Renewable Energy Investment Project Evaluation Model Based on Improved Real Option

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Abstract This study constructed a real option valuation model that the risk could be adjustable based on the characteristics of renewable energy projects and the idea of the Capital Asset Pricing Model and used this model to valuate the renewable energy projects considering selling green electricity certificate revenue. And then, it verified the effectiveness and rationality of this model through the investment projects of the wind power.

Keywords Capital Asset Pricing Model · Real option · Renewable energy

1 Introduction

As the main body of the social economy, enterprise plays a vital role in the renewable energy popularization and the industry development. For the renewable energy, power generation industry in China is in the early stages of the industry, and there are still many uncertainties. All of those factors, such as policy, economy, technology, energy, and resources, will affect the evaluation of the value of renewable energy power generation projects. The scientific and prudential evaluation of the project value will be related to the interests and development of the enterprises and the whole society. Traditional investment decision methods are

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S. Feng et al. (eds.), *Low-carbon City and New-type Urbanization*,
Environmental Science and Engineering, DOI 10.1007/978-3-662-45969-0_4

difficult to accurately assess the value of the project due to the uniqueness of energy and its industry development. Real option theory which is a quantitative tool of the option value of investment project makes an effective mining to the value of the management flexibility and the strategic value of the investment. At present, there have been some researches which make an application of real option concept in making an evaluation of renewable energy investment project in foreign. Lee and Shih (2010) made a point that "the policy effectiveness evaluation model" integrated the cost-effective curve which was brought by renewable energy technology innovation with the real options model. The model quantified the effectiveness of the policy through the analysis of the uncertainty in fossil fuel prices and policy-related factors and studied the current renewable energy policies in Taiwan through empirical analysis (Lee and Shih 2010). Through a study of ethanol-expanded reproduction investment, Pederson and Zou (2009) established a model which embedded the risk factors of market price in investment decision and made use of the available historical market price data, using real options method and Monte Carlo simulation method to evaluate investment decisions of expanding ethanol reproduction problems (Pederson and Zou 2009). Cheng et al. (2011) revealed the changes about clean energy investment strategic choices and strategic value which is due to the lead time of power generation equipment investment and uncertainty of future electricity demand with the binomial real options model which is based on continuous compound option. However, the current studies had a lack of analysis about systemic risks which cannot be distributed outside the enterprise. In general, we always directly divide the value into two parts (the discounted value of future cash flows and option value of investment projects); when we use the real options to valuate the value of investment projects, we mainly use the risk-free rate to discount future earnings without taking the market risk factors that cannot be dispersed into account, and to some extent, resulting in partial distortion about the option value of the project. This paper which is based on analyzing the investment characteristics of renewable energy projects and drawing the idea about Capital Asset Pricing Model brings the non-dispersed systemic risks into the assessment of the project value and builds an improved real option valuation model with the risk adjusted. Then, this paper will make an evaluation of renewable energy investment projects which are under the quota system; we can verify the effectiveness and feasibility of the model through analyzing a typical case of wind power industry and then make some proposals on the investment and operation of renewable energy projects.

2 Model Construction

2.1 Investment Characteristics of Renewable Energy Project

According to the provisions on the type of renewable energy under the "Renewable Energy Law" and "renewable energy quota management approach (draft)," renewable energy generation projects mainly refers to wind power, solar power, biomass power, geothermal, ocean energy power generation, and other non-hydro-renewable energy generation projects. There are obvious differences between renewable energy generation project investments and traditional thermal power project investments. Firstly, renewable energy generation project has a characteristic of investment irreversibility. Because of the higher degree of specialization of renewable energy generation equipment, the majority or all of the initial investment may become a sunk cost as long as making a decision to invest in a renewable energy project that makes the investment irreversible. Secondly, renewable energy return on investment is more uncertain. Many factors will have an enormous impact on the financial income of renewable energy power generation projects, such as policy changes, international and domestic market environment, and technological innovation. Huge differences may exist between the actual yield and the expected yield of investments in renewable energy projects since there are many uncertainties. On the one hand, the investment may generate spillover benefits in a good external environment and internal management; on the other hand, if the risk brings an assault on the project, and the manager could not manage risk well, it will certainly bring losses to the project; third, renewable energy generation projects are more strategical. The exhaustion conventional fossil fuels and increasing awareness of social environment will make renewable energy get a huge development although all kinds of uncertainties exist in renewable energy industry. The current renewable energy investment may not bring corporate large amount of cash incomes, but as the situation develops, the rise of renewable energy sources will make the value of the project gradually reflected, and early investments also lay the foundation for future competition of companies in related fields. Meanwhile, it can promote local employment and local investment, establish good relations with government departments and social image, and can also bring more potential revenue for enterprises, if the enterprise actively participates in renewable energy project investments. So, companies should analyze the impact of renewable energy generation projects for the future development of enterprises, from a strategic point of view.

We could see the option property of renewable energy projects after we analyzed the investment characteristics of renewable energy projects; the option value can be expressed as a function $V = f(S, X, \delta, T, r)$; here, S is the present value of expected future cash flows of a renewable energy project, X is the exercise price which is the initial investment to get this option, δ is the uncertainty about the value of renewable energy projects, T is the validity of the option, and r is the risk-free rate. According to the investment decision criteria, investors will decide to carry out the execution when the present value of cash flow of the project and the option value are greater than the value of the initial investment. In general, the value assessment of the investment project is directly divided into two parts: the discounted value of future cash flows and the option value of the investment projects in the current value assessment research based on the real options. Among that, it uses the risk-free rate for discounting future earnings when calculating the net present value, and the option value is calculated based on a point of project risk management, using the risk rate, so risk caliber is inconsistent in the calculation of different parts of the same project value. The reasons for analyzing this contradiction are that the non-fragmented market risk factors are not taken into account in the calculation of the net present value (NPV) of the project and the option value of the project depends on the project NPV calculations; this also causes partial distortion of the project option value to a certain extent. Therefore, this thesis draws on Lenos' (2007) analysis of market risk theory to make a risk adjustment for the expected return on investment project. A real investment market can be obtained through an analogy with financial market, if, making analysis of the real assets from a financial market perspective, we bring related investment data into model when calculating financial assets with CAPM, and the obtained expected returns on investment should be the basis of the discounting of investment projects; if not, company can choose other more competitive projects to invest. This also avoids the situation with market segmentation among projects in the market, and yet, contradiction that calculated caliber of different values appears unified in the same project. We need to identify types of options that the project contains and select the appropriate real option pricing method when evaluating the option value of energy power generation projects. Considering that renewable energy power generation investment projects have growth value and strategic value and management flexibility value, the option type that project contains can be defined as growth option. According to the optional time characteristic and the convenience of data acquisition of the renewable energy power generation project, this thesis adopts the B–S option model for renewable energy power generation projects to evaluate the option value. In February 2012, the National Development and Reform Commission issued a "renewable energy quota management approach (draft)"; the quota system would affect renewable energy generation projects valuation; this study considered the benefits the relevant provisions of green electricity certificate could produce for the projects. Consequently, this study holds that the total value of renewable power generation project consists of three parts including the risk-adjusted net present value, the option value, and the income of selling green electricity certificate. What must be clear is that, there has not been a corresponding market which can carry out the relevant certificate transaction and the "draft" only gives a rule on the corresponding quota proportion of 2015. This study brings the sale of green power certificate into the evaluation of the total value of the project in order to have a better reflect on a good growth in the future of the renewable power generation project.

2.2 Model Construction

1. Risk-adjusted NPV

   Firstly, consider the project's NPV of expected cash flows in the case that items are not adjusted for risks. According to NPV, risk-adjusted NPV formula is (1):

$$\mathrm{NPV}_r = \sum_{t=1}^{n} \mathrm{CI}_t/(1+r)^t - \sum_{t=1}^{n} \mathrm{CO}_t/(1+r)^t \quad (1)$$

where n is the investment period, CI_t is the cash inflows in t year, CO_t is the cash outflows in t year, and r is the discount rate. Further in reference of the idea of CAPM, achieving the desired rate of return on investment projects through the risk analysis of the renewable energy industry, and making risk adjustment, we get (2):

$$k = E(R_i) = r + \beta_i[E(R_m) - r] \tag{2}$$

Here, k is the risk-adjusted discount rate, which means the discount coefficient of the return on investment at the market average level; $E(R_i)$ is the expected equilibrium returns on asset i; $E(R_m)$ represents the expected return on the market portfolio of all assets; β_i indicates the system risk of assets i that is the sensitivity of asset i when faced with the changes of market m; and r is the risk-free rate. If we brought the risk-adjusted discount rate into the project NPV calculations, we can get formula (3):

$$\mathrm{NPV}_k = \sum_{t=1}^{n} \mathrm{CI}_t/(1+k)^t - \sum_{t=1}^{n} \mathrm{CO}_t/(1+k)^t \tag{3}$$

Looking at the meaning of the coefficients in formula (3), in addition to NPV_k and k, the other coefficients are the same meanings as formula (1). NPV_k represents the risk-adjusted NPV; k is the risk-adjusted discount rate.

2. Risk-adjusted option value of the project
Through risk-adjusted NPV, we will post the data on behalf of the related adjustments into B–S option pricing model, calculating the option value of the projects included. The simplified model formula which is obtained by partial differential equations is:

$$C = SN(d_1) - Xe^{-r(T-t)}N(d_2) \tag{4}$$

Here, $d_1 = \frac{\ln(S/X)+(r+\delta^2/2)(T-t)}{\delta\sqrt{T-t}}$, $d_2 = d_1 - \delta\sqrt{T-t}$.
The representative meanings of coefficients in these three formulas are as follows: C is the option value of the project; S is the market value of the underlying asset; X is the option exercise price; δ is the price volatility of the underlying asset; r is the risk-free rate; T is the expiration date of the option, t is the current time, $T–t$ is maturity of the option; and $N(\bullet)$ is the cumulative normal distribution density function. Calculating the option value depends on the NPV calculations; here,

$$S = \sum_{t=1}^{n} \mathrm{CI}_t/(1+k)^t, \quad X = \sum_{t=1}^{n} \mathrm{CO}_t/(1+k)^t$$

3. Assessing incomes from selling green electricity certificates of the project.
   The income from sale of green electricity certificates W_c is affected by some variables, such as the annual generation capacity Q, the proportion of green electricity quota ρ, the certificates price P_c, and so on; it can be expressed as formula (5):

$$W_c = Q^*(1-\rho) * P_c/1000 \tag{5}$$

   Thus, the NPV of income from selling green electricity certificates during the full life cycle project period of the renewable energy generation can be expressed as formula (6):

$$\mathrm{NPV}_{W_c} = \sum_{t=1}^{n} W_c/(1+k)^t \tag{6}$$

4. The total value of the project
   Finally, adding the project's risk-adjusted net present value, option value, and the present value of the project to sell green electricity certificate together, incorporating into the calculation of the total value of the project, we can get the total value assessment model of renewable energy project based on improved real options, as formula (7):

$$\begin{aligned} W &= C + \mathrm{NPV}_k + \mathrm{NPV}_{w_c} \\ &= SN(d_1) - X\mathrm{e}^{-r(T-t)}N(d_2) + \sum_{t=1}^{n} CI_t/(1+k)^t \\ &\quad - \sum_{t=1}^{n} CO_t/(1+k)^t + \sum_{t=1}^{n} W_c/(1+k)^t \end{aligned} \tag{7}$$

3 Case Analysis

Company A is a large listed enterprise which specializes in new energy development, design, construction investment, and the development, promotion, and application of low-carbon technologies; it was successfully listed in Hong Kong in late 2010. It is ready to invest a wind power project W which is located in province H and plans an installed capacity of 49.5 MW. The wind power project is in line with our strategic planning for renewable energy power development; it plays a great, significant, and positive role in the optimization of the structure of H provincial power source, increasing the reliability of supply and servicing for local economic development, achieving sustainable development; therefore, the selected case here is a representative and typical one. The whole cycle of wind power project

W will last 21 years, the construction period is 1 year, the completed full productive capacity is 49.5 MW, the production period is 20 years, and the annual full-load running time is 2,500 h. The initial investment is 5.00 million yuan. All of the funds are invested in the first year, and 4.33 million yuan is the fixed capital, and the rest is the circulating capital and others. According to state regulations, the acquisition-subsidized electricity price is 0.62 yuan/KWh when power generation equipment operates within 30,000 h, exceeding 30,000 h; the acquisition may refer the local average price 0.41 yuan/KWh; the project runs with higher cash inflow in the first 12 years. The residual rate of fixed assets is 5 % in the end of project operations, approximately converting into 21.65 million yuan, withdrawing liquidity is 1.49 million yuan, and the annual generating capacity of the wind farm is expected to be 1.2375 billion kWh.

1. Risk-adjusted NPV and NPV calculations are not risk adjusted
   If we use risk-free rate for the expected future net cash flows discounted items without considering environmental risk factors. Through the formula (1), the NPV of the project is 132.53 million yuan. Now, the NPV is greater than zero; we should invest in this project in accordance with judgment criterion of investment decision.
   Considering the impact of systemic risk factors that the project faces, we should use a risk-adjusted discount rate k on risk-adjusted NPV. As the long-running cycle of the project, and the entire operating period is 20 years, we refer to the Ministry of Finance-issued 20-year bonds in the recent years, choosing the 20-year half-year interest-bearing debt which was published in by the ministry of finance, national debt code 010713, taking its 4.52 % annual interest rate as the risk-free interest rate r of this case. We can obtain the coefficient $\beta_i = 1.155$ while using the method in reference Xia et al. (2004). Then, selecting the difference between the closing price of Hang Seng Index 17,668.83 in September 23, 2011, and the closing price of Hang Seng Index 19,411.46 in June 29, 2012, as a return on investment, on this basis, we can obtain the return on investment in this period $R_m = 9.86$ %. Taking the above parameter values into formula (2), the expected return on investment assets is the risk-adjusted discount rate:

   $$k = E(R_i) = r + \beta_i[E(R_m) - r] = 10.69\,\%$$

   The risk-adjusted NPV is −82.93 million yuan when we put k into formula (3) to calculate. At this point, the risk-adjusted NPV is less than zero; the investor should invest in the project according to the investment decision criterion. Through the comparison between NPV_r and NPV_k, you can see that the NPV of the project is reducing when we consider the systemic risk of the project; this is because of taking no account of systemic risk, and investors expect the same investment returns; lower risk will increase the expected returns of investors, and relatively higher risk will lead to lower expected returns. When the systemic risk was brought into reward system, according to the thought of discounted cash flow, investors would reduce a certain level expectations of expected cash flows because of the increased risk. Seen from the difference between the results, we need to take environment and systemic risks that the investment faces into account when calculating the NPV of the project; otherwise, that poses a potential danger to project operation without considering the risks to make the investment value artificially high.

2. Option Value of the Project
Here, we use B–S option pricing model to evaluate option value of the project; this model needs definite volatility of the underlying asset. This study selects the stock's closing price of company A between February 15, 2012, and July 10, 2012; then, using historical volatility method to forecast the volatility of revenue growth of this investing enterprise, the day volatility of assets δD is obtained as 2.15 %, so the annual volatility δY is 34.11 %. According to the formula of B–S option model, and bringing the above parameters into formula (4), we obtain $d_1 = 1.2728$, $N(d_1) = 0.8985$; $d_2 = 0.2903$; $N(d_2) = 0.3853$. The option value of project $C = 300{,}050{,}000$ yuan.

3. Green electricity certificate revenue
At present, although there are no specific detailed rules for the implementation of renewable energy quota index, the practice of renewable energy quota system has been set, so the evaluation of the renewable energy power generation project investment needs to consider the increased revenue that the quota brings for the enterprise. "Renewable energy power quota management approach (draft)" provides the quota proportion of large-scale renewable energy generation enterprises that accounted for 6.5 % for their own, while a prescribed amount of green electricity certificates is 1,000 K/Wh. The price of the certificate must be defined if you would have revenue from energy renewable green electricity certificates inserted into the value evaluation of the project. Ideally, the price of green electricity certificates should be the difference between the marginal cost of renewable and conventional electricity power. Selecting the average of the lower limit 0.15 yuan/KWH and the upper 0.5 yuan/KWH of wind power green electricity certificate estimates in literature Li et al. (2012) to valuate the price for green power certificate (Xia et al. 2004), the price of a green electricity certificate is obtained as 325 yuan. According to the basic data of wind farms, when the annual generating capacity is 1.2375 trillion KWH, the number of green power certificates that companies can sell is 115,706 besides the need for companies to meet their quota for the proportion of renewable energy. Due to the differences between the marginal cost of different renewable energy relative to conventional electricity, you can use multiple certificates to be adjusted for different green electricity certificate designing different weights; for instance, a certificate of solar green electricity can be used for five copies and wind power is one, and the multiple choice of this paper for wind power project certificate is double which conforms to cost expectation of current wind power electricity. Taking the data into calculation formula (6) of green power certificate revenue, we can get the project-sale income of green electricity certificates as 37.6

million yuan a year; if the project runs for 20 years, the total NPV is RMB 343.19 million.

4. The total value of the project
   Adding C, NPV_k, and $NPVw_c$, the project's final value is 560,310,000 yuan. According to the investment decision criterion, we should invest in the project. Based on risk adjustment of interest rate and the evaluation of the option value, you can dig deeper into the value of the project and avoid overestimation of risk returns, and the impact of systemic risk is also brought into the project evaluation.
5. Sensitivity analysis
   Further, find out the sensitivity factors of project financial data to make reference for investment decisions. This study selected annual full-load generation time, initial investment, and feed-in tariff; these three indicators affect prime operating revenue of the project; then, we use a single sensitivity analysis to separately calculate the sensitive degree of the whole project value when index increases or decreases by 5 % or 10 %. The specific calculation results are shown in Table (1).
   As shown in the table, the uncertainly factor which affects the project value most is annual full-load generation time, and its sensitive coefficient is around 4.5, followed by a feed-in tariff with sensitivity coefficient of about 4.35; the last is the initial investment, sensitivity coefficient of around −2.25. Through break-even analysis of the project, we can get the break-even annual full-load generation time of the project as 1,937.8 h, and feed-in tariff level of profit and loss balance as the current 76.73 % of feed-in tariff level. In the operation of the project, therefore, people need to strengthen the maintenance and repair of wind turbine in order to ensure the benefits and the value of the project, to ensure that

Table 1 Sensitivity analysis

Uncertain factors	Rate of change (%)	Change rate of the project value (%)	Sensitivity coefficient (%)
Original scheme	0	0	0
Annual full-load generation time	−10	−44.78	4.48
	−5	−22.44	4.49
	5	22.53	4.51
	10	45.15	4.51
Initial investment	−10	22.66	−2.27
	−5	11.30	−2.26
	5	−11.26	−2.25
	10	−22.47	−2.25
Feed-in tariff	−10	−43.30	4.33
	−5	−21.70	4.34
	5	21.80	4.36
	10	43.67	4.37

the unit can carry on the production capacity according to the plan without loss due to the equipment failure; at the same time, it also shows that projects face a greater uncertainty when it is the insufficient run caused by the natural environment. The sensitivity coefficient of the initial investment is relatively smaller; enterprises need reasonable budget and strict control to ensure that the project will not appear larger as initial investment increases, and yet minimize the amount of investment. Although the feed-in tariff is not controllable, it can reflect the sensitivity of the project value when the project faces price level fluctuations, so the influence of electricity price fluctuation on the project value cannot be ignored due to the primary business of project electricity sales.

4 Summary

The investment value of renewable energy projects is affected by multiple internal and external factors, considering the non-diversifiable systemic risk and selling green electricity certificate revenue in the quota system; this study constructed a real option valuation model in which the risk could be adjustable and improvements can be made to evaluate the value of renewable energy projects. This model brings potential losses which can be created by external systemic risk of the firm into value assessment system, providing a new idea for value assessment of that type of investment projects to effectively reduce investment risks. The mode still has some limits. First, the market risks cannot be measured correctly; the project risk coefficients of the model are only adjusted by financial markets data with the help of the relation of the financial markets and the real investment. This method will impact the calculation results. Secondly, due to the long operating cycle of renewable energy power generation projects, when we use option valuation model to calculate the value of the project, the method of historical volatility may not accurately reflect the project's asset volatility of future changes in a longer period of time, so how to better determine the volatility of project assets worth further investigation.

Acknowledgments Supported by the humanity society, and scientific research funds of the Ministry of Education for the western and border areas. (Project No: 13XJC630003).

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