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Improving Economic Assessments of Clean Development Mechanism Projects Using Real Options

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Abstract

Currently, there is increasing pressure from global community to reduce the greenhouse gas emissions, the main cause of climate change. One of several programs to reduce the greenhouse gas is Clean Development Mechanism or CDM by the United Nation. The amount of greenhouse gas reduction through CDM projects in developing countries can be sold to developed countries so that they can increase the maximum cap of the emissions to be emitted into the environment. It is this carbon credit from CDM projects that is of financial value, and thus should be viewed as a new type of asset. This could help improve the financial outlook of CDM projects such as renewable energy generators (REGs) because not only these projects usually involve higher costs of technology but also high uncertainty from the prices fluctuation of input commodity, output products, and carbon credits, for instance. Valuing CDM projects full of uncertainty by conventional discounted cash flow (DCF) approaches such as net present value (NPV) could underestimate the intrinsic value and inherent risk of these projects. Accordingly, the aim of this paper is to propose a new approach for valuing the financial viability of CDM projects that considers risk, flexibility, and carbon credit into the economic analysis, using real options theory and risk-flexibility theory.

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1. Introduction

Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities. Threats to

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energy security include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents, natural disasters, the funding to foreign dictators, rising terrorism, and dominant countries reliance to the foreign oil supply [1].

Future global demand for energy is on the increase as a result of economic growth, especially in emerging economies. For example, according to a report by the U.S. Energy Information Administration [2], total world consumption of marketed energy is expected to increase by 49 percent from year 2007 to 2035. World energy consumption in 2035 is estimated to be about 739 quadrillion BTU, with the largest projected increase in energy demand from non-OECD economies, especially from the BRIC countries (Brazil, Russia, India and China).

Given that world oil prices remain relatively high through most of the projection period, the U.S. EIA in 2011 predicted that liquid fuels and other petroleum will be the world's slowest-growing source of energy, with an average annual growth rate of 0.9 percent from 2007 to 2035, whereas total energy demand is predicted to grow by 1.4 percent per year. Renewables, on the other hand, are expected to grow at a much faster rate, i.e., about 2.6 percent per year. Another study by Morrison [3] forecasted that a global demand for renewable energy resources will grow on average around 7.5% annually from 2010 to 2035, given that near Kyoto Protocol will be met. Therefore, compared with the forecast by Morrison [3], the U.S. EIA's estimate of growth in renewable energy is considered quite conservative.

Increasing oil prices, as well as concern about the environmental impacts of fossil fuel use and strong government incentives for increasing the use of renewable energy in many countries around the world, contribute to improved prospects for renewable energy sources worldwide. Moreover, with the pressure from global community to reduce the greenhouse effect, which is said to have polluted the world and is a major factor contributing to global warming in recent years, the United Nation has rectified legal framework aiming at reducing the greenhouse gas through several programs. Notable among these programs is Clean Development Mechanism or CDM.

The Clean Development Mechanism (CDM) is one of the mechanisms of the Kyoto Protocol, under which projects to reduce, avoid or sequester emissions of greenhouse gases undertaken in countries categorized as non-Annex I countries (i.e., developing countries) under the Kyoto Protocol can generate carbon credits that can be used in Annex I countries (i.e., industrialized countries) to assist these countries to meet their greenhouse gas emissions targets [4]. According to Pacudan [5], projects that qualify for CDM include the following: end-use energy efficiency, supply-side energy efficiency, renewable energy, fuel switching, agriculture, industrial processes, solvent and other product use, waste management, and sinks (afforestation and reforestation).

Carbon credits are quantified and verified reductions in greenhouse gas emissions or avoided or sequestered greenhouse gas emissions that are tradable and have a financial value, and are created under a legal framework for greenhouse gas trading such as the Kyoto Protocol. Under the CDM framework, carbon credits are typically measured in terms of Certified Emission Reductions or CERs in which each unit is equivalent to the reduction of one metric tonne of CO2e. Considered as a new type of asset, the carbon credit generated by CDM projects improves project financial viability and attracts more funds into the development of these projects. Ultimately, the CDM will help stimulate investments on renewable energy projects in developing countries.

However, there is uncertainty surrounding CDM projects that make investors reluctant to commit in these projects. For example, many of CDM projects such as renewable energy use commodity as the input, which fluctuates wildly in recent years. Increase in commodity prices inevitably reduces the profit margin of the projects accordingly. As for the carbon credits produced by CDM project, together with a relative new carbon market, there is price uncertainty of CERs. For this reason, it may be inappropriate to value CDM projects using conventional methods such as net present value (NPV) or internal rate of return

(IRR) because these methods assume management has no impact on project value during project's life, and neglect flexibility which may be of value to the projects in the future.

It would be a travesty that some highly valuable CDM projects were cut short because, according to the results of NPV analysis, they were considered economically unviable. Since they were thought of as financially failed projects, rejecting them is the obvious answer to the investors. True, even take into account the value of carbon credits produced by the projects, some of CDM projects may still have a weak financial outlook. However, government support programs such as feed-in tariff (FIT) can help improve the prospect of these projects.

We believe that conventional economic evaluation methods are inadequate to be used to justify the financial viability of CDM projects. It is this premise that motivates us to investigate into how the current CDM projects are being evaluated financially and how to improve the economic valuation methods by capturing risk, flexibility, and carbon credits uncertainty into the analysis so as to better risk profile of the projects.

2. Conventional Project Economic Analysis

Methodologies for project economic analysis such as net present value (NPV) and internal rate of return (IRR) are based on the calculations of a future cash flow adjusted for time value of money. The NPV can be computed by the following equation:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0, \qquad (1)$$

where
- n: the number of project years,
- t: project period (year),
- r: discount rate per period (year),
- CF_t: cash flow at the end of year t,
- I_0: initial investment.

This equation can be applied to case example project, a 1000 kWh bio-power plant (as shown in Fig. 1 below), for which its NPV can be represented as

$$NPV = -(I_0 + I_{CER}) + \sum_{t=1}^{T} \frac{(R_t + S_t + CER_t - C_t)}{(1+\mu)^t}, \qquad (2)$$

where
- I_0: initial investment of the project,
- I_{CER}: cost of CDM registering,
- R_t: revenue in year t,
- S_t: subsidy received in year t,
- CER_t: revenue received from selling carbon credits in year t,
- C_t: operating cost in year t,
- μ: the risk-adjusted discount rate computed using capital asset pricing model, i.e., $\mu_j = r_f + \beta_{mj}(r_m - r_f)$ for the project asset j, where r_f, r_m and β_{mj} is risk-free rate,

market rate of return, and correlation between the project asset j and the market, respectively.

Substitute revenue and cost functions in Eq. (2), we then have

$$NPV = -\left(I_0 + I_{CER}\right) + \sum_{t=1}^{T} \frac{P_t \times O_t + S_t + CER_t - C_t - OM_t}{\left(1+\mu\right)^t}, \tag{3}$$

where P_t is the output price, O_t the quantity of output, C_t fuel cost, and OM_t operating and maintenance (O&M) cost, all relative to year t .

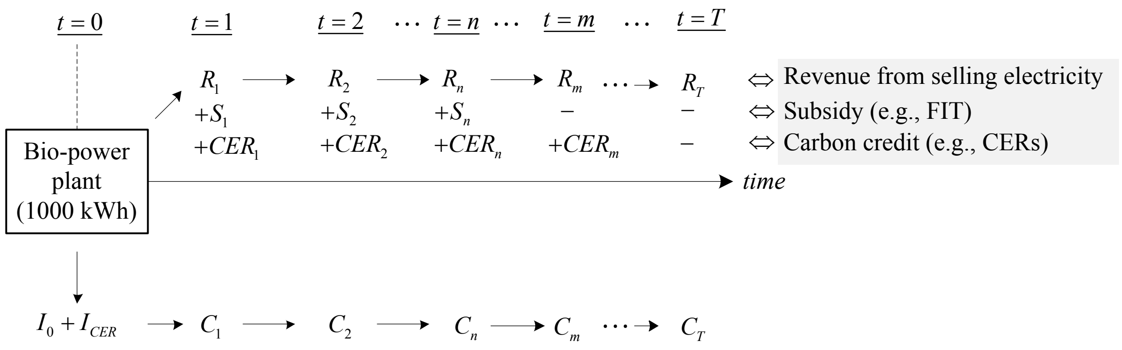

Fig. 1. Cash flow stream of bio-power plant investment

2.1. Illustrative Case Example: A 1000 kWh Bio-power Plant

For the purpose of illustration, we will assume that the project last for 25 years. Other keys parameters are given in Table 1. Calculating the net present value of this investment using Eq. (3) with the discount rate of

$$\mu = r_f + \beta\left(r_m - r_f\right) = 5 + 2.0(10-5) = 15\% \ ,$$

the NPV of the example case project is then expected to be \$1.8 million ($NPV = +1.8$ million), and its internal rate of return is about 30%, i.e., $IRR = 30\%$. Because the NPV is positive, it therefore indicates that the project is worth undertaking.

Table 1. Key parameters of a 1000 kWh bio-power plant investment

Parameters	Value	Parameters	Value
I_0	\$2 million	O_t	5,000,000 kWh/year
I_{CER}	\$0.2 million	CER_t	\$560,000/year*
P_t	\$0.1/kWh	C_t	$C_1 =$ \$0.21 million**
S_t	\$0.01/kWh for $t = \{1, 2, ..., 7\}$	OM_t	\$0.12 million/year**

**Estimated annual amount of CERs is 80,000, and the price of CERs is \$7/tonne carbon*
***Adjusted for 3% inflation after year 1 and thereafter*

3. Real Options Theory

Prior to the development of real options, corporate managers and strategists were grappling intuitively with the elusive elements of managerial operating flexibility. Many recognized that the discounted cash flow (DCF) criteria often undervalued investment opportunities because they ignored important strategic considerations (for example, see [6] and [7]).

It was Myers [8], while confirming that part of the problem results from various misapplications of the underlying theory, who first acknowledged that there are inherent limitations with standard DCF approaches when it comes to valuing investments with significant operating or strategic options. He suggested that options pricing holds the best promise for valuing such investments.

Then, Trigeorgis and Manson [9] clarified that option valuation can be seen operationally as a special, economically corrected version of decision analysis (DA) which is better suited to valuing strategic options. Further, Baldwin and Trigeorgis [10] proposed remedying the underinvestment problem and restoring competitiveness by developing specific adaptive capabilities viewed as an infrastructure for acquiring and managing corporate real options.

Dixit and Pindyck [11] provided the first detailed exposition of a new theoretical approach to the capital investment decisions of firms, emphasizing the important characteristic of irreversibility of most investment decisions, and the ongoing uncertainty of the economic environment in which these decisions are made. This new approach recognized the option value of waiting for better, but incomplete, information. The focus of their book Investment under Uncertainty was on understanding investment behavior of firms, and developing the implications of this theory for industry dynamics and government policy concerning investment.

3.1. Definition of Real Options

What is an option? Robert S. Harris and Robert M. Conroy at Darden School of Business of University of Virginia gave the definition of an option as follows [12].

> "An option gives the holder the right, but not the obligation, to buy (call option) or to sell (put option) a designated asset at a predetermined price (strike or exercise price). The designated asset that can be bought or sold is called the underlying asset. This can be either a financial asset (stock, bond, Treasury bond, forward contract, currency, stock index, etc.) or a physical one (a raw material or mining asset, for example). Options have value because their terms allow the holder to profit from price movements in one direction without bearing or with limiting risk in the other direction. The value at which an option is bought or sold is sometimes called the premium."

And what is "real option"? Copeland and Antikarov [13] defined the term "real option" as the right, but not the obligation, to take an action (e.g. deferring, expanding, contracting, or abandoning) at a predetermined cost called the exercise price, for a predetermined period of time – the life of the option. In addition, de Neufville et al. [14] classified real options into two types: those that are "on" systems and treat the technology as a black box, and those that are "in" systems, and provide the flexibility and the options through the details of the design.

3.2. Real Options Valuation

In this paper, we assume the prices of electricity and carbon credit are known at the present but not in the next year and remain constant after year 1 (e.g., one-time step analysis). For simplicity, we also assume that prices of electricity and carbon credit can move in two directions to certain up and down values.

Fig. 2 depicts price movement of both electricity and carbon credit. For instance, there is a probability p_{uu} that the prices of electricity and carbon credit will increase to P_{1u} and CER_{1u}, respectively, in the next year ($t=1$), and the probability that the price of electricity will increase and the price of carbon credit will decrease is p_{ud}, and so on.

For each path, we can compute the value of the project in terms of NPV, and then decide whether or not to invest into the project. For example, if the NPV of the first path is $NPV_{\omega(1)}$, then the payoff of the project (Π) is computed by

$$\Pi = \max(NPV_{\omega(1)}, 0) \tag{4}$$

By taking into account of the probability of each path (p_{ij}), we can compute the expected NPV of the project as

$$E\left[NPV\right] = \left[p_{ij}\right] \cdot \max_{i,j\in\{u,d\}} \left(\left[\frac{\{-I - I_{CER}\}}{(1+\mu)} + \sum_{t=1}^{T} \left\{ \frac{\left(P_{ti} - C_{v,t}\right)\times O_t + CER_{tj} - C_{f,t}}{(1+\mu)^t} \right\} + \sum_{t=1}^{n\le T} \left\{ \frac{S_t}{(1+\mu)^t} \right\} \right], 0 \right) \tag{5}$$

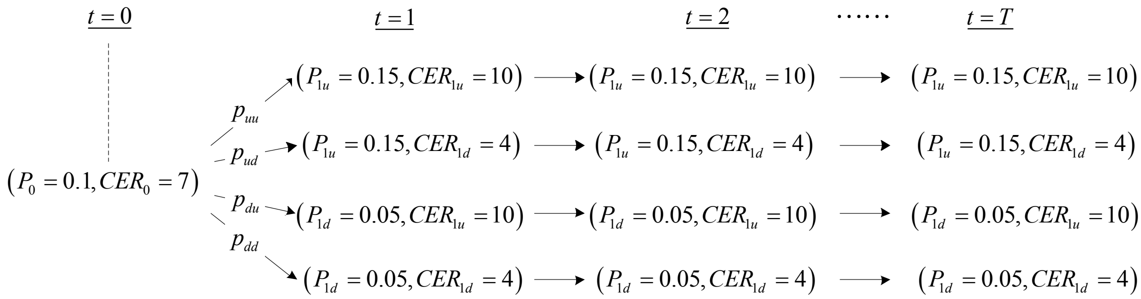

Fig. 2. Prices uncertainty of the electricity output and CERs

3.3. Real Options Valuation of the Example Case Project: A 1000 kWh Bio-power Plant

For the sake of illustration, we will assume that: $p_{uu} = p_{ud} = p_{du} = p_{dd} = 0.25$. We can compute the expected NPV of the project if we choose to wait for more information to be arrived in one year ahead by substitute the parameters given in the previous example into Eq. (5). We then have

$$E\left[NPV\right] = 0.25\times\max\left(4.39,0\right) + 0.25\times\max\left(1.68,0\right) + 0.25\times\max\left(1.45,0\right) + 0.25\times\max\left(-1.25,0\right)$$

$E[NPV] = \$1.88$ million.

Fig. 3 below shows 2 simulated paths of future biomass prices, assuming the current price of biomass, C_0, is 750 baht/tonne, and $\alpha_C = 0, \sigma_C = 0.5$.

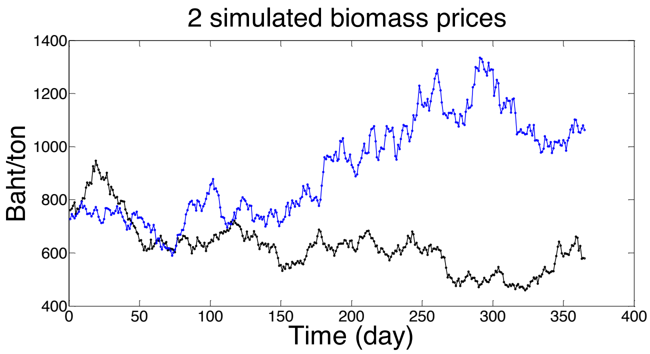

Fig. 3. Simulated biomass prices using geometric Brownian motion

The price movement of carbon in markets such as the EU emissions trading system or EU ETS (see Fig. 4 for the history prices of the EU ETS), $CER(t) = X(t)$, can also be represented by geometric Brownian motion with drift as $dX = \alpha_X X dt + \sigma_X X dz$.

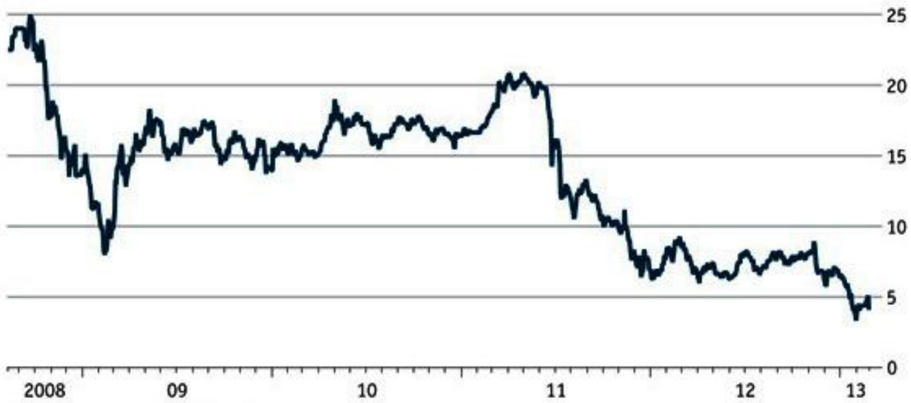

Fig. 4. EU ETS Carbon spot price, € per tonne (Source: *The Economist*)

4. Risk Flexibility Theory

4.1. Conceptual Framework of Risk-Flexibility Theory

Risk-flexibility theory (RFT) was first introduced by Chiara and Kokkaew [15] as a complement of the real options theory for infrastructure risk analysis. According to Kokkaew et al. [16, 17], flexibility can be classified as:

a) *System flexibility*, which refers to the quality of an actual system capable of physical adaptation to various "purposes" or "conditions."

b) *Managerial flexibility*, referring to the ability of project managers to manage a system as is in a way that makes it adaptive or responsive to uncertainty.

c) *Contractual flexibility*, referring to flexibility created by insurance policies for covering residual risks (those risks that cannot effectively be managed through system and managerial flexibility).

A good example of how to use the combination of these three types of flexibility in order to attain the most effective risk management would be fire risk management. For instance, a homeowner may use fire-proof materials or install fire alarming system to make his house less harmful to fire incident, if occurred. In this case, fire-proof materials or fire alarming system represents system flexibility of the house. If fire did occur and the fire protection system is not unable to handle the intensity of the fire, the homeowner can call city's fire department for help. This reaction of the homeowner in response to fire incident is managerial flexibility. And if the worst case occurred, the house was burn down, how can the loss be covered? One question may arise: does the homeowner have fire insurance? If so, the homeowner could file a claim for fire compensation. This insurance represents contractual flexibility of the homeowner.

Flexibility can be of two types: opportunity-enhancing flexibility and risk-hedging flexibility. Opportunity-enhancing flexibility is one that capture the upside uncertainty (beneficial outcomes of uncertainty), while risk-hedging flexibility is one that curbs or mitigate the unfavorable outcomes of uncertainty.

At the heart of the RFT is the optimal (i.e., cost-efficiency) combination of different types of flexibility to be acquired or implemented into a project. In the next section, we illustrate how the risk-flexibility approach can be used with real options valuation to determine the value of the case example project.

4.2. Valuing a 1000 kWh Bio-power Plant Using Risk-Flexibility Framework

To illustrate the attractiveness of using risk-flexibility approach with real options valuation, we will keep the calculation complexity to a minimum. We assume that, once the project is operated, project manager considers using a forward contract to hedge the price volatility of CERs. Therefore, the project manager has 2 options available for different purposes, with "option to wait" for deciding to invest only if uncertainty reveals favorably and "forward contract" for eliminating price uncertainty of CERs.

The diagram in Fig. 5 represents the scheme of using these two options for risk management in the case example bio-power plant.

Similar to the calculation presented in the previous section, the expected NPV of the case example bio-power plant is computed as

$$E\left[NPV\right] = 0.25\times\max\left(3.48,0\right) + 0.25\times\max\left(3.48,0\right) + 0.25\times\max\left(0.55,0\right) + 0.25\times\max\left(0.55,0\right)$$

$$E\left[NPV\right] = \$2.01 \text{ million.}$$

Therefore, the value of "option to wait" plus CER forward contract is the difference of project values between investing today and waiting for one year and acquiring a CER forward contract at the delivery price of \$8/tonne. The expected project value with a combination of waiting strategy (i.e., managerial flexibility) and acquiring the forward contract (i.e., contractual flexibility) is therefore \$0.21 million (\$2.01- \$1.80m).

4.3. Optimal Investment in Flexibility

Acquiring or implementing flexibility could increase the costs of a project. Therefore, optimal combination of flexibility should be analyzed to determine the most cost-effective collection of flexibility. This can be done by identifying all possible combination of flexibility and its associated costs. The combination with the highest economic efficiency index (or benefit/cost ratio) should be considered by project managers.

5. Conclusions

This paper has demonstrated how real options theory and risk-flexibility theory can be used as an alternative technique for the economic evaluation of CDM projects. This is because the conventional discounted cash flow (DCF) may underestimate the true value of the projects because it ignores high uncertainty surrounding the CDM projects. From risk-flexibility theory perspective, project managers should embrace uncertainty, rather than avoiding it, but only with proper risk management tools put in place. The results from numerical example showed that acknowledging flexibility and including it into the project could increase the net present value of the project, thereby increasing the chance that the project will be accepted and get the go-ahead. However, not all combination of flexibility can result in better project value. Costs associated with implemented flexibility should therefore be estimated and included into the analysis to help managers determine which combination of flexibility yield the most benefit to the project.

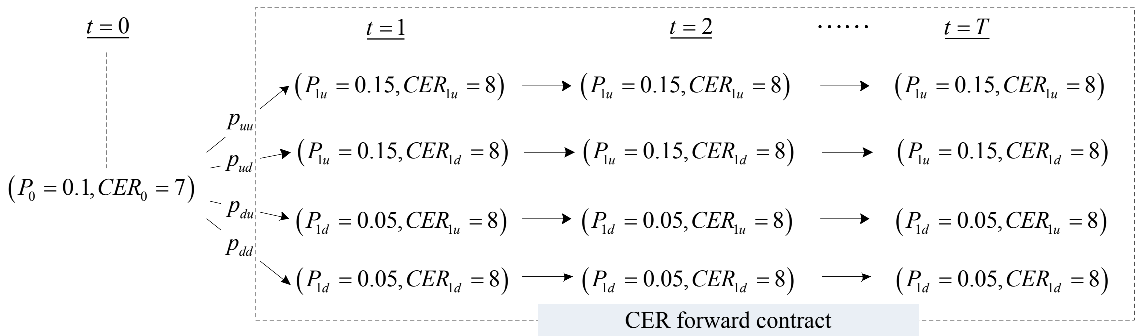

Fig. 5. Prices uncertainty of the electricity output and constant price of CERs by acquiring a forward contract

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