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Analysis of Real Option Valuation Method for High-tech Start-Up Enterprises

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Abstract:

Under the background that the development of high and new technology has become an important feature of the era of knowledge economy, high and new technology start-up enterprises have continuously increased their proportion in economic growth and become an important driving force to promote the positive development of society. In this paper, combined with the characteristics of high-tech start-up enterprises, new ideas of their value assessment are explored, and scientific and reasonable valuation methods are used to measure their real value, which is helpful to promote the development of such investment and financing. From the perspective of strategic investors, projects depend on each other and interact with each other, which makes projects have strategic value. The concept of real option assessment is introduced into the valuation method, and the equity value of high-tech start-up enterprises is assessed by using the pricing model. In order to achieve high growth or face complex operation conditions, project investment also needs to adjust its decision-making with the change of environment.

Keywords*: High-tech, Start-up enterprises, Equity valuation, Strategic investment, Real options.*

I. INTRODUCTION

Since the end of last century, the high-tech industry represented by the information industry has become more and more important in the global economic development. In particular, the depth, breadth and efficiency of knowledge transfer have become higher and higher with the technological upgrading, which has greatly shortened the time from high-tech start-ups to industry giants, because the development of these enterprises is closely related to the continuous innovation and development of high and new technologies [1]. In traditional industries, it often takes decades or even longer for an enterprise to become an industry giant from its foundation. At present, it can even be completed in ten years from its foundation to becoming a world top 500. However, in the start-up period of high-tech enterprises, venture capital is often required to provide funds to maintain operations, purchase necessary instruments and equipment for production and open up the market, while the operating cash flow of the start-up

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enterprises is often negative valued by the most popular cash flow method. The real option method is based on the option pricing method, which evaluates and invests the underlying assets at the exercise price [2]. The premise of the option pricing theory is that the underlying assets and the risk-free loan assets can form an equivalent investment portfolio and the shares will remain valid after listing [3]. For investment in high-tech start-up enterprises, it is important to have products with core technology and a suitable enterprise structure when the enterprise develops, but investment decisions are equally important [4], especially when the investment is carried out in multiple stages. By adjusting the stage selection of the original plan, investors can correctly analyze, quantify and evaluate the impact of each stage on the project value according to the uncertain factors such as the changes of the environment and market [5], among which the important factor is the lack of funds for the development of high-tech start-ups and the need for external financing, which will inevitably involve the judgment of the enterprise value. How to accurately evaluate the enterprise is the basic prerequisite for the success of investment and financing [6].

Real option method is widely used in venture capital, enterprise merger and acquisition, natural resources valuation, investment evaluation, intangible assets valuation and so on [7]. In 2014, relevant scholars studied the new real option model based on multiple uncertainties (CCS) investment valuation [8] and the attempt to apply the real option method in the continuous supply chain [9], and then further studied the real option contract and the chain collaboration of dual procurement sources [10]. Due to their respective innovative technologies, high-tech start-up enterprises find it difficult to find enterprises with similar industry, scale, business, financial status and other aspects in the market, so it is difficult to use the market comparison method to value these enterprises [11-13]. In China, high-tech enterprises are defined as "enterprises that research, develop and transform technological achievements in the state-supported high-tech fields to form core independent intellectual property rights of enterprises and conduct business activities based on them [14]. Investors have an important influence on whether the investment will be exercised or not at a certain time in the future. Arguably, the asset investment valuation of real projects has a similar theoretical basis to that of financial option pricing, which provides a theoretical basis for us to use financial option pricing model to solve project investment decision-making problems [15], so as to avoid and reduce risks and find value growth points in uncertainty. At the same time, the application of option pricing theory can correct and supplement the factors neglected, underestimated or uncertain by traditional investment methods in strategic value investment projects, so as to better carry out valuation [16].

In the early development of high-tech enterprises, tangible assets accounted for a small proportion, but intangible assets in the enterprise development process plays a vital role [17]. Industrial upgrading and transformation is the inevitable requirement of current economic development, and independent innovation has become an important development strategy of the country. As the leading force of technological innovation, high-tech start-ups are an important guarantee for the transformation of

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China's economic growth mode [18-20], so it is an important topic to make a reasonable valuation of them. Enterprise value can be regarded as a compound function, which includes the past and present profitability and future development potential of the enterprise, and also reflects the expectations of current and potential investors of the enterprise. According to economic and financial theories, the common real options in investment mainly include deferred options, phased investment options, scale change options, abandonment options, conversion options and growth options [21]. Investors who follow the example of financial options can be regarded as having real options, i.e. an option to invest in a real asset, and has the right to choose whether to exercise the option. If the product market share is expected to expand rapidly, the future cash flow will increase substantially, and the net present value of the final investment will be positive [22], so we can take this opportunity to invest. Real option theory provides a new perspective for enterprise investment decision-making, which breaks through the limitations of traditional decision-making methods. The value of option under environmental uncertainty is more effective and scientific than net present value method [23].

II. AN OVERVIEW OF REAL OPTION THEORY

2.1 The Meaning and Characteristics of Real Options

Real option is a term used to distinguish financial options from real assets after extending the concept of options in finance to real assets [24]. To put it simply, it is to use the concept and theory of options to define options in real assets. Many high-investment projects may not bring immediate returns, but can create more favorable opportunities in the future through the improvement of the overall ability of enterprises, so enterprises may be willing to choose other investment projects at the expense of short-term cash flow. That is to say, when investors decide to invest in a physical asset, they not only consider the cash flow that will be generated by the physical asset, but also consider the right to acquire or sell the physical asset at a specific price in the future, which is called real option, so we think that the investment of this physical asset has the nature of option [25]. The internal factors of the daily operation of the company are relatively stable. Real option theory holds that under uncertain conditions, enterprises should take actions to improve the possible profit opportunities in the future, instead of passively waiting for changes. Such pre-emptive micro-investment behavior enables companies to develop or make flexible decisions. Affected by these uncertain factors, the value of high-tech start-ups fluctuates on the horizontal axis like the same curve. The deterministic factors of enterprises are reflected in the horizontal axis of stability, and the fluctuation of enterprise value comes from uncertain factors. Enterprises can't "buy" real options from the market with fair price, but "create" real options through initial investment, which does not correspond to the full market price of real options.

The real option method can make better use of the option characteristics to deal with the uncertainty of the project. Risk may add value to the project and therefore may be viewed as an opportunity. The

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comparison between real option method and traditional investment evaluation method for the valuation of uncertain items is shown in Fig 1.

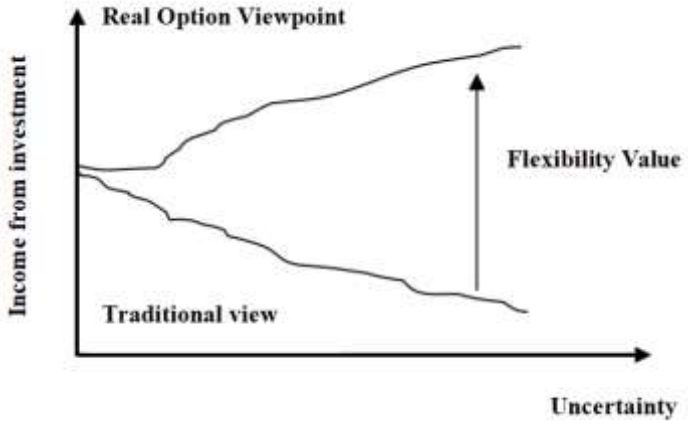

Fig 1: Valuation difference of uncertain items between real option method and traditional investment evaluation method

2.2 Classification of Strategic Investment Behaviors

With the increase of follow-up investment, the production capacity and scale of enterprises gradually expand, and the value created by enterprises also increases, so the value of growth options is a very important component of enterprise market value [26]. In today's society, intangible assets are increasingly becoming an important part of an enterprise, such as trademark, reputation, management level and human resources, etc., which have attracted more and more attention from the enterprise, because they cannot only set up a good social image for the enterprise, but also enhance the competitiveness of the enterprise. Deferred investment means that there will be similar investment opportunities in the future even if the investors do not invest now, i.e. if the investors are not satisfied with the investment conditions at that time, they can wait for changes to improve the investment conditions. Of course, not all investment opportunities can be delayed, because the rank of investment is very important when there are many competitors. In most cases, strategic investments can be delayed. When recognized by the market, its products will have a strong growth and the expected benefits will be higher than those of traditional enterprises. However, given the high growth commonly seen in emerging technology companies, uncertainties are compounded by a variety of factors, so emerging technology companies come with high risks. Regarding strategic investment as a complex including real option approach, this paper analyzes in advance the impacts of changes in the external environment, the company's own strategy, and the actions of competitors on the value and decision-making of real options. In strategic management, the real option theory is applied and tested, and various empirical studies are

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classified and evaluated, with special attention to the test of enterprise real option investment performance.

In practice, cash flow, net present value, market uncertainty, competitive situation and enterprise's control over the market will all have an impact on the value of investment projects. The three factors that determine the project value are shown in Table I and Fig 2. Therefore, the option game strategy can be analyzed according to the uncertainty P of the market and the first-mover advantage Y+U of the enterprise.

According to the definition formula

$$D_i = a + \sum_{j=1}^{n} b_j p_j + r_i Y + u \tag{1}$$

As shown in Table II and Fig 3.

TABLE I. Three factors that determine the project value

	State	Policy decision
Net present value of projects	11.35	9.05
Market uncertainty	10.71	12.30
Market Control	11.39	11.80

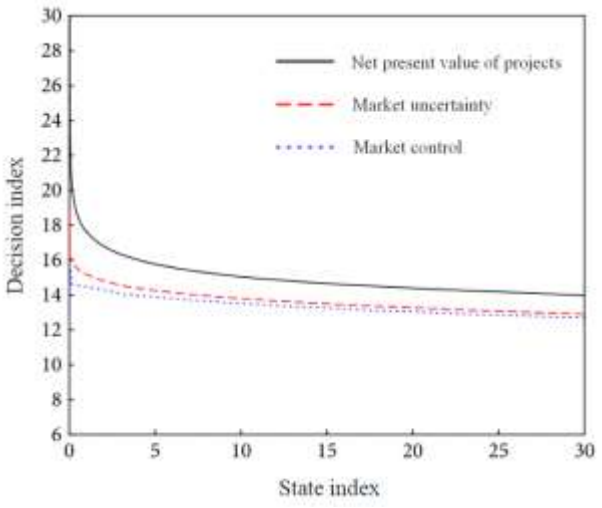

Fig 2: Three factors determining project value

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TABLE II. Investment strategies based on market uncertainty and dominant position

	Settlement	Value
Immediate investment	12.18	15.35
Deferred investment	5.38	8.09

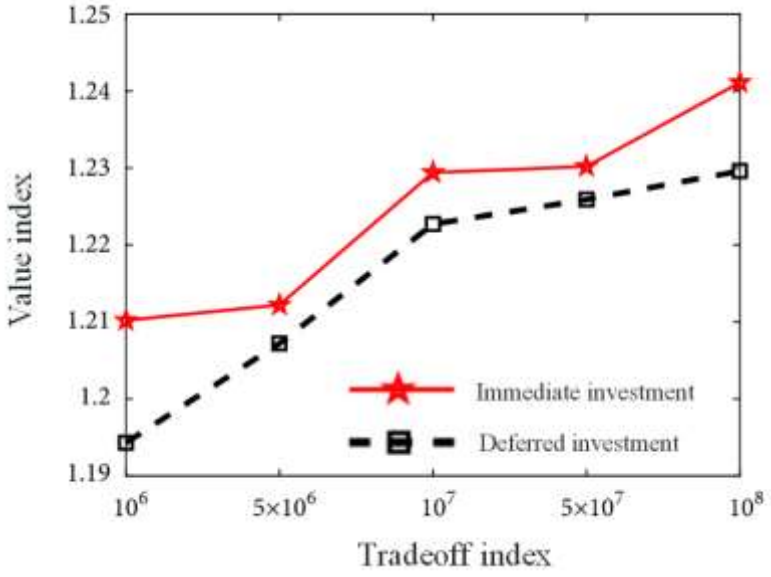

Fig 3: Investment strategy based on market uncertainty and dominant position

2.3 Application of Real Option Valuation Method

The biggest difference between high-tech start-ups and traditional enterprises is that the former has the characteristics of high growth and high return. However, they also have high risks due to many factors and great uncertainty. Nevertheless, the increasing difficulty in identifying relevant parameters during the valuation process clearly reduces the accuracy of the valuation. High-tech value is divided into the value of existing assets, which can bring stable cash flow to the enterprise and can be analyzed using traditional valuation methods such as discounted cash flow method, price-to-book ratio and price-to-earnings ratio, and the value of potential growth options. The idea of valuation for high-tech start-up enterprises is as follows: firstly, the current asset value owned by enterprises is assessed according to the traditional enterprise valuation method under the premise of eliminating uncertainty; secondly, the potential value of future investment opportunities owned by enterprises is estimated based on the real option method. However, the main business, scale, strategy, equity structure and trading

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activity of the enterprise may be significantly different from those of the reference sample company, so the reference significance of its financial indicators is actually not high. Because the traditional valuation methods may produce large errors in the value estimation of such enterprises, which is not conducive to investors' investment decision-making, it is necessary to choose a suitable valuation method to evaluate the characteristics of listed companies in the initial stage. In order to make up for the limitations of traditional valuation methods in this respect, it is necessary to provide a new perspective of analysis and decision-making at the level of enterprise investment theory and practice, so that investors can determine investment objectives according to the growth rate of the company under the same conditions. Real option valuation method is not a negation of traditional valuation methods, but an improvement and perfection of them, both of which have their own scope of application. In specific applications, the option value should be analyzed based on the actual conditions and the project's own conditions. The value-added estimation methods of high-tech start-ups are shown in Table III and Fig 4.

TABLE III. Value-added evaluation of high-tech enterprises

	Balance	Value
Management ability	19.07	9.43
Innovation ability	13.51	9.08
Environmental adaptability	13.23	8.17

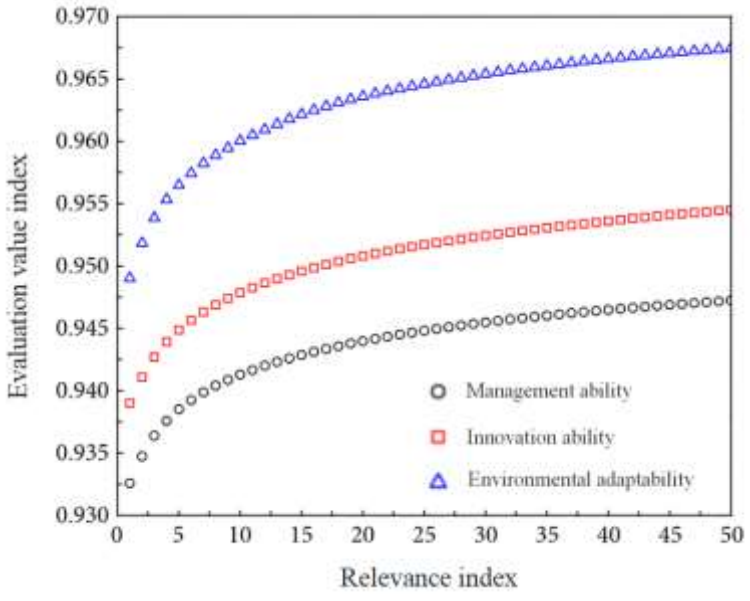

Fig 4: Value-added evaluation of high-tech enterprises

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The high growth of high-tech enterprises is not only affected by the opportunities of intangible assets appreciation, but also depends on the ability of the management team to turn good ideas into real success. There are two key problems to be solved in project decision-making: one is to determine the option value of the strategy, the other is to evaluate the investment option of the project, and to choose the ideal scheme when the investment value of the project is determined, which of course requires finding the optimal implementation value. Evaluating the benchmark enterprise through the standardized ratio coefficient and selecting the appropriate ratio can fully reflect the key factors that will affect the asset value of the enterprise, and control those parameters that need to be focused on, such as market share, price-earnings ratio, etc., which is mainly to evaluate the individual real options. In the actual operation of enterprises, there are often many factors, which interact with each other in a dynamic decision-making way and have an impact on the value of investment projects. When enterprises gain advantages in the changing market environment, uncertainty often brings more development opportunities, and these opportunities have a certain value to enterprises. The greater the uncertainty, the greater the option value that can be brought to the enterprise. When the equity value of a company is less than the initial investment amount of the company, the company owner should consider exercising a waiver option to suspend the investment.

The three aspects of real option correspond to each other in strategic management, which are known as real option investment decision and real option investment decision dj, real option implementation j-1 and real option decision m.

According to the formula

$$W_j = d_j \Big/ \sum_{j=1}^{m} d_j \tag{2}$$

As shown in Table IV and Fig 5.

TABLE IV. Investment decisions in practice

	Distinguish	Quantification
Investment opportunity	0.34	0.19
Investment structure	0.26	0.08
Investment Mapping to Options	0.35	0.13

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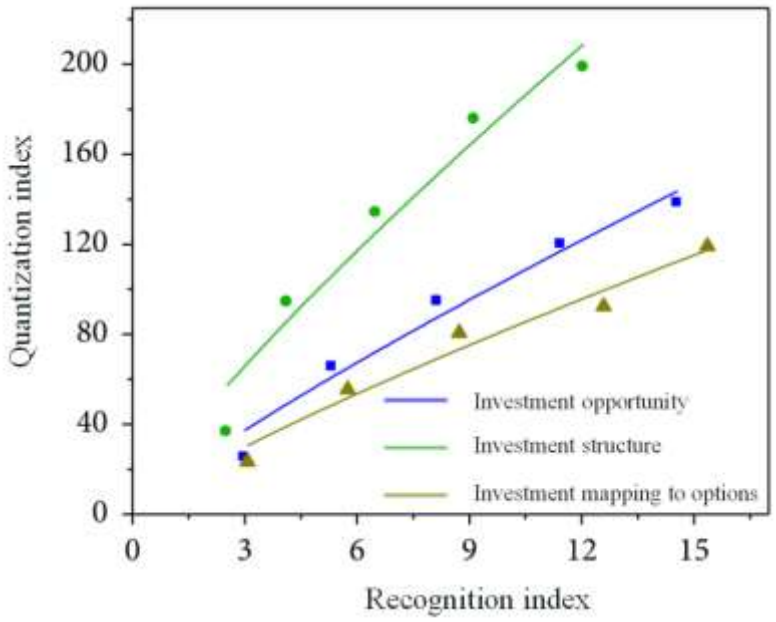

Fig 5: Investment decisions in practice

III. CHARACTERISTICS AND QUANTIFICATION OF HIGH-TECH START-UPS

3.1 Characteristics of High-tech Start-ups

With the development of technology, intangible assets are more important than tangible assets for the survival and development of high-tech start-ups, accounting for a larger proportion in the enterprise asset structure, and also bringing higher risks. In the initial stage of high-tech enterprises, the investment period of tangible assets is limited, and intangible assets account for a small proportion of the enterprise's asset structure. The patented technology developed or held by enterprises, characterized by rapid upgrading, is the basis of the development of such enterprises. The investment choice of the company depends on the initial investment of the strategic project and its value, which is different from the general standard option. Such options are long-term, while the corresponding enterprise is not yet mature, which depends on the delay of strategic projects. Due to the high risk of startups and many uncertainties, many factors will affect the valuation of startups, presenting a state of "partly known and partly unknown". It is necessary to invest heavily in R&D of high-tech start-ups to lead the consumer market by continuously increasing R&D investment. Only in this way, new products can continuously meet market demand, maintain market competitiveness and enable enterprises to obtain considerable excess profits.

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According to this formula, the weight table of all factors of high-tech start-up enterprises is summarized as follows:

$$P = P(Y = 1) = F(\beta_i X_i) \tag{3}$$

As shown in Table V and Fig. 6.

The value of potential growth options of high-tech startups Y = 1 is the value of assets that have not yet brought positive returns to the enterprise (P), but may bring stable cash flows (F) and earnings in the future , usually be assessed using real option pricing method.

TABLE V. Weight of each element of high-tech start-up enterprises

	Policy decision	Innovate
Research and development capability	20.36	15.33
Business management ability	19.71	14.96
Corporate Development Ability	19.05	14.22

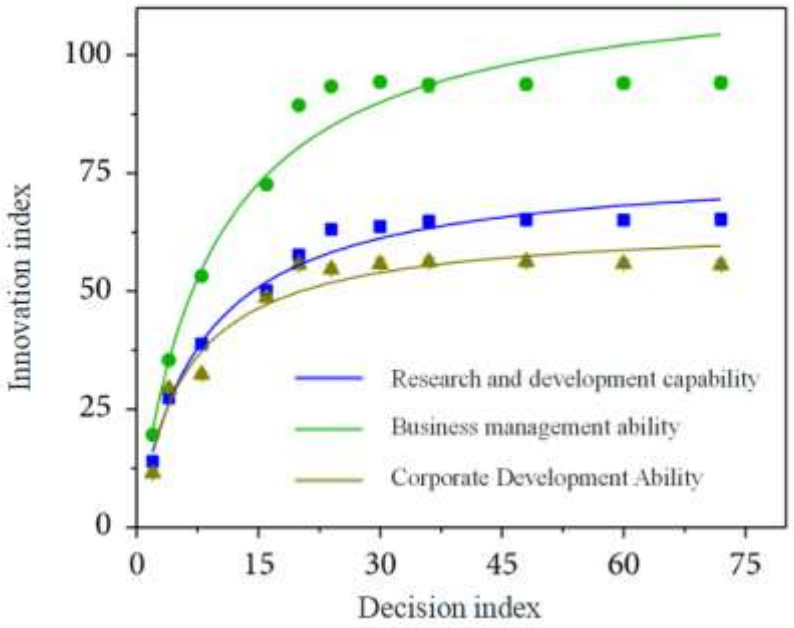

Fig 6: Weight of each element of high-tech start-up enterprises

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3.2 Fuzzy Quantification of High Growth Rate

High-tech start-up enterprises have both certainty and uncertainty, in which certainty refers to the profitability of the existing assets of enterprises, which is the economic basis of enterprises' sustainable operation and also includes mature products of enterprises. In the early stage of high-tech start-up enterprises, products are often not tested by the market and may not have a clear market segment. Option pricing model is based on portfolio, which is a function of call option value, including five observable variables, namely current stock price P, option exercise price C, option maturity D, risk-free interest rate RI, stock price fluctuation E, and other variables. The corresponding function is:

$$P_S - P_A = \frac{\rho}{2C_q^2 A_1^2} Q_1^2 \tag{4}$$

As shown in Table VI and Fig 7.

TABLE VI. Factors affecting enterprise valuation

	Cycle	Quantification
Growth Rate in Growth Phase	3.20	2.21
Time Length of Growth Phase	2.17	1.95

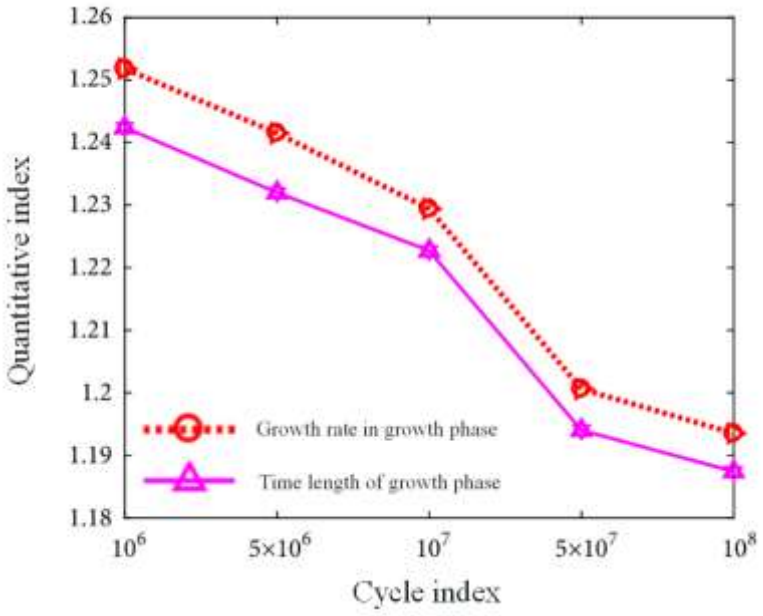

Fig 7: Factors affecting enterprise valuation

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The design of index system should follow the principles of scientificity, systematicness, operability and comparability. By using the analytic hierarchy process, various factors that affect the growth rate of high-tech start-up enterprises are divided into different aspects and different levels according to their attributes. It is necessary to establish an evaluation index system for the growth rate of high-tech start-ups, and the greater the uncertainty of investment projects in the future, the higher the corresponding option price. Therefore, it is necessary to consider the inherent characteristics when judging the feasibility of option exercise or conversion. Furthermore, the ability to delay an investment is particularly important because the outcome of the investment is irreversible, and it is not always possible in practice to delay an investment. Due to the limitation of stock issuance and circulation, the insufficient number of tradable stocks makes the trading activity insufficient, which makes the equity holders unable to avoid risks immediately. In addition, the lack of liquidity will also increase the cost of information acquisition and implementation. These difficulties in island trading of equity will correspondingly increase the difficulty of reliable estimation of real options in reality, which inevitably makes the pricing model more complicated than that of single period, because it is necessary to combine more relevant parameters and information with real options method for prediction.

Option pricing model is based on portfolio, which is a function of call option value, including five observable variables, namely current stock price P, option exercise price C, option maturity D, risk-free interest rate RI, stock price fluctuation E, and other variables.

The corresponding function is

$$P_S - P_A = \frac{\rho}{2C_q^2 A_1^2} Q_1^2 \tag{5}$$

$$U = RI + L\frac{dI}{dt} + E \tag{6}$$

Let A be a set of all real numbers, and define P as a fuzzy subset on the set of real numbers. If C has a member function, according to the formula:

$$Q_i = C_q A_i \sqrt{\frac{2\Delta P_i}{\rho}} \tag{7}$$

When the risk is neutral, it is assumed that the expected value of European call option Y (S) at maturity R (S) is:

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$$\frac{Y(s)}{R(s)} = \frac{G(s)\mathrm{C}(s)}{1+G(s)\mathrm{C}(s)H(s)} \tag{8}$$

Due to the risk-neutral assumption, the European option price 1+ C(S) H(S) can be expressed as:

$$\frac{Y(s)}{N(s)} = \frac{G_D(s)G(s)}{1+\mathrm{C}(s)H(s)} \tag{9}$$

By using the equivalent relation between call option JS and put option K;

$$\frac{I(s)}{U(s)} = \frac{Js+b}{JLs^2+(bL+JR)s+bR+K^2} \tag{10}$$

Increasing the risk-free interest rate will lower the price of the put option exercise on the expiration date, thus lowering the put option price N, so the risk-free interest rate j-1 is opposite to the put option price N:

$$f\left(x\right) = \sum_{j=1}^{n} \alpha_j N\left(\mu, \sigma_j^2\right) \tag{11}$$

There are many autocorrelation in real options, such as between sub-items of the same project and between multiple investment projects. Therefore, the data sequence is preprocessed, and the buffer operator is further divided into strong and weak. The relationship between price and decision-making results can be observed by analyzing the fuzzy comprehensive evaluation method layer by layer, and it is easy to analyze the valuation changes of projects in different investment stages or different market conditions. Among them, the data is monotonically decreasing when the buffer operator is weak, and monotonically increasing when the buffer operator is strong. Investors have chosen to invest in high-tech start-ups, which currently have no profits or even losses, mainly because they are concerned about their potential growth, which will be huge once the market approves. At the same time, due to the irreversibility of investment, once a decision is made, it means giving up other profit opportunities. Therefore, if possible, investors will wait for more new information before making a decision, adjust or even change the original decision, so as to avoid heavy losses caused by changes in circumstances.

There are five variables in the option pricing model: the underlying asset price, the exercise price, the volatility of the underlying asset price, the period of validity and the risk-free interest rate. Any variable

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change will have the same influence on the real option value and the underlying asset price change. The higher the underlying asset price, the greater the value of real options, namely:

$$dF_r = ybdx \tag{12}$$

The sensitivity analysis of underlying asset price changes is shown in Table VII and Fig 8.

TABLE VII. Sensitivity analysis of underlying asset price

	Volatility	Rate of change
Underlying asset value	11.68	9.13
Real option value	10.25	10.71

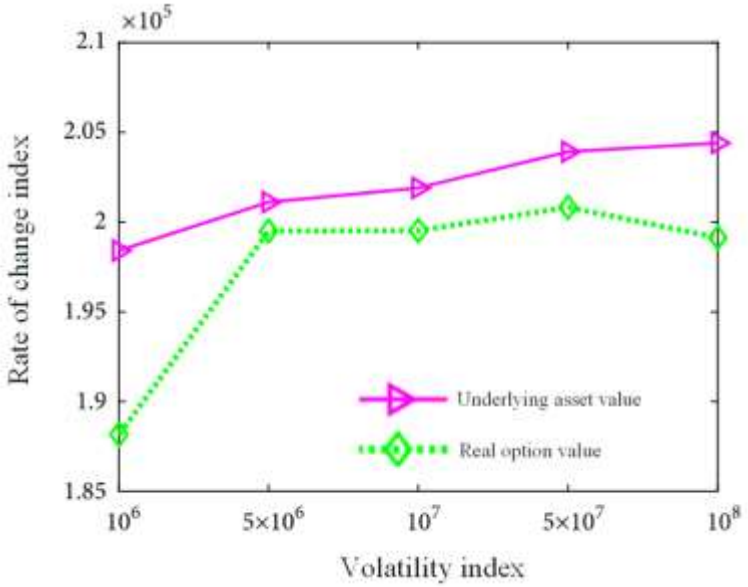

Fig 8: Sensitivity analysis of underlying asset price

3.3 Quantitative Analysis of Negative Cash Flow

Since the measure of shareholder income is net income, investors will pay more attention to the company's cash flow when the discounted cash flow model is used to evaluate the company, because in this model, cash flow will affect the company's value. The concept of real options is introduced into corporate valuation as the use of real options approach not only considers the time value of cash flows, but also places more emphasis on the valuation of the likelihood of growth for real option holders. If the

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cash flow of an enterprise is very unstable, it may indicate that there is little or no profit. Mastering the historical results, market development and main business, especially focusing on the analysis of the return on net assets and the growth rate of operating income, can lay the foundation for predicting the future free cash flow of the enterprise. At the same time, due to the differences in technology mastery, product research and development, product characteristics and geographical location of high-tech enterprises, there is no ideal reference enterprise for comparison, and its value is mainly derived from the future growth potential, and research and development investment must be continuously increased in the development process, which will inevitably increase the cash expenditure, thus affecting the stability of cash flow. Therefore, only the cash flows are expected to cover the option-related costs, less the value of the real assets, and the portfolio is adjusted accordingly to ensure that the options are in line with the underlying asset price changes, thereby obtaining the pricing of the real options. In order to make it suitable for the valuation of high-tech start-ups, it is necessary to apply fuzzy mathematics theory to quantify the characteristics of zero or negative cash flow, so as to apply it to discounted cash flow method parameters. The quantitative analysis of negative cash flow characteristics is shown in Table VIII and Fig. 9.

TABLE VIII. Quantitative analysis of negative cash flow characteristics

	Expect	Increase
Corporate Overall Value Assessment	13.25	17.05
Assessment of Equity Value of Enterprises	12.91	16.12

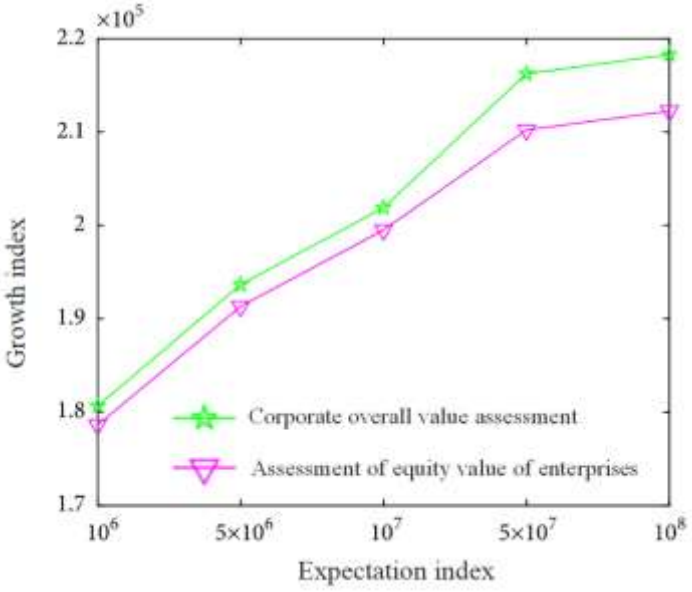

Fig 9: Quantitative analysis of negative cash flow characteristics

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The basic form of discounted cash flow method growth model explains how to quantitatively analyze the situation of no cash flow or even negative cash flow. For ease of calculation, the discount rate f(x) is considered to be a fixed value, the variable max:

$$Mu = f(x) = Mu_{\max}(1 - \frac{x}{x_{\max}}) \tag{13}$$

Now let's assume that n is a given fuzzy trigonometric function, that is, the value of high-tech start-up enterprises can be expressed as a fuzzy number x, which is also expressed as:

$$N\left(\mu, \sigma_j^2\right) = \frac{1}{(2\pi)^{1/2}\sigma_j} e^{\frac{1}{2\sigma_j^2}(x-\mu)^2} \tag{14}$$

The score x of the target high growth rate relative to the first-level index is obtained by using the fuzzy comprehensive evaluation method. Finally, the evaluation value of the growth rate at a specific growth stage is obtained by connecting the comprehensive evaluation score with the interval value t of the growth rate:

$$P_R = \frac{P(t+1) - P(t)}{P_N} \tag{15}$$

$$P(X \le R) = P \tag{16}$$

There are three possibilities for the maturity value of an option. An asset can have three prices at the end of the second stage, i.e. the final price of the underlying asset is u2S when the first stage is up, udS when both stages are up, and d2S when both stages are down. According to the formula, the final price of the underlying asset is d2S. The two-stage binomial pricing chart is shown in Fig. 10.

$$Fuu = \max(u^2 S - X, 0) \tag{17}$$

$$Fud = \max(udS - X, 0) \tag{18}$$

$$Fdd = \max(d^2 S - X, 0) \tag{19}$$

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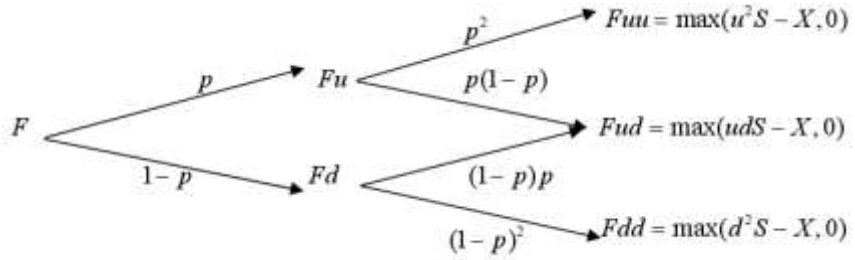

Fig. 10 Two-stage binomial pricing

When the option pricing model is used to evaluate the equity value, the return risk characteristics brought by equity assets reflect the volatility of portfolio return, including volatility and range of change. Real options have a variety of choices under various circumstances, regardless of whether they are ultimately invested. At the same time, it is very difficult to find comparable companies in industry, technology, scale, environment, market and other aspects in the valuation process, and the general operating history is also short. The above characteristics are also the difficulties in applying the discounted cash flow model to the valuation of high-tech start-up enterprises. Investment decision makers can adjust their decisions in time according to the progress of the project and the changes of the internal and external environment, so as to cope with the impact of uncertainty on the project and improve the value of project investment. For enterprises, cash flow mainly refers to the net cash flow after tax. Patent technology has further development opportunities in different time periods, which can be seen as a separate growth option. Therefore, the real option brought by the R&D model of high-tech enterprises is a compound option, whose discount rate depends on the risk level of the estimated future cash flows of assets. The risk level of assets is in direct proportion to the discount rate that the greater the risk of assets, the higher the discount rate, and vice versa.

IV. CONCLUSIONS

In this paper, the real option model of equity valuation of high-tech start-ups from the perspective of strategic investors is studied. As the real option theory can strengthen the decision-making ability of investors, correctly assess the complex changes in the operating strategies under different risk conditions, it is more suitable for the decision-making process of venture capital. The strategic investment projects with real option method are likely to be different, so the analysis of uncertainty can adjust the uncertainty in different aspects, identify the projects with option value greater than net cash loss, so as to find more investment opportunities for the company and grasp the strategic investment projects more comprehensively. Secondly, all option pricing models have their own assumptions, in which real options have the characteristics of both financial options and real assets. In practice, due to the change of industry status and core competitiveness, it is not enough to use the traditional cash flow method to value

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the entire enterprise. Therefore, it is necessary to combine the extended option value with the existing asset value. The potential profit opportunities of the enterprise correspond to high risk, high growth and high technology. Incorporating the value of potential profit opportunities into enterprise valuation can accurately reflect the future development potential of high-tech start-ups and comprehensively evaluate high-tech start-ups by combining tangible assets, intangible assets and human resources, so it is a more comprehensive, accurate and forward-looking valuation method, which is of great significance to help high-tech start-ups successfully raise funds.

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