Chapter 36
The Option-Pricing Model of Wind Power Investment Projects Included Value-Leaking Losses

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Abstract Compared with conventional generation, the investment in the wind power faces more risks. In this paper, we considered the value leaking losses in the wind power project which stem from the cash flow and convenience value ratio proposed a unique approach based on the method presented by Copeland and Antikarov, and illustrates the approach with an investment of the wind power project example.

Keywords Binomial decision tree · Real option · Wind power · Value-leaking losses

36.1 Introduction

Starting essentially from scratch just a few years ago, China has been the country with most installed wind power capacity. In the past year, China has more than 80 wind turbine manufacturers, four of which are among the top 10 globally by market share. China's officials have spoken off the record of targets that will reach 150 GW by 2015 and 250 GW by 2020 (Dalu and Yongwang 2011). Compared with conventional generation, the investment in the wind power faces more risks, such as the fluctuation of electricity prices, high operation costs, the power transmission bottlenecks and uncertainty of investment policies (Allcott 2011).

Considering the high-risk characteristics, the traditional discounted cash flow method is hardly used for calculating the value of the wind power projects for the

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reason that it would not take the value of managerial flexibility into account, which was inherent in project. Compared with discounted cash flow, the real option valuation techniques would be suit for the risky wind power projects because the real options derived from managerial flexibility (Brandao et al. 2005; Smith and von Winterfeldt 2004; Amram and Kulatilaka 1998; Orinai and Sobrero 2008; Smith and Nau 1995).

In this paper, we considered the value leaking losses in the wind power project which stem from the cash flow and convenience value ratio, proposed a unique approach based on the method presented by Copeland and Antikarov.

The rest of the paper is organized as follows. Section 36.2 introduced a decision tree approach to the real-option problem discussed by Copeland and Tufano. Section 36.3 provides an extension of this approach to the wind power project in which the value leaking losses have been considered. This approach is illustrated in Sect. 36.4 with a numerical example. In Sect. 36.5 we summarize this approach.

36.2 The Basic Option-Pricing Model

The venture capital firm plan to invest to a wind power project. Investment validity can be divided to N stages which cost Δt, the investment in the t stage is I_t. The initial value is V. We assume that the asset value will increase to Vu with probability p at the end of each stage, and will decrease to Vd with probability $1-p$, where $u = e^{\sigma\sqrt{\Delta t}}$ is greater than 1 reflecting the growth ratio of the project value, $d = 1/u$ is smaller than 1 reflecting the reduction ratio of the project value, and $p = \frac{e^{rt}-d}{u-d}$ (John et al. 2008) is the risk neutral probability which can be used to calculate the expected value when the future payoffs had been known, and r is the risk free rate which can be used to discount the future payoffs. When we continued to apply the same percentage changes to the values of the wind power project, this method could be extended to multiple stages. When stage $t = i$, the value can be shown in Eq. (36.1):

$$V_{ij} = Vu^{j-1}d^{i-j} \tag{36.1}$$

Here $j = 1, 2, \cdots, i, i = 1, 2, \cdots, N$.

According to Marketed asset disclaimer proposed by Copeland and Antikarov (Copeland and Tufano 2004), the present value of the project without options is the best unbiased estimator of the market value of the project. Under this assumption, the value of the project without options serves as the underlying asset in the replicating portfolio. So we can price the options with the traditional option pricing methods proposed by Myers if the changes of the project value exclude options are assumed to vary over stages follows a random walk stochastic process, such as geometric Brownian motion. This decision analysis approach to valuation can be described as follows:

Step 1: Without regard to managerial flexibility, the expected present value of the project can be calculated by the traditional discounted cash flow method. The expected present value of the project in each stage is:

$$\bar{V}_i = \sum_{t=i}^{n} \frac{C_t}{(1+\mu)^{t-i}} \tag{36.2}$$

where μ is the risk adjusted discount rate,and $C_t$is the cash flows in each stage.

Step 2: To analyse the risk of the wind power projects, the volatility σ can be calculated by the Monte Carlo simulation (Esber and Baier 2010) of the project future earnings.

Step 3: Given the initial expected project value and the project volatility determined as indicated above, a binomial tree can be constructed to model the stochastic process for project value.

Step 4: Identifying and pricing those real options in the project. Beginning at the last stage, we calculate the value of the options, and mark node the maximum of the options value and the investment in the stage. Then the value of the options can be obtained by decision tree in which each node can be calculated by the replicating portfolio. At last, the expected present value included the managerial flexibility can be obtained in the initial stage.

The basic option-pricing model is not only intuitively appealing but also computationally transparent. The real options in the project can simply be modeled with decision nodes in the tree. However, value-leaking losses are the common phenomenon in real assets pricing. Considering value leaking losses, we modified the basic option-pricing model, try to construct a unique binomial tree not only by the expected present value in each stage and in each statu, but also value-leaking loss, and use option-pricing method to solve the binomial tree.

36.3 The Modified Option Pricing Model Included Leaking Losses

In fact, value-leaking losses are the common phenomenon in real assets pricing, which stem from the cash flow and convenience value ratio. In the modified option-pricing model, value-leaking losses can be set a part of calibration assets, and the proportion can be changed by stage because the management of the risky project would be a multistage decision process.

To calculate the value-leaking loss, we introduce the rate $k_i = C_i/\bar{V}_i$ into the option-pricing model. On one hand, the rate k_i would be changed by stage i because the proportion can be changed by stage, on the other hand, the rate k_i

would not be changed by statu j, because value-leaking losses is set a part of calibration assets. So the value-leaking loss in the stage i and the statu j can be defined as $C_{ij} = k_i V_{ij}$.

In the modified option-pricing model, the first two steps are identical to the method proposed by Copeland and Antikarov. However, we provide an alternative solution methodology to reflect value-leaking loss in the third step. The asset price binomial tree would be constructed not only by the expected present value in each stage and in each statu, but also value-leaking loss. For completeness, we interpret the modifications of the third step in detail.

Firstly, calculating the value of the project deducted the leakage V^1_{ij} :

$$\begin{aligned} V_i^{1u} &= u(V_{i-1} - C_{i-1}) \\ V_i^{1d} &= d(V_{i-1} - C_{i-1}) \end{aligned} \tag{36.3}$$

In Eq. (36.3), the symbols u correspond to the value up state of the projects and d correspond to the value down state of projects. V_{i-1} is the value of the project in previous stage. $C_{i-1} = k_{i-1} V_{i-1}$ is the value-leaking loss in previous stage, which reduces the project value in the subsequent stages. Specially, $k_0 = 0$, because when $i = 0$, the project has not yet been initiated, and there are no value-leaking losses in the initial period.

Secondly, calculating the expected present value of the project deducted the leakage V^2_{ij} :

$$V^2_{ij} = \frac{V^1_{ij}}{(1 + r)^i} \tag{36.4}$$

Thirdly, calculating the expected present value of the value-leaking loss in each stage and in each statu:

$$C^1_{ij} = k_i V^2_{ij} \tag{36.5}$$

Lastly, calculating the expected present value of the project in each stage and in each statu V_{ij} :

$$V_i = V^2_i + \sum_{m=1}^{i} C^1_m \tag{36.6}$$

Thus, Eq. (36.6) can provide us the value of every node in each chance of the binomial tree. Because the risk neutral probabilities have been used, the present value of the wind power project at the initial stage could be getted by the means of payoffs discounted at the risk free rate.

36.4 A Numerical Example

The modified option-pricing model can be illustrated by solving for the value of an wind power production project. The example project has estimated 29 MW per year, the wind power price starts at $10 per megawatts (MW) and grows at 11 % per year over its 4 year operating life. In this example we assume the risk adjusted discount rate is 10 % each year, the risk free rate is 5 % each year and the standard deviation has estimated 35 %. The initial investment is $9 million.

At the end of the third year, the project can be selled by salvage of $4 million. There is also a $1 million per year fixed cost that is not shown in the Table 36.1. We firstly discuss the expected value of the future cash flows showed in Table 36.1. All values are in ten thousand of dollars.

In the initial Year, the present value of the expected cash flows is $8.7 million, which was calculated by the risk adjusted discount rate 10 % each year. According to the assumption proposed by Copeland and Antikarov, this can be served as the best estimate of the current market value of the wind power project excluded options. Because the up-front investment is $9 million, the project's NPV is −0.3 million.

In this example, we assume $\Delta t = 1$, incorporate the values of u, d, and the risk neutral probability p into the model, and calculate by the formulas defined previously. So we can get $u = 1.42$, $d = 0.71$ and $p = 0.48$.

Because the other assumption is that these returns are normally distributed, the project values are lognormally distributed and can be modeled as a Geometric Brownian Motion with constant volatility. The binomial approximation to the GBM process may be modeled by binomial tree. To construct the binomial tree, the following parameters are necessary: project value in the initial stage, the values of u and d, the risk neutral probability, the risk free rate of return, the volatility reflecting the risks of the project, and the project cash flow payout ratios calculated by the formulas defined previously. The value of the wind power project could be getted by the usual dynamic programming approaches, and the discount rate of the expected cash flows adopt the risk free rate. Figure 36.1 shows the binomial tree of value of project excluded options, and the asset price in each stage and in each statu.

According to the real option theory, the modified binomial tree can be used to price the real options because it represents the underlying asset. In this case, investors can abandon the wind power project in the third year for price of $4 million. The investor might need the abandon option if it is averse to risks in the

Table 36.1 Cash flows and ratio for the wind power project

Years	0	1	2	3	4
Net cash flows		222	257	297	340
PV of cash flows	870	957	808	606	340
K = FCF/PV		0.232	0.318	0.49	1

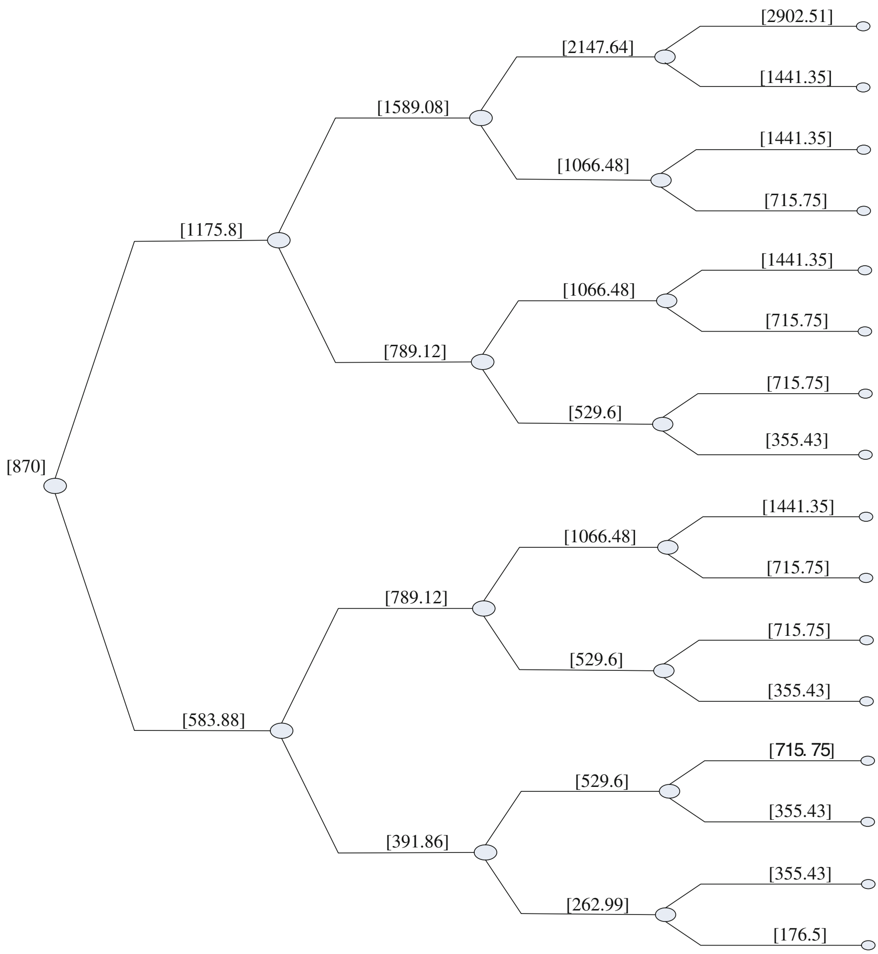

Fig. 36.1 Binomial tree of the project value excluded options

following stages. According to the option-pricing model proposed by Copeland and Antikarov, the value of the project including the abandon option can be evaluated by simply inserting a decision node in Year 3. In the end of the third year, the value of the project including the abandon option is:

$$VO_{3j} = \max(V_{3j}, 400/(1 + 0.05)^3)$$

And the value of the project including the abandon option in the end of the second year and initial year also can be computed using the same risk neutral. The expected present value of the project considering flexibility would be $8.81 million. However, the required up-front investment is $9 million, so the project's NPV

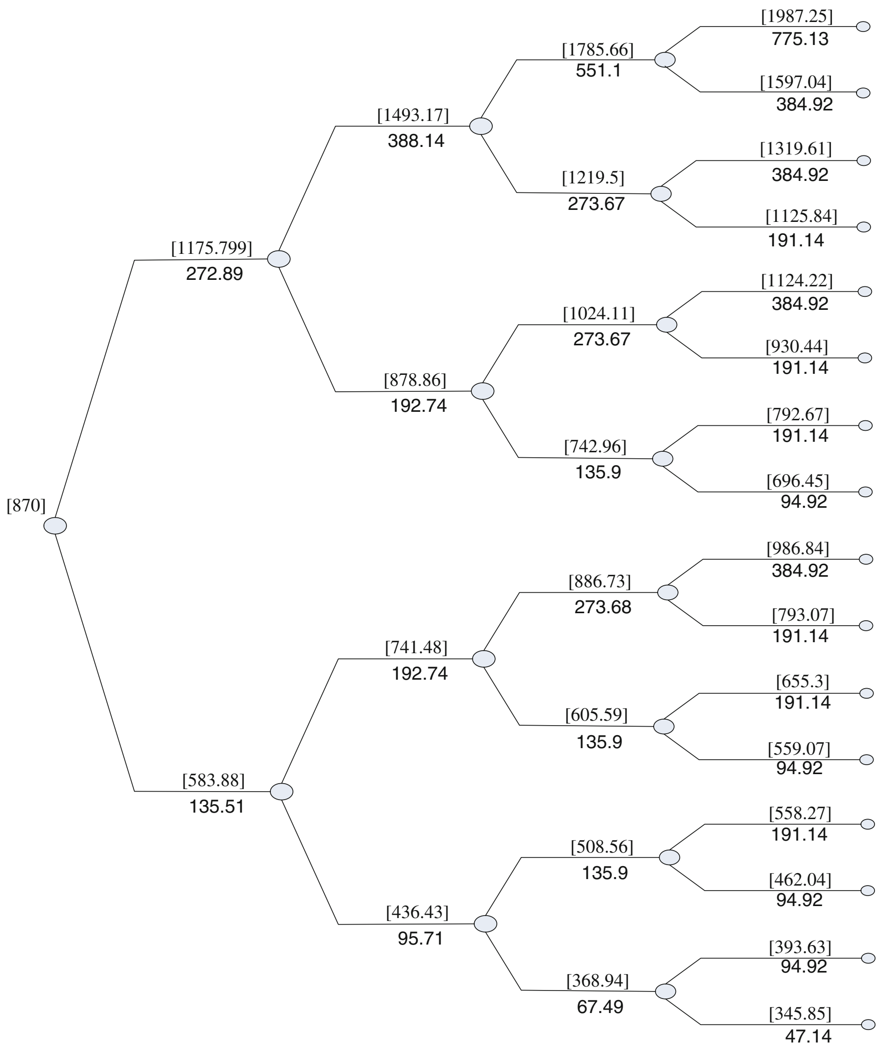

Fig. 36.2 Value of project with option to divest

is −0.19 million. The conclusion is that the wind power project would not be worth to invest.

According to the modified option-pricing model proposed by us, the binomial tree can be used to price the real options because it represents the underlying asset. The construction of the tree and the process of calculating the present value can be illustrated in Fig. 36.2. In addition, suppose investors have the right to abandon the project in the fourth year of its life. The firm might specifically want this option if it is averse to risks later in the project life. Given the binomial tree representation, increased to $10.09 million, so the project's NPV is 1.09 million. The conclusion is that the wind power project would be worth to invest. Compared with the CA approach, our method is more reasonable for a wind power project.

36.5 Conclusion

When discussing the investments in real assets, Discounted cash flow method maybe the most widely used approach for the valuation of projects. However, it is not fit for the wind power projects because Discounted cash flow method is hardly account for managerial flexibility inherent in the projects. In this article, our discussion expanded on the approach presented originally by Copeland and Antikarov, modified the real option pricing model and set up a unique binomial decision tree including the value leaking losses in the wind power project. Firstly, we outlined a decision tree approach to the real-option problem discussed by Copeland and Tufano, then provided an extension of this approach to the wind power project in which the value leaking losses has been considered. This approach has been illustrated with a numerical example. Compared with the basic option pricing model, our approach discussed the value leaking losses in the wind power project which stem from the cash flow and convenience value ratio.

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