( C_E = 8.88 \) is obtained. So \( V_T = NPV_I + D_t C_E = -0.74 + 8.88 = 8.14 \). Considering the intrinsic value of iron ore investment projects and the value of expanding real options of iron ore investment projects, the decision of steel enterprises to invest in this project is appropriate and profitable.

**Summary**

Traditional investment decision avoids uncertain risks in iron ore investment, but also ignores the value of extended real options implied in iron ore resources project management. The real option investment decision-making model based on the extended real option theory provides a valuable way
for Chinese steel enterprises to make investment decisions in iron ore projects, which is also an optimization and improvement of the traditional net present value decision-making method.

Especially in the face of the risk of rising and fluctuating global iron ore prices, this investment strategy enhances the risk tolerance of Chinese iron and steel enterprises in investment projects and improves the investment efficiency. At the same time, this strategy can reduce China's iron and steel enterprises' excessive dependence on overseas iron ore and strengthen their own supply of raw materials, which is in line with the long-term strategic interests of steel enterprises to invest in iron ore.

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Reference