ISSN 1749-3889 (print), 1749-3897 (online)
International Journal of Nonlinear Science
Vol.12(2011) No.1,pp.112-116

Analysis on the Strategy of Wind Power Investment under Uncertainty

Chunhua Chen[1] *, Zhengnan Lu[2]
[1] School of Finance & Economics, Jiangsu University, 212013, Zhenjiang
[2] School of Business Administration, Jiangsu University, 212013, Zhenjiang
(Received 6 June 2011 , accepted 30 July 2011)

Abstract: Considering two kinds of uncertain factors—electricity price of wind power and wind power generation capacity, wind power investment strategy selection model is established by using real option. The empirical analysis show that the factors, such as risk-free rate, growth rates of electricity price of wind power and wind power generation capacity considerably affect the strategy of wind power investment, While the factors such as life cycle of wind power project and initial investment cost have relatively limited influence.

Keywords:uncertainty; real option; wind power investment strategy; electricity price of wind power; wind power generation capacity

1 Introduction

The cost of wind power initial investment is irreversible. If the wind power projects can't normally combine to the grid, it is difficult to guarantee its profit, therefore, it is most important for the investor of wind power to choose the reasonable investment strategy under so many uncertain factors. Ming Yang (2010)[1] thought that CDM project benefits had significant effect on net present value (NPV) of wind power project. Shun-Chung Lee (2010) [2] evaluated the social and economic benefits of wind power development in the uncertainty of fuel oil price. Zhu Lei (2010) [3] considered that electricity price of wind power consisted of the sales income of wind power on line and the income of selling certified emission reduction after carrying out carbon trading system and change with the carbon price changing in the carbon trading market. So he also considered that the strategy of wind power investment should fully take electricity price of wind power into consideration. Apart from the price, the wind power generation capacity also influenced the strategy of wind power investment. Liu Min (2010) [4]thought that wind power generation capacity was an important but uncertain factor for wind power investment. Further, Bellamy (2007)[5] and Wang Wen-ping (2008) [6] analyzed the choice of wind power investment strategy from the uncertainty of cash flow.

The existing research mainly used real option theory to assess investment strategies under the single uncertain factor, but there is little research on the wind investment strategy under many uncertain factors. Here, we use the research of Dixit. A.K (1994) [7] and tries to construct a model of wind power investment strategy binding two factors- electricity price of wind power and wind power generation capacity, and analyzes the influence of the factors, such as risk-free rate, growth rates of electricity price of wind power and wind power generation capacity on critical point of wind power project earning.

2 Model constructions and analysis

Suppose electricity price of wind power P is obedient to geometrical Brownian movement:

$$dP = uPdt + \sigma_1 Pdz_1 \tag{1}$$

Where u_1 represents expectations and σ_1 represents standard deviation.
Suppose wind power generating capacity Q is obedient to geometrical Brownian movement:

*Corresponding author. *E-mail address*: chunhua760203@yahoo.com.cn

IJNS.2011.08.15/520

$$dQ = u_2 Q dt + \sigma_2 Q dz_2 \tag{2}$$

Where u_2 represents instantaneous expectations and σ_2 represents standard deviation.

Investor of wind power has an investment opportunity to select electricity price of wind power or wind power generating capacity. While investment opportunity has been chosen, the opportunity will disappear. Therefore, the investment option of wind power is similar to financial option, which is also a kind of real options.

Under the situation of no-arbitrage in the market, the return of portfolio is equal to the risk-free rate r, and the income option value of portfolio $F(P,Q)$ should satisfy the equation:

$$\begin{aligned}\frac{1}{2}\sigma_1^2 P^2 \frac{\partial^2 F(P,Q)}{\partial P^2} + \frac{1}{2}\sigma_2^2 Q^2 \frac{\partial^2 F(P,Q)}{\partial Q^2} + \rho u_1 u_2 PQ \frac{\partial^2 F(P,Q)}{\partial P \partial Q} + (r-u_1)P\frac{\partial F(P,Q)}{\partial P} \\ + (r-u_2)Q\frac{\partial F(P,Q)}{\partial Q} - rF(P,Q) = 0\end{aligned} \tag{3}$$

Where ρ is correlation coefficient of P and Q.

Suppose the investment income of wind farm is $Y = PQ$ and option income is $F(Y) = F(P,Q)$, the equation (3) can be rewritten as:

$$\frac{1}{2}(\sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_2)Y^2 \frac{\partial^2 F(Y)}{\partial Y^2} + (2r + \rho\sigma_1\sigma_2 - u_1 - u_2)Y\frac{\partial^2 F(Y)}{\partial Y} - rF(Y) = 0 \tag{4}$$

From $F(Y) = 0$, the general solution of equation (4) is obtained as:

$$F(Y) = A_1 Y^{\beta_1} \tag{5}$$

The characteristic equation for equation (4) can be rewritten as:

$$\frac{1}{2}(\sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_2)\beta(\beta-1) + (2r + \rho\sigma_1\sigma_2 - u_1 - u_2)\beta - r = 0 \tag{6}$$

From equation(6), the result is obtained as:

$$\beta_1 = \frac{-(\eta-\alpha) + \sqrt{(\eta-\alpha)^2 + 4r\alpha}}{2\alpha}$$

Where $\alpha = \frac{1}{2}(\sigma_1^2 + \sigma_2^2 + 2\rho\sigma_1\sigma_2)$, $\eta = 2r + \rho\sigma_1\sigma_2 - u_1 - u_2$

Also the value of wind power investment $V(Y)$ is obtained as:

$$V(Y) = -I + \int_{\theta}^{\theta+\tau} Y e^{(u_1+u_2-2r)t} dt = -I + \frac{Y e^{(u_1+u_2-2r)\theta}}{2r - u_1 - u_2}(1 - e^{(u_1+u_2-2r)\tau}) \tag{7}$$

Where θ is construction period, τ is length of service for wind power project, I is wind power initial investment cost. The conditions of value matching and smooth paste are:

$$V(Y) = F(Y), V'(Y) = F'(Y) \tag{8}$$

From equation (7)and (8), critical value of wind power investment income and the coefficient of wind farms' expected return are obtained as:

$$Y^* = \frac{\beta_1(2r - u_1 - u_2)}{(\beta_1 - 1)e^{(u_1+u_2-2r)\theta}(1 - e^{(u_1+u_2-2r)\tau})} I, \tag{9a}$$

$$A_1 = [\frac{Y^* e^{(u_1+u_2-2r)\theta}(1 - e^{(u_1+u_2-2r)\tau})}{2r - u_1 - u_2} - I]Y^{*-\beta_1} \tag{9b}$$

Therefore, option income of wind power investment can be further gained:

$$F(Y)=\begin{cases}[\dfrac{Y^{*}e^{(u_1+u_2-2r)\theta}(1-e^{(u_1+u_2-2r)\tau})}{2r-u_1-u_2}-I](\frac{Y}{Y^{*}})^{\beta_1}, Y<Y^{*}\\ [\dfrac{Ye^{(u_1+u_2-2r)\theta}(1-e^{(u_1+u_2-2r)\tau})}{2r-u_1-u_2}-I], Y\geq Y^{*}\end{cases} \tag{10}$$

To sum up, the paper can get the following conclusions:

(1) According to the decision of tradition NPV, $Y^{NPV}=\frac{2r-u_1-u_2}{e^{(u_1+u_2-2r)\theta}(1-e^{(u_1+u_2-2r)\tau})}I$ is critical value of the decision. If$Y\geq Y^{NPV}$, rational wind power investors will choose wind farm investment.

(2) According to the decision of real option SNPV, $Y^{*}=\frac{\beta_1(2r-u_1-u_2)}{(\beta_1-1)e^{(u_1+u_2-2r)\theta}(1-e^{(u_1+u_2-2r)\tau})}I$ is critical value of the decision. If $Y\geq Y^{*}$, rational wind power investors will choose wind farms investment.

(3) According to the decision of real option SNPV ,if the uncertainty of electricity price of wind power is only considered, the income critical value of electricity price of wind power is:

$$P^{*}=\frac{\beta_1(r-u_1)}{(\beta_1-1)Qe^{(u_1-r)\theta}(1-e^{(u_1-r)\tau})}I$$

Where $\beta_1=\frac{-(\eta-\alpha)+\sqrt{(\eta-\alpha)^2+4r\alpha}}{2\alpha}$, $\alpha=\frac{1}{2}\sigma_1^2$, $\eta=r-u_1$.

If $P\geq P^{*}$, rational wind power investors will choose wind farm investment. The conclusion is in conjunction with the result in the literature (3).

(4)According to the decision of real option SNPV, if the uncertainty of wind power generation capacity is only considered, the income critical value of wind power generation capacity is:

$$Q^{*}=\frac{\beta_1(r-u_2)}{(\beta_1-1)Pe^{(u_2-r)\theta}(1-e^{(u_2-r)\tau})}I$$

Where $\beta_1=\frac{-(\eta-\alpha)+\sqrt{(\eta-\alpha)^2+4r\alpha}}{2\alpha}$, $\alpha=\frac{1}{2}\sigma_2^2$, $\eta=r-u_2$.

If $Q\geq Q^{*}$, rational wind power investors will choose wind farm investment.

3 Empirical analysis

Same to reference [3], this paper analyzes the data from wind farm in Inner Mongolia Hu-teng tin Le. The data are shown in Table1.

Table 1: Model parameter

Parameter	Data	Data sources	Parameter	Data	Data sources
I (Yuan)	214129600	reference [3]	u_1	0.02	reference [3]
Q(KWh)	59190000	reference [3]	σ_1	0.03	reference [3]
P(Yuan)	0.5	reference [3]	u_2	0.05	hypothesis of the paper
θ(Year)	2	reference [3]	σ_2	0.04	hypothesis of the paper
τ(Year)	20	reference [3]	ρ	0.5	hypothesis of the paper
r	0.05	reference [3]			

From Table 1, the results by calculating are shown in Table 2. Thus the paper could get several conclusions:

(1) Considering two kinds of uncertain factors—electricity price of wind power and wind power generation capacity are, the investment gains of wind farm project is 2.9595 e+007 Yuan. According to the traditional NPV method, the project investment income of the critical value is 2.5118 e+007 Yuan. And according to the real option method the project investment income of the critical value is 4.1240 e+007 Yuan. Using the traditional NPV method to choose investment strategies, the wind power investor will choose to execute investment plan; but using the real options method to choose investment strategies, the wind power investor will choose to wait for executing investment plan. Apparently, according to the two methods to decide the strategy of wind power investment, the completely opposite scheme will be gained. The reason is that the former only considers the value of wind power investment income and the latter further considers the options value. Wind power is a capital-intensive industry which have large- scale investment and high risk. The investment

strategy of wind power should consider the uncertain profit of wind farm. It is relatively appropriate to use real option method to choose investment strategy.

(2) Considering the uncertainty of electricity price of wind power is considered, the electricity price of wind power is 0.5 Yuan but the critical value of the project investment income according to the real option method can be calculated as 0.6480 Yuan. If using the real option method to choose investment strategies, the wind power investor will choose to wait for executing investment plan.

(3) Considering the uncertainty of wind power generation capacity, wind power generation capacity of the wind farm project is 5.919 e+007 KWh but the critical value of wind power generation capacity according to the real option method can be calculated as 3.2069 e+007 KWh. If using the real options method to choose investment strategies, the wind power investors will choose to execute investment plan.

Table 2: Model calculation results and strategic choice

Uncertain Factors	Profit	Calculation results	Strategic choice
PandQ	Y	2.9595e+007	-
	Y^{NPV}	2.5118e+007	Execute
	Y^*	4.1240e+007	Waiting
P	P	0.5	-
	P^*	0.6480	Waiting
Q	Q	5.919e+007	-
	Q^*	3.2069e+007	Execute

Table 3 describes the change of parameters which have effects on the critical value of wind power project income. The conclusion could be provided as follows:

(1) If construction cycle of wind farm shortens one year, the life cycle of wind power project can lengthen 10% and the initial investment costs can fall 10%, the range ability of critical value is inferior to the corresponding parameter variation. Obviously, they have relatively limited effect on decision-making for wind power investment.

(2) If the risk-free rate, electricity price of wind power and wind power generation capacity promotes 10% each other, the range ability of critical value are much higher than the corresponding parameter variation. Obviously, they have significant effect on decision-making for wind power investment.

Therefore, considering two kinds of uncertain factors—electricity price of wind power and wind power generation capacity, the rational investors of wind power should focus on the factors such as the risk-free rate, growth rates of grid price of wind power and wind power generation capacity.

Table 3: Change of parameters for critical value of wind power project income

Change of parameters	Critical value Y^*	Range ability(%)	Change of parameters	Critical value Y^*	Range ability(%)
I drop10%	3.7116e+007	-10	u_2 promote 10%	3.6693e+007	-11.026
θ shorten 1 year	4.0021e+007	-2.9559	σ_2 promote 10%	4.1548e+007	0.74685
τ promote 10%	3.8512e+007	-6.6149	r promote 10%	6.7244e+007	63.055
u_1 promote 10%	3.1306e+007	-24.088	ρ promote 10%	4.1436e+007	0.47527
σ_1 promote 10%	4.1636e+007	0.96023			

4 Conclusions

If electricity price of wind power or wind power generation capacity is considered separately, the strategies of wind power investment will be different. Compared with the uncertainty of wind power generation capacity, the uncertainty of electricity price of wind power has relatively apparent influence on decision-making for wind power investment. Furthermore, considering the uncertainty of electricity price of wind power and wind power generation capacity, the rational investors of wind power should focus on the factors such as risk-free rate, growth rates of grid price of wind power and wind power generation capacity.

Acknowledgments

Research was supported by the Humanities, Social Sciences Research general project of Ministry of Education (No. 09YJA630052), the College of Philosophy and Social Sciences key researchbase of major project of Jiangsu (No. 2010-2-9).

References

[1] M. Yang, Francois Nguyen and Philippine De TSerclaes. Wind farm investment risks under uncertain CDM benefit in China[J]. *Energy Policy* , 38 (2010) (3):1436-1447.

[2] S. Lee, L. Shih. Renewable energy policy evaluation using real option model -The case of Tai-wan [J]. *Energy Economics*, 32 (2010):S67-S78.

[3] L. Zhu, Y. Fan, X. Zhang. A study on Chinas wind power investment based on real options and preemption[J].*Journal of Applied Statistics and Management*, 2(2010):328-335.(In Chinese)

[4] M. Liu. Assessment on the wind power investment decision-making strategy[J].*Journal of Guizhou University(Natural Science Edition)*, 1(2010):72-75. (In Chinese)

[5] M. Bellamy, J. Sahut. Real option and consequences of a sudden cash flows decrease in investment strategies [J], *Banqueet Marches*, 88 (2007):40-45.

[6] W. Wang, H. Yang.The application of real option on wind power generation project investment decision[J], *Power System and Clean Energy*, 2(2008):42-46. (In Chinese)

[7] A.K. Dixit, R.S. Pindyck. Investment under uncertainty[M], Princeton: Princeton NJ,1994.