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REAL OPTIONS MODEL FOR VALUATING CHINA GREENTECH INVESTMENTS

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ABSTRACT

The environmental issues of China have attracted global concern. Recent past has witnessed significant investments made in a broad range of greentech businesses – encouraged by significant political and economical drive. Among these, Carbon Capture and Storage (CCS) is considered a promising business. This paper describes a decision problem faced by a firm in determining the optimal timing to invest in a CCS project to reduce CO2 emissions and therefore minimize the purchase of emissions credits. A real options model is developed to simulate the decision process in which the price of emissions credits is assumed to follow a binomial process. It quantized the effect of inflation and depreciation, and worked out the optimal time to invest greentech project. In this model, the firm is assumed to make optimal decisions about a CCS project when the price of emissions credits reaches critical value.

KEYWORDS

Environmental Issues, Real Options, Carbon Capture and Storage, China Greentech Investment, Optimal Timing

1. INTRODUCTION

Environmental issues have increasingly influenced corporations' overall strategy and operations all over the world. New policy terms like Energy Saving/Lean Energy, Carbon Emission Reduction, Greenhouse Gases (GHG) Trading, Cap-and-Trade Program, and so on, are spreading globally constraining companies' development. Every company from any country has to obey those rules to avoid trouble from all of their stakeholders.

Among all the counties, China, with its gigantic development achievement, immense population and economy scale, and up surging energy consuming and demand, has become the focus of global environmental issues. International policy principles and international policy organizations have significant affect on the development of China's greentech markets. In addition, certain international agreements like the 1997 Kyoto Protocol claim China government to promulgate specific environmental policy actions. Almost half of the Certified Emission Reduction Certificates (CERs) registered under the Kyoto Protocol have got their corresponded projects in China. Meanwhile, bilateral relationships with other countries and economic blocs also have affected China's environmental markets.

Under the combined forces of politics and economics, China is driving to and has to become a responsible global citizen. By far, China has done a lot to protect environment from deteriorating rapidly, and laid a substantial foundation for greentech market. China's government has already established plans and programs, laws and standard, fiscal incentives and subsidies, industrial promotion, and price management policies to respond to the urgent environmental issues. The government has released series of greentech relevant industry revitalization plans for industries such as new energy, equipment manufacturing, and logistics. As a result, a wide range of businesses begin to implement mature or new emerging greentech solutions so as to respond to the broad environmental issues.

China has already set a target of deriving 20% of energy source from renewable sources by 2020.

However, even if this aggressive target is achieved, there is still 80% of its energy derived from coal. In this paper, we choose to research the application of Carbon Dioxide Capture and Storage (CCS) in the cleaner conventional energy sector for academic and practical reasons.

From the view of firms involved in the environmental issues, for example, whether to invest in the CCS project, it faces not only the legal constraints, but also economical and financial structure changes. GHG emissions credits, government fines, stakeholders' intervention and so on may cost a lot of money and resources; consequently, they may finally decrease the profit of a company and even hinder its development. In order to minimize environmental cost, companies can either purchase credits from market or reduce GHG emissions through installing green technology equipments and systems or introducing new processes from other companies. The purchase of credits may be economic in the short run, however, the cost of these credits are assumed to increase over time as the number of available credits gets decreased by regulation. With the emerging markets in GHG emissions trading, it is becoming increasingly important for managers to determine whether to invest in environmental programs and green technology or to purchase emissions credits, and to make tradeoffs in cost between them.

Traditionally, investment selection decisions are evaluated by Discounted Cash Flow method (DCF), where the Net Present Value (NPV) is often used. However, DCF often leads inevitable underestimate to high technology projects which may actually be feasible, mainly because of the high risk rate estimated in the beginning. Moreover, DCF is not a sufficient methodology in the situation of strategic flexibility where investment decision would be deferred to some proper future date. It cannot deal with the possible varying cost of GHG emission credits, either.

In essence, corporations have the option to defer purchase to some future time. One tool that can prove beneficial in this type of investment environment is the use of real options. This approach treats options at different stages as part of its decision making process. A real options method is applied in this paper to evaluate the investment decisions of greentech projects. The optimal time to invest greentech project is determined through real options model. According to the characteristics of investment in greentech project, it quantized the influence of inflation and depreciation and took full consideration of emission credits cost and profit. Its feasibility and advantage have been investigated in the analysis of a demonstration projects supported by government. The result further provides practical and managerial insights into the application of the real options analysis to greentech investment.

2. REVIEW OF CHINA GREENTECH MARKET

According to China Greentech Report 2009(*The China Greentech Report^{tm} 2009*, 2009), greentech is defined as 'Technologies, products and services that deliver benefits to users of equal or greater value than those of conventional alternatives, while limiting the impact on the natural environment and maximizing the efficient and sustainable use of energy, water and other resources'.

Since the policy of reform and opening in 1978, China has gone through rapid economic growth and turns into a huge and resilient economy, with a sound improvement in living standards for its people. With an annual economy growth rate of 10% on average, China becomes the third largest economy and the second energy consumer in the world (*The China Greentech Report^{tm} 2009*, 2009). However, this tremendous achievement comes at significant environmental cost. It is now the largest emitter of greenhouse gases (GHGs), and constitutes of over 20% of CO_2 emissions from the burning of fossil fuels annually, 80% of which comes from burning coal, China's predominant energy source. What's more, China is facing the dual problems of water scarcity and water pollutions, and also serious land degradation. Although the environmental problems are unavoidable to any country with the same experiences of industrialization, China's immense scale and rapid growth speed, as well as the urgent state of the world's environment, make China's environmental issues a global concern.

International policy principles like 'Sustainable Development' and 'Common But Differentiated Responsibilities', and international policy organizations, such as the United Nations(UN), the World Trade Organization(WTO), the International Monetary Fund(IMF), the World Bank and the Asian Development Bank(ADB), all have significant affect on the development of China's greentech markets. In addition, certain international agreements claim China government to promulgate specific environmental policy actions, of which the 1997 Kyoto Protocol is the most famous. Almost half of the Certified Emission Reduction Certificates (CERs) registered under the Kyoto Protocol have got their corresponded projects in China. Last but not the least, bilateral relationships with other countries and economic blocs, for example, the China-US Strategic and Economic Dialogue (S&ED), the EU-China Energy and Environment

Programme, also have affected China’s environmental markets.

Under the combined forces of politics and economics, China is driving to become a responsible global citizen. By far, China has done a lot to protect environment from deteriorating rapidly, and laid a substantial foundation for greentech market. Guided by the policy principles of Scientific Approach to Development, Harmonious Society, Equal Emphasis on Mitigation and Adaptation, Efficiency Improvement and Conservation, Energy Structure Optimization and so on, China’s government has already taken a lot of actions to solve the problem.

Specifically, China has already established: 1. Plans And Programs, including the Five Year Guidelines and the 4 trillion Yuan economic stimulus plan in 2008; 2. Laws And Standard, including Renewable Energy Law (2005) and the Circular Economy Law (2008); 3. Fiscal Incentives And Subsidies, including tax exemptions, consumption related taxes, natural resource related taxes, and subsidizes in areas like New Energy Vehicles and Biomass Power Generation; 4. Industrial Promotion, including favourable financing to greentech sectors and requirement of environmental and energy disclosures from listed companies; 5. Price Management Policies, including the feed-in tariff for wind power is released in July 2009. The government has released series of greentech relevant industry revitalization plans for industries such as new energy, equipment manufacturing, and logistics. As a result, a wide range of businesses begin to implement greentech solutions so as to respond to the broad environmental issues. The range of businesses constitutes of 3 broad categories (energy supply, resource use and other markets), 9 broadly-defined market sectors and 40 focused segments across, as illustrated by Table-1.

Table 1-The China Greentech Market Map

source: The China Greentech Report 2009

	Energy Supply			**Resource Use**			**Other Markets**		
Sector	Cleaner Conventional Energy	Renewable Energy	Electric Power Infrastructure	Green Building	Cleaner Transportation	Cleaner Industry	Clean Water	Waste Management	Sustainable Forestry And Agriculture
SEGMENT	Cleaner Coal	Solar Energy	Transmission	Optimized Design	Cleaner Road	Optimized Design	Water Extraction	Waste Collection	Sustainable Forest Management
	Cleaner Oil	Wind Power	Distribution	Sustainable Materials	Cleaner Rail	Sustainable Materials	Water Treatment	Waste Recycling	Sustainable Land Management
	Cleaner Gas	Bio-Energy	Energy Storage	Energy Efficiency	Cleaner Air	Efficient Processing	Water Distribution	Energy From Waste	Sustainable Farming Communities
	Nuclear Power	Hydro-Power	Demand Management	Water Efficiency	Cleaner Waterway		Water Use	Waste Treatment	Optimized Crops
		Wave Power	Supply Flexibility				Wastewater Treatment	Sustainable Waste Disposal	
		Geothermal Energy							

China has already set a target of deriving 20% of energy source from renewable sources by 2020. However, even if this aggressive target is achieved, there is still 80% of its energy derived from coal. In this paper, we choose to research the application of Carbon Dioxide Capture and Storage (CCS) in the cleaner conventional energy sector for academic and practical reasons.

First, China is the world’s largest CO_2 emitter, China accounts for 24% of global energy related CO_2 emissions, US for 21%, EU-15 for 12%. Second, coal remains the main source of energy even though strong policy incentives for energy efficiency, renewable and other low carbon technologies. In 2009, China derived 70% of its primary energy from coal, and this heavy dependence is projected to continue into the long future(Seligsohn, Liu, Forbes, Dongjie, & West, 2010). Third, CCS is able to reduce GHGs emissions while coal use continues, whereby this technology is a key element in current state if China. Last but the least, the Ministry of Science and Technology is developing a long-term CCS strategy and, some leading Chinese energy enterprises such as Petro China and Shenhua Group, have been investing in CCS technology demonstration projects. This undoubtedly makes our research feasible in data collection and useful in practical aspects.

3. LITERATURE REVIEW

As organizations become increasingly environmentally conscious, investment decision on greentech has been capturing attention of the management. Some researchers have discussed how environmental investments could benefit organizations (Bonifant et al, 1995; Nehrt, 1996; Porter et al, 1995). Nevertheless, these studies mainly investigated the issues in an empirical or conceptual way, and did not propose effective decision models. In practice, some models have been proposed for internal use by corporation management, such as stochastic dynamic optimization (Birge et al, 1996), mixed integer programming (Mondschein et al, 1997), activity based costing (Presley et al, 1994), and data envelopment analysis (Sarkis, 1999). Even though these models are advanced and scientific, the most popular technique used by organizations is the utilization of the Discounted Cash Flow method (DCF) based on cost-benefit analysis. The DCF method, where the Net Present Value (NPV) is often used, is simple and practical, but, to a large extent, ignores the option to defer an investment. Therefore, the dynamic option value embedded in the options, which can be very significant in some investments, is neglected.

The fundamental hypothesis of the traditional DCF method is that future cash flow is static and certain, and management does not need to rectify investment strategy according to the changing circumstances (Myers, 1977). Nevertheless, this is inconsistent with the facts. In practice, corporations often face plenty of uncertainties and risks, and management tends to prior the operating flexibility and other strategy issues, to which they would even like to sacrifice current valuable cash flow (Donaldson, 1983).

Ross(1995) pointed out that it might lead to wrong decision when applying NPV (Net Present Value) method to investment evaluation, for example, some investments, which are not one-off but consist of several follow-up investments, may be objected by management because of minus NPV value of the early investment. NPV method maintains principle of ‘accept now’ or ‘accept never’, and this obviously goes against the tradeoff between the values of present investment and future reinvestment. Myers(1987) argued that, although part of the investment evaluations may have been improper in its application, the embedded limitation of traditional DCF, which became especially apparent in the process of evaluation to investment with operational or strategic options, could not be denied.

Other than DCF, Real options analysis can be devoted to deal with investment options and managerial flexibility.

The Real options method has its root in financial options, and it is the application and development of financial options in the field of real assets investment. It is generally believed that the pioneering literature in real options is by Myers (1977), in which he proposed that, although corporation investments does not possess of forms like contract as financial options do, investments under situation of high uncertainty still have the characteristics similar to financial options, therefore, the options pricing method could be used to evaluate the investments. Subsequently, Myers(1977) suggested a ‘Growth Options’ to corporation investment opportunity, and Kester (1984) further developed Myers’ research, and argued that even a project with negative present NPV value could also have investment value only if manager had the ability to defer investment in order to wait for the beneficial opportunity.

After three decades of development, the theory of real options has become an important branch and hot research topic. According to different managerial flexibility embedded in real options, Copeland (1992) and Trigeorgis (1993) divided real options into seven categories, including Option to Defer, Option to Alter Operating Scale, Option to Abandon, Option to Switch, and so on. Researchers have devoted into different options (O'Brien et al, 2003; Sing, 2002).

So far, real options theory has been applied to investment problems in many different fields, such as biotechnology, natural resources, research and development, securities evaluation, corporation strategy, technology and so on (Miller et al, 2002). It has also been applied to a gas company in British and leads to conclusion that certain projects are not economically feasible unless permits have a faster price rise(Sarkis et al, 2005).

In conclusion, traditional evaluation methodologies like DCF have undeniable limitations in face of investment options and managerial flexibility. In the particular field of greentech investment, where investment decisions may be deferred to certain appropriate future dates and the cost of emission credits may vary from time to time, the real options method can be proved beneficial in this type of investment.

4. REAL OPTION MODEL FOR VALUATING CHINA GREENTECH INVESTMENTS

The price of credit is unknown, and could vary from time to time according to factors such as future environment policy legislation, cost of alternative fuels, product market demand and so on. Assuming the prices of credit follow a multiplicative binomial process, based on the statistical growth rate of credit μ, the expected price at the end of first time period A_1 can be described as:

$$A_1 = A_0 e^{\mu \Delta t} \tag{1}$$

where

A_1= the price of credit at the end of fist time period

A_0=the initial price of the credit

μ=growth rate of the credit

To set up the real options model for valuating China greentech investments, a binomial lattice, which is the most popular and widely employed model for option valuation, is applied to illustrate the price process of the credits.

The value of the credit price would move either upward or downward at each predefined time interval. Denote the rate of upward move as u and the rate of downward move as d, where $u > 1 > d > 0$. By the volatility σ, the u and d are calculated as follows:

$$u = e^{\sigma \Delta t} \text{ and } d = 1/u \tag{2}$$

where

σ=the rate of volatility

Let q denote the probability of credit price moving upward, thereby $1-q$ denote the probability of credit price moving downward. Since there is no substantial reason to assume any specified probabilities, we set $q = 0.5$.

In the binomial lattice, the expected credit price is:

$$A_1 = qA_0u + (1-q)A_0 d \tag{3}$$

Now we can solve σ by setting the right-hand of Equations (1) and (3) equal, and attain σ as a function of μ. According to (Sarkis et al, 2005), taking consideration of long-term real growth rate and inflation rate, a nominal growth rate μ is estimated as 0.05366, therefore, the value of volatility σ is estimated as 0.3305.

Denote the total numbers of times of the decision periods which a organization decide whether to invest the greentech equipment as T, for example, if the organization considers the CCS investment decisions annually during 20 years, then $T = 20$. Let j denotes the number of upwards moving of the credit price, and k denotes the number of downwards moving of the credit price, where$j, k = 0,1,\cdots,T-1$. In general, the expected price of credits is given:

$$A_t^j = A_0 e^{(j-k)\sigma} \tag{4}$$

where

A_t^j=price of credits at time t with j times of upward moves

j= the number of upward moves, $j = 0,1,\cdots,T-1$

k= the number of downward moves, $k = 0,1,\cdots,T-1$

Under risk-neutral probabilities, the value of options is the discounted expected value. Let p denote the probability for an up move, and it is given as:

$$p = (e^{r\Delta t} - d)/(u-d) \tag{5}$$

In addition, the effect of inflation and depreciation should not be neglected in the process of a long-term decision making. Generally speaking, the initial cost of the installation of the equipment will be increased by the expected inflation rate and decreased by the present value of the tax shield from depreciation. Following the assumption of (Sarkis et al, 2005), given a 7-year accelerated depreciation schedule and a cost of capital about 10%, the depreciation reduces the investment by 30%. Although it is not accurate to discount the 7-year depreciation tax shield into a present value, because the depreciation in fact occurs year by year during the seven years, it reflects the effect of depreciation on initial cost to some extent. However, managers should keep in mind that this schedule of depreciation results in a decision of delaying installation. Another factor that will delay installation is the operation cost of the equipment, but we are going to ignore it in this model as its effect to decision is comparatively tiny.

$$C_t = C_0 + C_f - C_d \tag{6}$$

Where

C_t= total cost of time period t

C_0=initial cost of the equipment

C_f=cost increased by inflation

C_d = cost decreased by the present value of depreciation tax shield

Now we are ready to calculate the option value at each time period via the comparison with the net present value (NPV). The NPV at the last time point is the present value of income, which equals the emissions savings (denoted byE_t), multiply the price of the credits (A_t^j), minus the present value of cost (C_t), that is $NPV_t^j = A_t^j E_t - C_t$. However, in the middle of the decision period, situation is different to some extent, as we need take the expected cash flows next period into consideration. Therefore, the NPV at the middle node is the value of income less the cost and plus the expected cash flows next period under risk neutral probabilities discounted by the risk free rate:

$$NPV_t^j = A_t^j E_t - C_t + [p * NPV_{t+1}^{j+1} + (1-p) * NPV_{t+1}^j] \quad (7)$$

To put them into one formula, NPV is given by:

$$NPV_t^j = \begin{cases} A_t^j E_t - C_t, & t = T \\ A_t^j E_t - C_t + [p * NPV_{t+1}^{j+1} + (1-p) * NPV_{t+1}^j], & t < T \end{cases} \quad (8)$$

Where:

NPV_t^j=net present value at time t after j upward moves

E_t=emission savings in tons at time t

As pointed out above, there are only two possible movements from one time point to the next period of the price of credits, $A_{t+1}^{j+1}$is $A_t^j * u$ for an upward move, while $A_{t+1}^j$is $A_t^j * d$ for a downward move. The option value can be solved backward. That's to say, we start at the final period, when $t = T$, if the NPV is positive, management implements the investment, if not, discards the investment. Therefore the option value here is the $O_T = \max(NPV_T, 0)$. Working back through the lattice, when it comes to $t < T$, the option value would be the expected option value in the next period under the risk neutral probabilities (p) discounted by the risk free rate r, that is to say, $O_t^j = [p * O_{t+1}^{j+1} + (1-p) * O_{t+1}^j]/e^r$. In general, the option value is given by:

$$O_t^j = \begin{cases} \max(NPV_t^j, 0), & t = T \\ [p * O_{t+1}^{j+1} + (1-p) * O_{t+1}^j]/e^r, & t < T \end{cases} \quad (9)$$

Where

O_t^j=option value at time t after j upward moves

After we gain all the values of options and NPVs, we can find the optimal time to implement the option, for example, to install the CCS equipment in a forward way. The optimal time to implement is the first time when the NPV is greater than the value of options., that is:

$$NPV_t^j > O_t^j, j = 0,1,\cdots,T-1 \quad (10)$$

At the beginning of the decision making, the NPV would be smaller than the value of options. As the increase of the price of credits, both the NPV and the value of options increase, however, the NPV has a bigger rate of increment than the value of options. Consequently, there will be a crossover at some time point which the NPV exceeds the value of options. In other words, if the price of credits never rises, there will no possibility for the NPV reach the level of the value of options, and the firm does not need to consider the investment of greentech equipment to mitigate the purchase of credits. This obviously should draw the attention of related policy makers.

5. ANALYSIS OF THE DECISION TO INVEST CCS PROJECT

We apply the model to a case of a hypothetical power plant faced with decision of whether to install CCS equipment or to purchasing CO_2 credits, and aim to work out the optimal timing, which is the critical price of credits, to exercise the decision. Data on the cost of installing a CCS equipment is taken from the project of Shenhua CTL (Ren, 2008) , one of the demonstration projects supported by government. In this example we assume the initial investment for the CCS project is 1.4 billion, $r = 0.045$, $\mu = 0.05366$, $q = 0.5$, $\sigma = 0.330$. The price of credits is about 14.72 Euro to Dec, 2010 according the Point Carbon's OTC price assessments("Point Carbon's Otc Price Assessments ", 2010), in addition, the Clean Development Mechanism (CDM) could provide roughly 11-32$ of CO2 for CCS investors, therefore we set $A_0 = 40\$$ for calculation. We build the lattice in 20 years steps and the result is demonstrated as Tabl-2:

Table 2-Binomial lattice for CCS project

Year	0		1		2		3		…	14		15		16		…	20	
Item	NPV	RO	NPV	RO	NPV	RO	NPV	RO	…	NPV	RO	NPV	RO	NPV	RO	…	NPV	RO
20																	105761	105761
19																	75670	75670
18																	54048	54048
17									…							…	38512	38512
16														59901	46866		27347	27347
15												42775	38195	42748	33404		19325	19325
14										30475	31109	30450	27185	30423	23730		13561	13561
…												…					…	
6										1243	1393	1218	1078	1191	796		−111	0
5										614	766	589	539	562	343		−405	0
4										161	353	136	209	109	100		−617	0
3							90	2964		−164	123	−189	53	−216	14		−769	0
2					−124	2351	−144	1981		−398	28	−423	7	−450	0		−878	0
1			−272	1854	−292	1550	−312	1280		−566	3	−591	0	−618	0		−957	0
0	−372	1453	−392	1203	−24	982	−432	787		−686	0	−711	0	−738	0		−1013	0

6. CONCLUSIONS

This paper presented a real options method to evaluate the investment decisions of greentech project. The optimal time to invest CCS project is determined through real options model. According to the characteristics of investment in greentech, this model quantized the influence of inflation and depreciation and took full consideration of emission credits cost and profit. The result of the analysis of a demonstration project verified its feasibility and further provided practical and managerial insights into the application of the real options analysis to greentech investment.

A limitation in this model is that it ignored the operating cost of the greentech project. Although we can take it into consideration through adjustment of the initial investment cost, the operation cost of greentech may significantly influence the result of lattice. Another limitation possibly exists in the simulation of the process of price paths as it may bring unbounded stochastic prices, while government will intervene in the price process. The usefulness of real options model to greentech investment is not influenced by these limitations, however, we will seek to work out these problems in future work.

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