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CCS Investment Decision Based on Real Options

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Abstract: Based on the theory of real options, this paper establishes a investment decision-making model that could evaluate the development of CCS considering some uncertainties: feed-in tariff, the clean price, carbon price, incentives and subsidies from the government and the progress of technology. This model calculates the investment value of CCS project by studying the binomial tree model of real options. It considers many details, analyzes the current situation of Chinas investment in CCS project, conducts scenario simulations and gets more accurate analysis on the value of our investment in the coming years. It gets the critical condition through calculating Chinas coal-fired power plant status and development trend. The paper will help the investment decision makers assess the development of renewable resources which may contain some uncertainties.

Keywords: real options; CCS; binomial tree; multi-perspective; investment decision

1 Introduction

Now coal makes up seventy percentage of China's total energy, whereas it produces large amounts of carbon dioxide in the process of coal generation. China has overtaken United States and became the largest emitter of carbon dioxide of the world in 2007. While in the next few decades, the situation that most of our energy comes from coal is hard to change. And therefore, the carbon capture and storage technology (CCS) which can capture and store carbon dioxide emitted by the carbon plants to realize the zero net emissions of carbon dioxide, is an effective way to mitigate the green house effect. But CCS is a new technology, different from the other two energy technologies, new energy development and energy saving. When it is applied to coal power system there is a lot of uncertainty. Real option theory can make a better evaluation on the CCS of coal power system compared to the traditional investment decision methods.

Real option is the expansion of option pricing theory in the real (non-financial) assets development, reflecting that the investors have right to make decision based on market changes in various forms if there is the possibility of space and investment in the future. To be specific, the thought of real option believes that investors have investment opportunities in a project. This opportunity gives investors the right to implement the investment project according to the investment cost within a certain time.

The foreign aspect, Ching-Tsung Cheng et al. [1] established a model based on sequential compound options, which may account for the lead time and uncertainty as a whole is established, and a numerical example on evaluating the optional strategies and the strategic value of the cleaner energy policy is also presented. Lei Zhu, Ying Fan[2] considered the existing thermal power generation cost uncertainty , a carbon price , electricity generation and investment costs and other factors based on real options theory to establish a carbon capture and storage (CCS) investment evaluation model . Xiangping Zhang et al. [3] used the carbon chain to analyze and evaluate the carbon dioxide capture and storage (CCS) complex energy conversion systems.Laurikka [4] studied the investment issues of the transformation of existing power plants to install a cogeneration system, and used Monte Carlo simulation method to simulate the emissions quotas, tariffs, fuel prices, a number of random variables. Blyth et al. [5] analyzed real option value investing coal-fired plant and installing CCS equipment under uncertain climate policy environment in the framework of real option. Abadie et al. [6] studied the real option approach to invest in CCS installations in coal-fired power station, considered two sources of risk, namely the price of emission allowance and the price of the electricity output, assessed the option to install a

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carbon capture and storage (CCS) unit in a coal-fired power plant operating in a carbon-constrained environment. Ming Yang et al. [7] used a real option approach (ROA) for analyzing the effects of government climate policy uncertainty on private investors decision-making in the power sector. Jana Szolgayova, Sabine Fuss and Michael Obersteiner [8] used real options modeling to assess the impact of different climate change policy instruments on investment, profits and cumulative emissions in the electricity sector. Sabine Fuss [9] analyzed the impact of uncertainty on investment decision-making at the plant level in a real options valuation framework. Gnther Westner and Reinhard Madlener [10] applied a spread-based real option approach to analyze the decision-making problem of an investor who has the choice between an irreversible investment in a condensing power plant without heat utilization and a plant with combined heat-and-power (CHP) generation. Sekar [11] analyzed and compared the pros and cons of three techniques-IGCC, NGCC (natural gas combined cycle power generation) as well as the ordinary coal-fired power plant-under different conditions of carbon dioxide policy. In the follow-up study, Sekar [12] analyzed how uncertain future US carbon regulations shape the current choice of the type of power plant to build, focused on two coal-fired technologies, pulverized coal (PC) and integrated coal gasification combined cycle technology (IGCC).

Domestically, Zhang Zhengze [13] analyzed the trade of carbon emission, the power and clean electricity prices, government investment subsidies and technical progress in the real option method framework, built investment profit equation reflecting these uncertainties of CCS project and binary tree and trigeminal tree model under the condition that investing real option has delayed, and made a sensitivity analysis on those uncertainties influencing the value of project.

To sum up, foreign studies about CCS investment on ordinary coal-fired power station go further, compared with domestic studies. At present, the research of this aspect develops not quite comprehensive. The model is so onefold that can not truly assess the coal-fired power station option value. Because of the specific differences of China's national conditions, we can not apply the foreign results mechanically. We must consider the reality of Chinas national conditions. CCS investment on this type of power plant will be a new research direction. Researches about CCS investment analysis on IGCC plants at home and abroad are few. To promote IGCC power plants to install CCS lacks of theoretical support. The method and model used for research are single, only focusing on the discrete option method. Therefore, the development of random options theory, seeking the best investment critical condition is a pressing issue.

2 Main factors in the model

2.1 Carbon price

When the carbon dioxide emissions from power plants in our country is lower than the original level, it can sell its surplus quota. However there is no mature carbon market in China, the price of carbon depends on the international market. CERs prices will be directly affected by the international carbon trading market. So the price of carbon emissions is another factor.

2.2 Feed-in tariff

When coal-fired power station invests the CCS project, large-scale CO2 capture system will consume a lot of energy, thereby reducing the output of electricity in coal-fired power station. Tariff as external factors beyond the control of coal-fired power stations, it is necessary to analyze the current situation and development to make sure the decrease income due to the investment of CCS project.

2.3 Clean price

The using of clean price is an incentive way to encourage the coal plants to apply the CCS technology. This paper intends to follow our decarbonization desulfurization clean electricity as clean electricity standards.

2.4 Incentives and subsidies from the government

The investment from the government on the CCS used in coal-fired power station system will reduce the investment from the investors. This way can actively encourage some relevant enter prises to invest the CCS technology and will have a significant impact on the further development of CCS.

2.5 Technology progress

Based on the study of Machteld [14]et al, we set Chinas investment cost of CCS technology decreased by 5 percent annually. Assuming the total investment cost of CCS technology equipment under the present technical condition is I,t years later it will turn toI_t, then we get $I_t = I \cdot e^{-0.05t}$

3 Model description

3.1 NPV method

For the investment on projects, if $NPV > 0$,we choose to invest;if $NPV < 0$,we will give up.However,there is potential value of the projects with $NPV < 0$.With maximizing profit as the ultimate goal,the target income equation of CCS project can be represented as follows: $NPV = CER_s \times C + P \times Q - I - C_{om} - P_0 \times Q_0 - I_p - I_f$
where, CER_s is certified carbon emission reduction, C is carbon price, P is clean price, Q is annual generation capacity of CCS, I is investment cost, C_{om} is operation and maintenance cost, P_0 is feed-in tariff, Q_0 is the generation capacity because of the use of CCS, I_p is fixed cost, I_f is other cost,here is carbon tax.

We can obtain NPV of CCS project is:

$$NPV = \sum_{t=\tau+2}^{\tau+T}(CER_s \times C + P \times Q)e^{-r_0(t-\tau)} - \sum_{t=\tau+2}^{\tau+T}(C_{om} + P_0 \times Q_0)e^{-r_0(t-\tau)} - \sum_{t=\tau+2}^{\tau+T}(I_p + I_f) \cdot e^{-r_0(t-\tau)} - e^{r_0\tau} I e^{-0.05\tau} \cdot (1-k) = (CER_s \times C + P \times Q - C_{om} - P_0 \times Q_0 - I_p - I_f)\frac{e^{-r_0} - e^{-r_0 T}}{e^{r_0} - 1} - I e^{(r_0 - 0.05)\tau} \cdot (1-k)$$

3.2 Investment evaluation model

Because carbon price C follows the binomial lattice stochastic process, we can replace C with C(k,i). Therefore the investment value of CCS project is:

$$V(k,i) = (CER_s \times C(k,i) + P \times Q - C_{om} - P_0 \times Q_0 - I_p - I_f)\frac{e^{-r_0} - e^{-r_0 T}}{e^{r_0} - 1} - I e^{(r_0 - 0.05)\tau} \cdot (1-k)$$

To facilitate the analysis, we consider that the investor can develop at any time node, thus the value rule of the best investment strategy is:

$$V(T,i) = max\{(CER_s \times C(T,i) + P \times Q - C_{om} - P_0 \times Q_0 - I_p - I_f)\frac{e^{-r_0} - e^{-r_0 T}}{e^{r_0} - 1} - I e^{(r_0 - 0.05)\tau} \cdot (1-k), 0\}$$

$$V(k,i) = max\{(pV(k+1,i+1) + (1-p)V(k+1,i))e^{-r(T/n)}, (CER_s \times C(k,i) + P \times Q - C_{om} - P_0 \times Q_0 - I_p - I_f)\frac{e^{-r_0} - e^{-r_0 T}}{e^{r_0} - 1} - I e^{(r_0 - 0.05)\tau} \cdot (1-k)$$

$$(0 \le k \le T, 0 \le i \le k)$$

4 Parameter estimation

4.1 Parameter estimation of carbon price

Due to the limited data, we take the sample interval from January to December, 2013. The average carbon prices are shown in Fig 1.

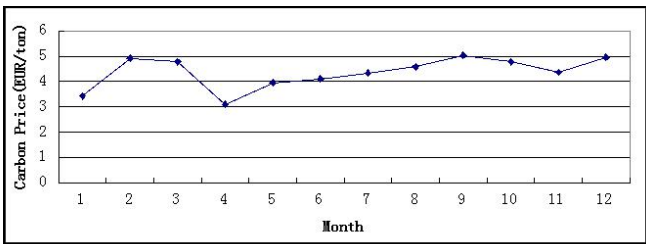

Figure 1: Historical data of carbon price

According to the carbon prices, we calculate the volatility of carbon price $\sigma = 0.6205$.

The average carbon price of 12 months in 2013 is 4.36 EUR/ton. And $1EUR = 8.2210yuan$, C(0,0) can be got 35.8435 yuan/ton. We can get the calculated results of carbon prices based on binomial tree theory. These results are shown in Table 1.

Table 1: The calculated results of carbon prices (yuan/ton)

2013	2014	2015	2016	2017	2018-2031	2032	2033
35.8435	66.66381	123.9852	230.5948	428.8736	...	2541239	4726343
	19.27217	35.8435	66.66381	123.9852	...	734659.4	1366362
		10.36218	19.27217	35.8435	...	212386.3	395008.4
			5.571488	10.36218	...	61399.82	114194.9
				2.995653	...	17750.38	33013.18
					...	5131.546	9543.945
						1483.504	2759.107
						428.8736	797.6439
						123.9852	230.5948
						...	...
							0.000272

4.2 Other parameters

Other parameters including CCS investment cost, CCS operation and maintenance cost, feed-in tariff, clean price, CCS dissipated energy, benchmark discount rate, risk-free interest rate are all shown in Table 2.

Table 2: Other Relative Parameters

Parameter	Symbol	Value	Notes
CCS investment cost	I	10000×10^6 yuan	According to [2]
CCS operation and maintenance cost	C_{om}	2000×10^6 yuan	According to [2]
Feed-in tariff	P_0	0.39 yuan/kwh	
Clean price	P	0.41 yuan/kwh	
CCS dissipated energy	α	0.2	
Benchmark discount rate	r_0	0.08	Mainly used to measure the opportunity cost taken by funds of the project [15]
Risk-free interest rate	r	0.05	Long-term loan interest rate in China [16]

5 Scenario Analysis

5.1 NPV method of CCS project

Table 3: NPV of CCS under different value of k(unit:10^6 yuan)

0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-29077	-28077	-27077	-26077	-25077	-24077	-23077	-22077	-21077	-20077

The data in Table 3 shows NPV of CCS project is less than 0 under different value of k. That is, according to NPV theory, we should not make investment immediately.

NPV theory approach just considers the current value of the project. Negative value just indicates the current value of CCS project. If you want to make a comprehensive judgment, you have to consider the current value and potential value of the CCS project.

Table 4: Investment value of real options (unit: 10^8 yuan)

2013	2014	2015	2016	2017	2018-2031	2032	2033
1.002158	2.158919	4.607974	9.738955	20.37027	...	211929.9	394403.7
	0.3514283	0.7843331	1.735214	3.802675	...	61053.14	113794.4
		0.1059200	0.2461121	0.5674855	...	17435.42	32671.64
			0.02575316	0.06261661	...	4825.760	9219.466
				0.00449742	...	1180.370	2439.559
					...	177.1836	479.5216
						...	...
							0

5.2 Investment value of real options

According to the investment decision-making rules with real options,we should make investment immediately because the data in table 4 is greater than 0.

Real options can consider potential value, so this method is more accurate than NPV method. When it is different between these two methods, we should choose the result from the real options.

6 Conclusions

This paper applies the real options theory and establishes a model that consider more factors of carbon price, clean electricity price, feed-in tariff, operation and maintenance cost and carbon tax and so on. Compared with the traditional NPV method, real options method can consider the potential value of the project, provide more accurate basis for decision makers. In this paper, the model can quantitatively analyze the project uncertainties, while the NPV method is only based on the value of the current stage,can not quickly and accurately take into account the future value of the project. Thus the real options method is more accurate than the NPV method.

The data applying the NPV method is less than 0. Based on the NPV method, we should abandon the CCS project. The data applying the real options theory is greater than 0. Based on the real options theory, we should make investment immediately. Because of the excellence of the real options, we should choose the result from the real options. So we can invest the CCS project now. And some relevant government departments can make appropriate policies.

This model that the paper established can also be used in other renewable energy project. At the same time, the established model still has limitations. These issues need to study in future work.

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