

A Modified Method of Mining Investment Assessment under Uncertainty

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Abstract The traditional assessment method for mining investment, has gradually shown its shortcomings in practice. This paper derives the concept of real option from generalized definition of option, and then derives the real option pricing formula by means of comparative analysis. Traditional decision making method is revised by real option method with Black-Scholes model, and guidelines are provided for venture capital decision making in mining industry. Finally, the paper comes to the conclusion that irreversibility, flexibility and uncertainty can be evaluated by the modified model in mining investment decision making.

Key words Investment decision making; Mining investment; Real option; Black-scholes model

1 Introduction

Mining project investment risks are growing as the uncertainties during economic operation are increasing. As a capital intensive industry, mining investment has a long return period and is influenced by macro-economy significantly. It is also related to complicated factors such as resource abundance, geological structure, topography, transportation, economical conditions of mining zone, water and power supply.

Basic data for feasibility study of mining investment project are generally based on forecast, which means the derived results are impossible to completely coincide with reality.

Mining investment is influenced by a number of uncertain factors such as metal price, production cost, resource condition, plan service life, economic and politic environment, which bring substantial uncertainty and risk. Mining investment decision is normally evaluated by discounted cash flow (*DCF*) methods, among which net present value (NPV) method (the accumulated sum of annual cash flows from the beginning of investment to the project termination converted into cash to construction period) is adopted most commonly. NPV method does not sufficiently consider the influence of uncertain factors.

Investment decision making process can be more scientific and reasonable if the time value of currency is taken into consideration. However, the above evaluation methods only consider from a static point of view. That means they can only decide to invest or not to an immediate situation without considering value created by management and its effect, and overvalue the own value of cash flow generated by project while neglecting its market value. To overcome these shortcomings, option theory, the latest development in modern finance, should be introduced into the process of investment decision making.

Since the traditional NPV method is easy to cause a false investment decision, does it mean it is no longer applicable? In fact, real option method cannot be adopted without NPV indexes. We can solve the problems in traditional investment decision making by revising NPV indexes with real option method, making more scientific and rational assessment in venture capital investment.

Real option analysis mainly utilizes existing methods and models adopted in analyzing financial option. Black-Scholes option pricing model is a typical sample. B-S model is raised in 1973 by American economists Fischer Black and Myron Scholes, who received Nobel Prize in 1997. *B-S* model has become the measuring standard in evaluating the reasonable option price.

2 Uncertainty Analysis on Mining Investment

Uncertainty analysis is to analyze and study the potential influences on investment profit caused by the changes of existing uncertain factors in mining investment, by which the financial and economical reliability of a certain project can be confirmed.

Uncertainty and risk are the two sides of a coin. During the whole process of mining investment, a number of factors such as the length of development period, change of total investment and capital source, reform of mining and metallurgical technique, fluctuation of metal price and the shifting of

national economical policy will all significantly influence project profit and expenses. Uncertainty analysis can minimize those risks by studying the existence and influence extent of uncertain factors.

The existence of uncertain factors is incurred by the economical environment both objectively and subjectively. On one hand, the factors taken into consideration in the economic assessment of a mining project will change along with the changes of time, locations and conditions. On the other hand, series of parameters, indexes, data and hypotheses are inevitably introduced in to the process of assessment, which bring uncertainty.

Essentially, the uncertainty analysis is to forecast potential risks and minimize inaccuracy of project assessment in mining investment by analyzing negative factors and exposing the least optimistic situation.

3 Limitations of Traditional Decision Making Method in Mining Investment

Although some traditional limitations of *NPV* have been tackled, some major defects caused by *NPV* method's neglect of the flexibility of management still cannot be hurdled.

(1) *NPV* method is practiced based on static conditions in decision making. Based on a fixed cash flow generated by mining investment and a rigid management model, *NPV* method only helps the instant decision of investment.

(2) A project whose *NPV* is below zero should be abandoned according to *NPV* method, but it may bring the company potential growth opportunity. Some strategic mining investment projects may be omitted by *NPV* method. A resource development project belongs to this category, for although its net cash flow may be negative, the company can obtain considerable mineral reserve which brings potential opportunity.

(3) *NPV* method omits the positive influence on cash flow by optimized management. For example, management team can chose timing of investment, adjust the forecast of cash flow by optimize investment plan according to the actual operating environment, and suspend or even terminate the project to mitigate or avoid further loss.

(4) Choosing a proper discount rate is difficult and *NPV* method is quite sensitive to it which is a critical parameter in deciding the value of project. As a parameter reflects the time value of capital, besides source of capital and future investment opportunity, discount rate is also influenced by industry risk, inflation, product price and cost structure, etc.

(5) Another major defect of *NPV* method is its hypothesis of mining investment being reversible, while most of the actual cases are quite the contrary. *NPV* method does not consider the loss of withdrawing initial funding, which is actually almost irreversible especially for large mining projects.

(6) *NPV* method considers mining project investment as a whole, neglecting the features of its different stages and their relations.

(7) As a single main body decision making method, *NPV* method does not consider the interactive effect among interrelated bodies of a project. In specific decision making environment, the value estimation of a certain body should take the strategic choice of its managing body into consideration, or else a correct decision cannot be made.

4 The Meaning of Modification of Introducing Black-Scholes Model into NPV Method

Though option pricing method introduced in real option evaluation based on stocks can make decision more flexible and reduce risks, inaccuracy can be incurred for the fluctuation of underlying asset of growth option in decision making under uncertain situation is not necessarily share the Gaussian distribution feature with stocks.

Investment assessment indexes that take the time value of currency into consideration help the investment decision making process become more scientific and rational. The assessment emphasizes the cash flow value generated by the project, as well as the market value of cash flow. To overcome the defects, we can bring the latest development in modern finance, option principle, into investment decision making process. Flexibility, uncertainty and irreversibility are three important features mining project investment and option share in common.

Investors can not only have the decision-making power at present, but also make decisions according to the real situation during construction. Mining investment project has the feature of volatility. Various risk factors in project investment can be categorized by different means. Categorized by different causes that incur risks, there are five types of factors. The first one is technical risk, which

refers to the advancement, applicability, reliability and the peer competition fierceness of techniques adopted. The second one is financial risk, which refers to volatility of interest rates and exchange rates in the market, inflation and fund-raising costs, etc. The third one is market risk, which refers to changes in commodity demand and competition in market. The fourth one is natural risk, which refers to project geological, resources reserve and climate conditions, etc. The last one is social risk, which refers to the social environment, such as social credit and political factors. All these factors contribute to the volatility of project investment value.

Mining investment decision is irreversible, for the initial cost is sunk cost. If investment direction changes, this part of cost is irrecoverable, which makes it critical especially in making crucial or strategic decisions. Company can choose investment timing according to the changes of external environment. Sometimes, it is necessary to delay the investment for gaining favorable information. It is notable that the delay does not necessarily mean the investor can have completely correct information.

The concept of real option is firstly raised by Myers in 1977. Investors have the right to buy or sell a real asset at a certain price in the future. As the subject matter is real asset, this type of option is accordingly named as real option. When assess a project, we should review not only the direct profitability indicates by *NPV* indexes, but also the flexibility of the project. Therefore, the true value of a project is composed of its net present value and flexibility value, and the flexibility value can be shown in option price:

$$V = NPV + C \tag{1}$$

In equation (1), *V* represents the true value of a project, *NPV* represents the net present value of a project, *C* represents option premium of a project.

In the above formula, *NPV* can be calculated from traditional *NPV* method, and then we need to confirm *C*'s value.

Black and Scholes made great contribution in option pricing, creating the famous European buyer option pricing model:

$$C = SN(d_1) - Ke^{-rt}N(d_2) \tag{2}$$

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)t}{\sigma\sqrt{t}} \tag{3}$$

$$d_2 = d_1 - \sigma\sqrt{t} \tag{4}$$

In above equations, *C* represents current option value, *S* represents current stock price, *X* represents exercise price, σ^2 represents natural log variance, *e* represents the base of the natural log function, *r* represents risk-free interest rate, *t* represents time to expiration, in years, *N*(*d*₁)&*N*(*d*₂) represents standard normal distribution function, σ represents option income volatility

5 Conclusion and Trend of Real Option Theory Study

Real option model is a revolution for investment decision making. Under the option law, the flexibility of changing behaviors according to the altered future situations conducted by the manager, i.e. the value of the manager's decision will be taken into consideration and be assessed.

Project investment may include portfolio of various options. Project investment includes only one option type is what we are studying at present. Financial option pricing theory from single option may not give accurate assessment of project investment value. The subject asset of stock option is number of shares whose price can be known from stock market, while the subject asset of real option is the project investment value, which is difficult to calculate. This imperfection needs further studying.

Black-Scholes model that gives clear mathematic result is only one of many methods that can be adopted in analyzing real option. In recent years, theoretical study on real option has shown a new trend, which can be elaborated as follows:

(1) Financial mathematics and financial option theory have been fully practiced in the study of real option pricing. Financial option pricing model cannot precisely describe real option, because the basic assets of real option are almost untradeable by observable prices in proximately continuous market. Searching new pricing model (e.g.: expanded BS model to practice option pricing method including untradeable and unobservable basic assets) becomes critical in the study. Financial mathematical theories such as potential theory, differential game theory, and stochastic optimal control theory are widely practiced in the study. The application of fuzzy logic theory into option study by M.O. Hutchinson is a good example.

(2) Assessing the value of project contained real option by option pricing theory and game theory is

a method targeted at solving the defects in traditional project investment assessment and decision making process. Several foreign scholars achieved progress in this field (such as Dixit and Pindyck studied game of strategy contained option method in 1994), and Chinese scholars are also introducing game theory as a tool. The combination of game theory and real option theory can be expected as one of the new development trends in the study of real option theory.

(3)The study of applicability of real option theory becomes the trend. For the deep involvement in financial mathematics, the application of the real option pricing faces considerable limitations. Thus, enhancing the applicability is the trend of its development.

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