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# The Application of Real Options Method in New Energy Vehicle R&D Investment Project: A Case Study of BYD Auto in China

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The development of automobile industry had hundred years, internal combustion engine automobile hold dominant position. But with the oil resources growing tensions and high oil prices, electric power will no doubt become the alternative energy sources. Many major automobile manufacturers, such as Toyota, Honda and Ford, are focusing on hybrid technology as the next generation of core at present. By way of continuing restrain oil consumption to promote energy diversification, in order to achieve long-term competitiveness of the enterprise itself. New energy vehicle is used unconventional sources of fuel as the driving force, integrated advanced technology of vehicle control and driver power with new technology and new structure. New energy vehicles include hybrid electric vehicles, electric vehicles, fuel cell vehicles and hydrogen vehicles.

BYD as a newly-emerged vehicle manufacturer，it is ahead in the production of hybrid, electric vehicles and automotive batteries in China. This paper is applying the real options approach to the field of R&D project. By using a case of BYD and making the process into multi-stage investment, the real option model to get the project's option value is set up. Combining binomial option with NPV, the more accurate value in the investment project is found out.

## 1. The model

### 1.1 pricing model

In general，option pricing technique assumes that the underlying asset follows some process. Asset value of discrete-time model is assumed to be discrete distribution. By the Cox, Ross and Rubinstein in 1979, the proposed discrete-time binomial option tree model is a typical representative of the model. Binomial option tree model assumes that the value of the underlying asset follows a binomial distribution. It is assumed that c is call option, the initial price of underlying asset S, strike price X, risk-free rate of interest r, time interval t, up factor u, down factor d, risk-neutral probability p, volatility of project value σ, total time period n, number of times of rise price j, and number of times of decline price n-j. Hence:

$$c = \frac{1}{e^{nr}} \sum_{j=0}^{n} \frac{n!}{j!(n-j)!} p^{j} (1-p) Max\left[0, u^{j} d^{n-j} S - X\right]$$

$$where: \quad u = e^{\sigma\sqrt{\Delta t}} \qquad d = \frac{1}{u}$$

### 1.2 Evaluation Steps

Step 1: Determine the variables of binomial option tree on each location. First, construct binomial option tree, estimate cash flows on each point. Each point can be expressed as a result of R & D achievement put into the

market, and also can be expressed that stops the project investment at some stage.

Step 2: Determine the volatility of project value. Usually It can through calculate the variance of the value of underlying asset to determine.

Step 3: Determine the u and d by using fluctuation ratio and then calculate underlying asset value.

Step 4: By using u and d to determine the risk-neutral probability p. Risk-neutral assumption is the important foundation of non-arbitrage equilibrium analysis. The core part is to construct a risk-neutral probability, using this probability to calculate the expected value of future profits, then discounting by risk-free rate of interest, it can get equilibrium price of asset. Risk-neutral probability is $p = \frac{(1+r)-d}{u-d}$.

Step 5: By using back stepping to calculate the option value of project. General term formula is $c_i^+ = \frac{c_{i+1}^+ \times p + c_{i+1}^- \times (1-p)}{(1+r)^{t_{i+1}}}$. The project value at each node minus the cash outflow at each stage, finally extracts c which is the initial project value.

### 1.3 Parameters

There are five variables to be used to calculate the value of the option: the value of the underlying asset S, strike price X, risk-free interest rate r, holding time of option value t and the volatility of the underlying asset $\sigma$.

Let the determinate parameters substitute into the option pricing model, calculate the option value in R & D projects contained, and then add the net present value of traditional investment decision-making methods, you can get the more accurate value of R & D project by using real option valuation.

## 2. Case description and relevant data

BYD Company is developing a new energy vehicle, which has the characteristic of multi-stage R & D projects. This development process is considered as the compound option which includes switch option and abandonment option. Top management forecast, complete this R & D project including three investment stages: research and development (2009), demonstration and application (2012), commercialization (2014); and estimate the success probability of each stage: research and development (85%), demonstration and application (80%), commercialization (85%).

At the end of each stage BYD company may decide whether to enter the next stage. The three disperse policy decision points can be seen the compound option which established by two discrete options.

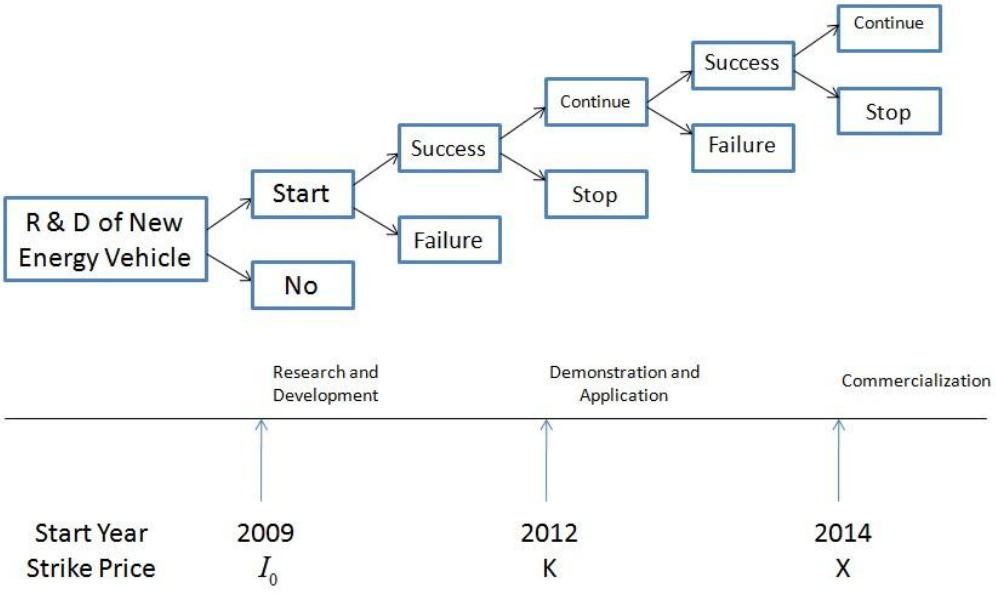


**Figure-1 Compound option of New Energy Vehicle R & D**

In 2009, BYD Company decided to invests or abandon this project. If choose research and development investment, the next it also need two stages investment. The two stages of investment decision-making can be seen as two options which together constitute a compound option after BYD Company invest $I_0$ of R&D.

The first option - the option of application would be automatically acquire when BYD company decide to invest in R&D of new energy vehicle. Therefore, $I_0$ can be seen as the price of first option. It will become due at 2012 when decide to invest application, the strike price is K of investment cost of application stage, this cost also is price of second option (commercialization stage). The underlying asset of first option is the value of option for commercialization stage, which means the value of the second option.

The second option will be acquire in 2012, become due in 2014. If the result of demonstration and application stage is good, BYD company will make a decision to invest the third stage - commercialization. The underlying asset of second option can be considered as the PV of cash flow new in 2014.

Meanwhile, the two options can be considered as abandonment of options which hold by BYD Company. In addition, these two options are not ordinary options which defined in the past. Because the value of underlying asset not only influenced by market quotation and economic risks, but also the strike price of options (investment cost of demonstration and commercialization, like promotion cost) change with sales' change. Therefore, these two options are switch options.

**Table-1 Estimation value of correlated variables which influence the cash flows of R&D in BYD**

| Market forecast | China |
|---|---|
| Market Potential in Automotive Sales (Ten thousand) | 1600 |
| Market Share Potential in New Energy Vehicle (%) | 25% |
| BYD Co. Expected Max Market Share (%) | 12.5% |
| Expected Sale Price (Ten thousand Yuan) | 10~15 |

Source: BYD Automotive Sales Service Company Limited.

**Table-2 the Company's profit situation which estimated by management from new energy vehicles**

| Time | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales Revenue | 0 | 0 | 0 | 7.5 | 15 | 130 | 174 | 180 | 200 | 250 | 360 | 400 | 240 |
| Production Cost | 0 | 0 | 0 | 6.38 | 12.8 | 101 | 135 | 140 | 152 | 185 | 259 | 280 | 168 |
| Gross Earnings | 0 | 0 | 0 | 1.13 | 2.25 | 28.6 | 38.3 | 39.6 | 48 | 65 | 100 | 120 | 72 |
| Operation Cost | 10 | 10 | 4 | 4 | 4 | 10.4 | 19.1 | 21.6 | 24 | 32.5 | 54 | 60 | 36 |
| Promotion Cost | 0 | 0 | 0 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 0 | 0 | 0 | 0 | 0 |
| Sales Cost | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| Depreciation | 0.2 | 0.2 | 0.2 | 0.4 | 0.6 | 1.5 | 1.2 | 0.8 | 0.4 | 0.2 | 0 | 0 | 0 |
| Pre-tax Net Income | -10.2 | -10.2 | -4.2 | -9.68 | -8.75 | 10.3 | 11.6 | 10.8 | 23.6 | 32.3 | 46.8 | 60 | 36 |
| After-tax Net Income | -12.75 | -12.75 | -5.25 | -12.1 | -10.94 | 7.73 | 8.67 | 8.1 | 17.7 | 24.2 | 35.1 | 45 | 27 |
| Working Capital | 0 | 0 | 0 | 2 | 2 | 4 | 3.5 | 2.4 | 1 | 1.5 | 2 | 2.5 | 1 |
| Capital Input | 2 | 2 | 10 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 |
| NCF | -9.45 | -9.45 | -12.9 | -15.4 | -14.5 | -1.28 | -0.13 | 0 | 10.5 | 16.3 | 26.5 | 35.9 | 19.4 |

Source: BYD Automotive Sales Service Company Limited. Unit: hundred million Yuan

## 3. Application of compound option in R & D project

### 3.1 Option value calculated by binomial option tree model

This case uses the binomial option tree to assess the option value of R & D project, first we need to determine the value of variables. The price of the underlying asset is 163.17 hundred million Yuan.

The fluctuation of the underlying assets value is in the random because of influence of economic risk, it can be found the movement of underlying asset by binomial option tree model. The volatility of the value of the underlying assets is determined by common marketing way. This paper choose both of listed companies（SAIC and Chang'an Automobile）as twin security who have the similar business, marketing and risk with BYD company. The average annual volatility of each stock is calculated by data of the year of 2008, and weighted mean value of two of stock's average annual profit as volatility of this program, the estimated value is $\sigma_p = 42.8\%$ (see Table-3).

**Table-3 Change paths in the underlying asset of R & D project of BYD**

Unit: hundred million Yuan

| Investment Stage | Research | | | Demonstration and Application | | Commercialization |
|---|---|---|---|---|---|---|
| Start Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | 163.17 | 250.30 | 383.96 | 589.00 | 903.53 | 1386.01 |
| | | 106.39 | 163.20 | 250.34 | 384.03 | 589.10 |
| | | | 69.36 | 106.40 | 163.22 | 250.39 |
| | | | | 45.23 | 69.38 | 106.42 |
| | | | | | 29.49 | 45.23 |
| | | | | | | 19.23 |

In the R&D compound options, the expenditure of application and commercialization are the first strike price and the second strike price of switch compound options respectively, and then all related expenditure is discounted to the strike price of each options from start time which are $I_0$=30.22，K=28.56，X=140.65(unit: hundred million Yuan ).

This R&D program includes switch compound options, that is, strike price----application and commercialization are also constantly changed by economic risk. Investment cost involves fixed cost and flotation cost, the fixed cost of application's discounting price is 1,099 billion Yuan, floating cost is relevant to sales revenue, and discounting price is 1,248 billion Yuan in the year of 2009. The volatility which estimated by management is 35%. So u=1.419, d=0.704. See table-4.

**Table-4 Change paths in flotation cost of application stage**

Unit: hundred million Yuan

| Investment Stage | Research | Research | Research | Demonstration and Application |
|---|---|---|---|---|
| Start Year | 2009 | 2010 | 2011 | 2012 |
| | 12.48 | 17.72 | 25.16 | 35.73 |
| | | 8.79 | 12.48 | 17.72 |
| | | | 6.19 | 8.78 |
| | | | | 4.35 |

In the table-4, add fixed cost into the column of the year of 2012 and then can get the total investment cost of application stage.

Accordingly, the fixed cost of commercialization stage's discounting price is 3,256 billion Yuan in 2014, and flotation cost's discounting price is 6,011 billion Yuan in 2009. Commercialization investment cost always used to experimental data which is 52. 5% evaluated by management. See table-5.

**Table-5 Change paths in flotation cost of commercialization stage**

Unit: hundred million Yuan

| Investment Stage | Research | | | Demonstration and Application | | Commercialization |
|---|---|---|---|---|---|---|
| Start Year | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | 60.11 | 101.59 | 171.68 | 290.14 | 490.34 | 828.67 |
| | | 35.59 | 60.14 | 101.63 | 171.77 | 290.28 |
| | | | 21.07 | 35.60 | 60.17 | 101.68 |
| | | | | 12.47 | 21.08 | 35.62 |
| | | | | | 7.38 | 12.48 |
| | | | | | | 4.37 |

In the table-5, add fixed cost into the column of the year of 2014 and then can get the total investment cost of commercialization stage.

Reference to the five-year government bonds interest rates in 2009, r=4%. The volatility is 0.23. In addition, the costs of second and third stage are variable costs, it need to use this two-stage variable costs to switch the two variable underlying asset value. Option value of new energy vehicle R & D as follows:

**Table-6 Option value of R&D project of BYD**

Unit: hundred million Yuan

| | Option of Application | | | | Option of Commercialization | | |
|---|---|---|---|---|---|---|---|
| Start Year | 2009 | 2010 | 2011 | 2012(FV) | 2012 | 2013 | 2014 |
| | 46.09 | 79.34 | 130.22 | 202.20 | 248.92 | 365.40 | 524.78 |
| | | 23.25 | 45.03 | 82.96 | 111.66 | 175.19 | 266.26 |
| | | | 7.80 | 18.44 | 38.21 | 69.73 | 116.14 |
| | | | | 0 | 6.85 | 16.18 | 38.24 |
| | | | | | | 0 | 0 |
| | | | | | | | 0 |

### 3.2 The traditional method: Net Present Value

New energy vehicle R & D of BYD Company is confronted with technical risk and economic risk. So the value of investment project under uncertainty can be expressed as the expanded NPV: Expanded NPV = static NPV + value of Real Option. From this we can see there are two factors that affecting the value of investment project:（1）cash flow of future income; (2) the value of investment opportunities. The binomial tree model has considered the value of real option. The traditional methods of investment analysis will consider the first factor. The discount rate is 12%. Combine table-1 and table-2, we can get the NPV of this project.

**Table-7 Computational process of NPV**

Unit: hundred million Yuan

| Time | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NCF | -9.45 | -9.45 | -12.9 | -15.4 | -14.5 | -1.28 | -0.13 | 0 | 10.5 | 16.3 | 26.5 | 35.9 | 19.4 |
| After technical risk-adjusted NCF | -8.03 | -8.03 | -11.0 | -10.4 | -9.83 | -0.78 | -0.08 | 0 | 6.43 | 9.99 | 16.2 | 21.9 | 11.9 |
| Discount factor | 0.89 | 0.8 | 0.71 | 0.64 | 0.57 | 0.51 | 0.45 | 0.4 | 0.36 | 0.32 | 0.29 | 0.26 | 0.23 |
| NPV | -4.66 | | | | | | | | | | | | |

## 4. Conclusion

From the above, the value of switch compound option is 46.09 hundred million Yuan. We can use the NPVt including the option value of project to assess the program, NPVt=c+NPV-$I_0$. So, criterion of investment decision is: when NPVt≥0, we can do this initial investment; When NPVt≤0, we can give up this investment. After technical risk-adjusted, the result is 4.3 hundred million Yuan. The results show that BYD Company can carry out the initial investment.

Net present value deems the future profits of project are determined, uncertainty will reduce the value of the project; the binomial option tree model deems the project's future revenue is uncertain; uncertainty will increase the value of the project. Therefore, the combination of the net present value and binomial option tree model is a good solution to solve the compound option problem in R & D projects.

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