ISEIS

Journal of Environmental Informatics 14(2) 110-116 (2009)

Journal of Environmental Informatics

www.iseis.org/jei

A Study on Measures to Activate CDM Taking Project Risks into Consideration

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Received 27 June 2008; revised 23 November 2009; accepted 2 December 2009; published online 7 December 2009

ABSTRACT. Global warming has been recognized as a serious issue since the fourth assessment report of the Intergovernmental Panel on Climate Change was published in 2007. Under these circumstances, Clean Development Mechanism (CDM) is expected to play a significant role, since it promises to reduce the economic gaps between developed and developing nations, as well as to economically reduce greenhouse gas emissions. In this paper, we first investigate how to evaluate risks in CDM. The real option theory is applied to quantify project risks in CDM, so that we can estimate the option values. In detail, a mathematical model of CDM is represented with a compound rainbow option, which includes continuous procedures from registration to investment. The evaluated results identify the condition of profitability, in which investment as CDM project is feasible. Our evaluation also quantifies how CDM projects become difficult to be executed due to the registration risk and the post-2012 risk. Then we investigate how to activate CDM projects. For this purpose, two options are considered: low interest loans by official financial institutions and the procurement of certified emission reductions, (CERs) by governments. The former relates to the low interest loans similar to environmental official development assistance (ODA), which certainly ease the financial burden of initial investments in CDM projects. Now that CDM projects related to ODA are already registered by CDM executive board, this option is worth evaluation. The latter, meanwhile, aims at lowering risks by the secure purchase of CERs by governments. Since the governments of the Netherlands and Japan have already established a system to purchase CERs generated by CDM, we need to assess the effect of the option to activate CDM. Based on actual financial data on CDM, we finally investigate how these options could increase the number of executable CDM projects.

Keywords: clean development mechanism, risk management, compound rainbow option, CER procurement, low interest loan

1. Introduction

Concern about climate change caused by the increased emission of greenhouse gases is growing around the world. We need to find an efficient and fair way of internationally reducing greenhouse gas emissions. Under these circumstances, Clean Development Mechanism (CDM) is expected to be a powerful option to narrow the economic gaps between North and South as well as to economically reduce greenhouse gas emissions. CDM was first defined in the Kyoto Protocol and initiated based on that Protocol. The following procedures are generally adopted in CDM:

(a) A company proposes a project in a developing country that does not have a numerical target under the Kyoto Protocol to reduce greenhouse gases.
(b) The developing country approves the implementation of this project as a CDM project.
(c) The company registers the project with CDM executive board at the United Nations.
(d) The company executes the project to reduce greenhouse gas emissions.
(e) An operational entity evaluates and certifies the quantity of reduced greenhouse gas emissions. Based on the evaluation, CDM executive board permits the issue of CERs.

Through these procedures, technology and money are transferred to the developing country that accepts CDM. This leads to economic development as well as the reduction of greenhouse gas emissions. Therefore, it promises to reduce the economic gaps between developed and developing nations as well as to economically reduce greenhouse gas emissions. Regarding the present situation of CDM, 1,834 projects have already been registered with CDM executive board, and CERs equivalent in total to 333 million tons of CO2 have been issued by those projects (United Nations Environment Program Risoe Centre, 2009).

Ueno et al. (2005) have made qualitative analyses of present issues in registering CDM projects with the executive board. Kittaka (2007) pointed out that CDM tends to have large project risks due to the necessity of additionality. Regarding quantitative analyses, Krey et al. (2005) have evaluated risks in transaction costs in registering CDM projects with the executive board. Meanwhile, Maeda (2006) has made correlation analyses between the costs of projects and reduced CO_2 emissions.

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ISSN: 1726-2135 print/1684-8799 online
 doi:10.3808/jei.200900160

In this article, we investigate how to manage risks in CDM projects. For this purpose, the real option theory is applied to investment in CDM projects. While past research focused on quailtative and quantitative analyses of risks and uncertainty in CDM projects, they did not apply the real option theory to manage these risks, as we do in this paper. Furthermore, the analyses in this paper are noteworthy in that we quantitatively show the effect of policy measures to manage financial risks.

On the one hand, this paper is based on broad international standpoints to activate CDM projects, while on the other hand it aims at evaluating promising policies at the national level so as to activate CDM. At first sight there seems to be some conflict between the international and national levels. However, this is consistent in that the national level of policies could activate the international level. Thus, we investigate two options to activate CDM projects -- low interest loans by official financial institutions and the procurement of CERs by governments. The former relates to low interest loans to ease the financial burden of initial investments; the latter aims at lowering financial risk by the secure purchase of CERs. Both policies are not international but domestic ones. However, CDM projects could be activated by these policies, so we can anticipate an international effect.

2. Adopted Measures

2.1. Various risks in CDM projects

According to the Japanese Ministry of Economy, Trade, and Industry (2006), executors of CDM are subject to force majeure risks, institutional risks, and other commercial risks in executing CDM projects. Force majeure risks include the post-2012 risk described below and other risks relating to additional international rules. Institutional risks include, for instance, risks on approval by host countries and validation and registration of CDM project as described below. Other commercial risks include the CER risks described below and other risks causing revenue fluctuation. These include risks on general projects abroad, as well as unique risks for CDM.

The document of the Ministry of Economy, Trade, and Industry (2006) also includes a description of response measures to the risks. These response measures include qualitative ones, such as the selection of appropriate host countries and adoption of reliable designated operational entities. Although these response measures are significant for executors of CDM, it is not necessary to investigate them in quantitative studies.

Therefore, we focus on the following risks as being important in quantitative analyses of CDM:

The question whether a project can be registered as a CDM project or not is certainly a crucial risk. If the executeve board of CDM does not register the project, practitioners of the project are not able to acquire CERs. This risk is called the 'registration risk'. So as to register a project under CDM, applicants need to prove that the project could not be executed unless it is registered under the CDM. In other words, they need to prove the additionality of the CDM.

At present, no political consensus has been accomplished on the framework to reduce greenhouse gases after 2012. If the basic framework of the Kyoto Protocol should drastically change, the value of CERs might be lost after 2012. For this reason, the future value of CERs is quite uncertain, so this poses a serious risk for practitioners of CDM. We call this risk the 'post-2012 risk'.

We should also pay attention to the risk that the asset value of CERs will change due to a fluctuation of CER prices in the future. This is called the 'CER risk'. We describe an evaluation of the CER risk in presumption in 2.2.

A CDM project is also subject to country risks due to poli- tical or economic instability in the host countries. Here we call these risks 'country risks'. These risks appear, for instance, as a fluctuation of exchange rates, leading to financial risks under CDM.

Among the above-mentioned risks, this article mainly focuses on risks 1, 2, and 3. In particular, the registration and the post-2012 risks are incorporated as significant factors in our mathematical model. The CER risk is also quantitatively evaluated in the model. The country risks are implicitly dealt with as volatility in revenue from CDM projects.

2.2. Application of the real option theory to CDM

Real option is the theory to evaluate the value of a project asset, taking the flexibility of investment in financial risks into consideration. In other words, we apply the methodology of financial engineering to evaluate the derivative price of financial commodities, such as the call option to a real asset. The standard procedures of estimating option values of real project assets are described, for instance, in Copeland's book (Copeland et al., 2002). Thus, the real option theory is useful to deal with financial risks in executing real projects. On the other hand, practitioners have to manage various financial risks in executing CDM, as described in 2.1. Therefore, we apply the real option theory to evaluate the option values of CDM projects.

Executing a CDM project generally comprises two steps in the decision-making process: registration as a CDM project and investment in plants, in which values of flexibility exist in each step. Furthermore, the finance of CDM includes two kinds of uncertainties in CER values and in other project assets. Therefore, we developed a mathematical model to invest in CDM as compound rainbow options based on our former analysis (Shinozaki et al., 2006).

Presumptions for developing this model are described as follows:

Values in CERs and in other project assets are assumed to follow the geometric Brownian motion. That is to say, we model probabilistic processes in two assets as in Equation (1). Equation (1) implies that the current value of each asset is certainly determined, but future values are probabilistically distributed with variances growing linearly with time:

$$dV/V = \mu dt + \sigma dz \quad (1)$$

where

V: asset of a project;
M: increase rate of asset V;
dz: increment of Wiener process;
dt: increment of time period;
Σ: volatility in increase rate of asset V.

An economic value in the investment opportunity $F(V)$ is defined to be equivalent to a call option in financial engineering, which is not the obligation but the right to buy a share of stock at a pre-specified price. That is to say, $F(V)$ is a value of the option by which they can exercise or delay the investment in the project, of which the asset value is V.

The decision-making process primarily consists of two steps: registration as a CDM project and investment in plants. In some cases, registration as a CDM project comes before investment in plants. In other cases, however, investment in plants is made first, followed by registration as a CDM project. Thus, the stages of the decision-making process become complicated, as shown in Figure 1.

We define the probability that an applied project is not registered by CDM executive board as the registration risk. On the other hand, we define the probability that CER value is lost due to change in the framework of the Kyoto Protocol after 2012 as the post-2012 risk.

According to CDM pipeline (UNEP Risoe Center, 2007), projects registered by CDM executive board include 40 projects with a 10-year duration, 110 projects with a 7-year duration, and 1 project with a 30-year duration. Accordingly, 7-year and 10-year projects account for more than 99% of the total projects. The influence of the post-2012 risk is less in 7-year projects than in 10-year projects. In this research, we focus on 10-year projects. In the future, we will also deal with 7-year projects.

The actual procedures for quantifying risks in CDM are described below. To estimate the above option values, we adopt numerical calculation methods utilizing the following binomial models. First, we decompose the total period T by n to acquire Δt, T/n. Then we determine a rising rate u and a falling rate d of asset values in a period Δt as in Equations (2) and (3), respectively. Based on these parameters, we express the binomial tree, calculating V_i, the value of asset in the node i. As far as σ on CER values and T are concerned, 0.24 and 10 years are adopted, referring to our former analysis (Matsuhashi et al., 2004):

$$u = \exp\left(\sigma \cdot \sqrt{\Delta t}\right) \tag{2}$$

$$d = 1/u = \exp\left(-\sigma \cdot \sqrt{\Delta t}\right) \tag{3}$$

$$rnp = \frac{\exp\{(r-\delta)\Delta t\} - d}{u-d} \tag{4}$$

We determine risk neutral probability taking account of the convenience yield δ. The risk free rate r and δ are assumed to be 0.050 and 0.044, respectively (Matsuhashi et al., 2004).

Dynamic programming is adopted for estimating the above option values, in which the optimal decision-making process is clarified by backward propagation using the principle of optimality (Imai, 2004). In other words, we evaluate the option value backward from time T as shown in Equation (5). Then we propagate to previous periods step by step as shown in Equation (6). By the above backward propagation, the option value $F_0(V)$ in the initial time is finally calculated. The initial time is assumed to be 2006:

$$F_T = \max(V_i - I, 0) \tag{5}$$

$$F_t(V_i) = \max(V_i - I, \frac{rnpF_{t+1}(V_{i+1}) + (1-rnp)F_{t+1}(V_i)}{1+r}) \tag{6}$$

We develop a mathematical model of the dynamic programming through multi-stages as shown in Figure 1. The characters and numbers under the arrows in Figure 1 imply costs required to transfer among different stages. Ipro and Icer correspond to initial investment costs for CDM and transaction costs for registering under the CDM, respectively. The probability that a project could be successfully registered is shown in the parentheses under the arrows. The arrows indicate that the project proceeds to different stages, depending on whether it could be successfully registered or not. We assume that at least two time periods are necessary from preparation to actual investment. The stages in which "Wait to invest" and "Wait to invest 2" are written correspond to the first and the second waiting time period, respectively. However, we assume only one time for application for investors, who first prepare to invest and then apply to register under the CDM. This is because they begin to invest in the projects if the first application failed.

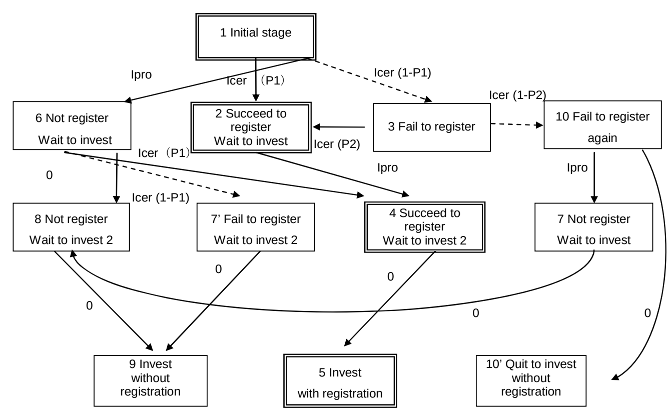

Figure 1. Procedures of registration and of investment with and without flexibility.

We also estimate project values without a flexible decision making process. In this estimation, we set a fixed decision making process regardless of the probabilistic fluctuation of project assets. These are shown as a series of the processes in double rectangles in Figure 1. Here we call this the passive present value of the project.

The option values estimated, $F_0(V)$, will coincide with the passive present value, V-I, in points with project assets larger than a certain value (Pyndyck, 1991), which is called the critical point. If a project asset is larger than the critical point, they generally decide to invest in the project immediately. In this sense, the critical point can be a threshold value for investment. We estimate this critical point so as to clarify how the above risks and uncertainties affect investment under the CDM.

3. Evaluated Results and Discussions

3.1. Application of the real option theory to CDM

As a case study, we surveyed actual data on CDM, on which economic data were acquired from New Energy and Industrial Technology Development Organization (NEDO 2, 2006), the Prototype Carbon Fund (PCF, 2006), the Global Environment Centre Foundation (GEC, 2006), and the United Nations Framework Convention on Climate Change (UNFCCC, 2006). Evaluated projects include various kinds of CDM projects, such as efficiency improvement in industrial sectors, recovery of methane from landfill sites, energy conservation in commercial sectors, and utilization of biomass energy. These projects have different characteristics, especially in revenue structure. If a CDM project is on fuel production from biomass resources, the revenue is from sales of the produced fuel and CERs. Most projects rely on main products, such as the fuel, as well as CERs for revenue. However, the share of CER value in total revenue varies widely depending on the characteristics of each project. For instance, shares of CER sales are generally high in projects that recover methane from landfill sites and utilize the gas for power generation, town gas production, and so on. In such projects, they convert the recovered methane into equivalent CO_2 reduction by multiplying 21 as Global Warming Potential. Thus, the equivalent CO_2 reductions become considerable amounts, and the revenue from CER sales often exceeds the sales of the main products. On the other hand, the share of CER value would be relatively small in projects relating to efficiency improvement in industrial sectors, such as steel production.

Table 1 at the end of this paper shows a list of the projects evaluated in this analysis. We plotted the data in Table 1 in the following figures so as to ascertain whether these projects are economically viable as CDM projects or not.

3.2. Results of risk analysis in CDM

According to the procedures in the last section, we first evaluated the critical points over which projects could be invested under the CDM. Computed results are shown in Figure 2. The X-axis in the figure means the net present value of acquired CERs divided by investment cost. The Y-axis in the figure means the net present value of the project except for CERs divided by investment cost in the critical point. That is to say, the upper horizontal line implies the boundary over which projects could be invested in even without revenue from CERs. On the other hand, the lower oblique line implies the boundary below which evaluated projects could not be invested in even with CERs. In Figure 2, the lower oblique line and the upper horizontal line were drawn as follows:

First, the value of Vcer/I is given as x_i on the X-axis. Then the critical value of Vpro*/I for the above Vcer/I is computed to be y_i according to the procedures in 2.2. This determines the plot (x_i, y_i) in Figure 2. In the same way, we calculate 11 critical values of Vpro*/I for 11 values of Vcer/I in the range of "0 $\leqq$ Vcer/I $\leqq$ 2." This determines the 11 plots from (x_0, y_0) to (x_{10}, y_{10}). The 11 plots from (x_0, y_0) to (x_{10}, y_{10}) make the lower oblique line in Figure 2. On the other hand, the upper horizontal line is determined from one of the above plots (x_0, y_0), where Vcer/I is zero.

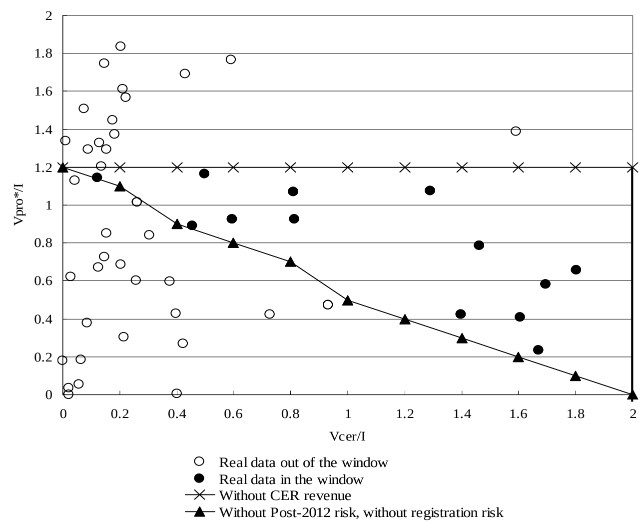

Figure 2. The window without the post-2012 risk and without registration risk and actual data.

Henceforth, a project could be invested in under the CDM if the plot of the project is located in a region surrounded by the upper and the lower bound. In this sense, we name the region as "the window for CDM". Thus, the plots of the projects should be included in the window, so that the projects could be invested in under the CDM. Figure 2 implies 13 projects are included in the window, so that these projects could be invested in under the CDM.

Next we show how the window becomes smaller due to the above-mentioned risks accompanying CDM. First, the registration risk makes the window smaller, as shown in Figure 3. If the registration risk becomes higher, fewer projects are included in the window, as shown in Figure 3. In particular, if the registration risk is 0.5, only one project could be invested in under the CDM.

The post-2012 risk also makes the window smaller, as shown in Figure 4. Thus, the number of projects that could be invested in under the CDM is reduced by the post-2012 risk, as shown in Figure 4. However, the impact of the post-2012 risk is not so strong as the registration risk, as shown in Figure 4. The reason is as follows:

The registration risk certainly decreases the intrinsic value of CDM projects. However, it increases the value of waiting, which is defined as "the option value -- the intrinsic value."

Since the registration risk makes the executors of CDM projects wait for the results of registration, the value of waiting will be increased. For the above reason, the asset values of the critical point increase by the registration risk, so that investment under the CDM becomes more difficult. On the other hand, the post-2012 risk not only diminishes the intrinsic value of CDM projects but also decreases the value of waiting. Since CER values would possibly be lost by the post-2012 risk, the value of waiting would be decreased. As a result, the critical point does not necessarily shift to the right due to the post-2012 risk. Although the impacts to the critical points are different, both risks certainly decrease the intrinsic value of projects, which worsens CDM.

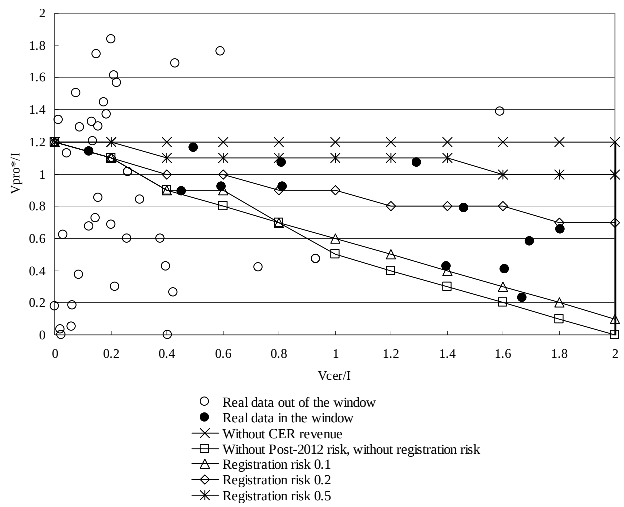

Figure 3. The window without the post-2012 risk and with registration risk and actual data.

3.3. Two policy options to manage risks in CDM

Here we propose two types of policy options to manage risks in CDM.

One option is the procurement of CERs by governments. As described in the previous section, the registration risk and the CER risk are crucial to activating CDM. Although we cannot directly control the registration risk and the post-2012 risk, we can lower the CER risk through governmental policy. The governments of donor countries can play an important role in order to reduce the CER risk. For instance, the CER Units Procurement Tender (CERUPT) initiated by the government of the Netherlands deserves attention. Under the CERUPT, the government purchases CER units acquired from CDM projects in which host countries and donor countries ratify the Kyoto Protocol. The Japanese government has also established such an institution to purchase CER units acquired from CDM projects. In the future, other governments should also take such a system into consideration. By adopting the CERUPT scheme and determining the purchase rate during CDM execution, we can diminish the CER risk. In this respect, we should note two kinds of payment procedures, up-front payment and payment on delivery, in which governments determine to purchase CERs.

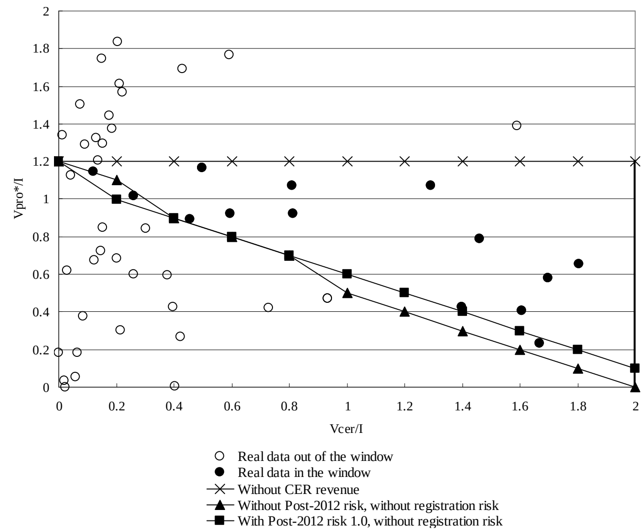

Figure 4. The window with the post-2012 risk and without registration risk and actual data.

If it adopts up-front payment, the government must pay for the CERs throughout the project period in advance to executing CDM. According to the NEDO document (NEDO 1, 2006), governments pay for the CERs throughout CDM period based on fixed CER prices. Therefore, the executors can receive benefits corresponding to interest from up-front payment, as well as benefits from lowering risk by fixed price. If it adopts payment on delivery, the government must exchange money for receiving the CERs every year. According to the NEDO document (NEDO 1, 2006), governments offer fixed CER prices during CDM period even with the payment on delivery. Unlike up-front payment, the executors of CDM projects cannot receive benefits corresponding to interest with the payment on delivery, but they can lower risk by fixed prices, which enlarges the window of the project.

The other option is low interest loans by official financial organizations. This relates to the low interest loans similar to environmental ODA, which certainly ease the financial burden of initial investments under the CDM. Now that CDM projects related to ODA are already registered by CDM executive board (UNEP Risoe Centre, 2007), this option is worth evaluation. In this paper, we quantitatively evaluate the advantage of this financial support. More concretely, we assume 1.0% referring environmental ODA, instead of ordinary private loan of 5%.

Figure 5 compares the windows in the above two payment procedures. The window for up-front payment is wider than the window for payment on delivery even if the post-2012 risk exists. Figure 5 also indicates the following: namely, the up-front payment could activate four more projects to be invested as CDM projects due to the wider window, while the payment on delivery could activate two more projects. From this figure, the government institution would not be very effective in activating many of CDM projects evaluated here. This payment procedure is more useful to activate CDM projects with higher Vc-

Table 1. Projects Evaluated in this Analysis

Titles of projects	Nation
Project of wind power generation in Patagonia region	Argentina
Energy saving options by recovering thermal energy in low temperature in Asominath steel plant in Brazil	Brazil
Energy recovery and utilization of thermal energy by pressure difference in natural gas pipeline	Brazil
Feasibility study of acquiring carbon credits from power generation utilizing landfill gas	Brazil
Project of energy conversion from sugar waste	Brazil
Project of hydropower generation	Chile
ESCO project using CDM scheme	China
Feasibility study of biogas utilization from anaerobic digestion of sewage sludge in Dairen	China
Feasibility study on promoting district heating system using renewable energy	China
Project of introducing cogeneration using natural gas in Tsingha University in Beijing	China
Project of introducing natural gas cogeneration in Tongkou city	China
Project of power generation utilizing landfill gas	China
Project of producing Ammonia synthesis gas in high efficiency	China
Project of utilizing coal mine methane in Binchao mountain	China
Project of utilizing coal mine methane in Shenjiang district	China
Survey of energy conservation for district heating system with cogeneration in Shangtong region	China
Survey of improved energy conservation in Ransyu petrochemical plants	China
Rehabilitation of iron production in Helwan steel plant in Egypt	Egypt
Rehabilitation of iron production in Helwan steel plant in Egypt	Egypt
Feasibility study on ethanol production from wasted sugar, molasses	India
Feasibility study on ethanol production from wasted sugar, molasses and bagasse	India
Survey of energy conservation in Gjaraht oil refinery plant	India
Feasibility study of effective utilization of bio-gas from waste disposal site	Indonesia
Feasibility study of using methane from palm oil plants	Indonesia
Project of energy production industries using solid and liquid wastes from palm oil plants	Indonesia
Project of improved waste disposal system in factories of producing starch from Tapioca	Indonesia
Project of power generation using urban solid wastes	Indonesia
Project of producing alternative energy using baggasses in sugar factory in Smatra island	Indonesia
Project of producing bio-diesel fuel from palm oil wastes	Indonesia
Project of recovering methane and power generation utilizing waste from pig breeding farm	Indonesia
Energy saving project of Bienchiang steel plant	Laos
Project of energy conservation in Bialao factory	Laos
Feasibility study of acquiring carbon credits from power generation using palm bunches	Malaysia
Feasibility study of effective utilization of bio-gas from waste disposal site	Malaysia
Feasibility study of producing bio-diesel fuel using vegetable oil	Malaysia
Feasibility study of suppressing methane emissions and biomass industries using solid wastes from palm oil plants	Malaysia
Feasibility study of suppressing methane emissions from landfill site by composting waste	Malaysia
Forced methane extraction from organic waste-water treatment plants for grid-connected electricity supply	Malaysia
Project of energy utilization from landfill gas	Philippines
Project of recovering methane from sewage	Philippines
Project of constructing biodiesel refinery	South Africa
Project of power generation utilizing landfill gas in Durban	South Africa
ESCO project for commercial buildings	Thailand
Feasibility study of acquiring carbon credits from biomass power generation	Thailand
Feasibility study of cogeneration using bagasses and rice husc	Thailand
Feasibility study of introducing cogeneration using biomass in an industrial park in the east coast	Thailand
Feasibility study of power generation using biomass from sugar factory	Thailand
Feasibility study of producing bio-diesel fuel from sunflower as energy crops	Thailand
Feasibility study on introducing high efficiency furnaces for process of hot rolling in steel production	Thailand
Project of energy utilization from landfill gas	Thailand
Small-scale CDM using solar power generation systems	Tonga
Project of methane utilization from landfill site in Tashkent city	Uzbekistan
Survey on modernization of district heating system in Prague	Uzbekistan
Direct ironore reduction of the Sidetool steel plant and rehabilitation in steel production	Venezuela
Feasibility study on ethanol and sugar production from sugarcane	Vietnam
Project of anaerobic digestion using waste water from crude rubber plants	Vietnam
Project of establishing infrastructures for Nunchack industrial park	Vietnam
Project of modernizing cement sector in the neighborhood of Hanoi	Vietnam
Project of power generation recovering bio-gas from waste disposal site	Vietnam

er/I, since the window becomes wider in higher Vcer/I. However, many projects in Table 1 have low Vcer/I, since they are mainly related to energy conservation or renewable energy. This is the reason why the payment procedure is not very useful here.

On the other hand, the effect of the low interest loan is depicted in Figure 6. The wider window also covers the region with lower Vcer/I, different from the other option. In this sense, these two policy options could complement each other.

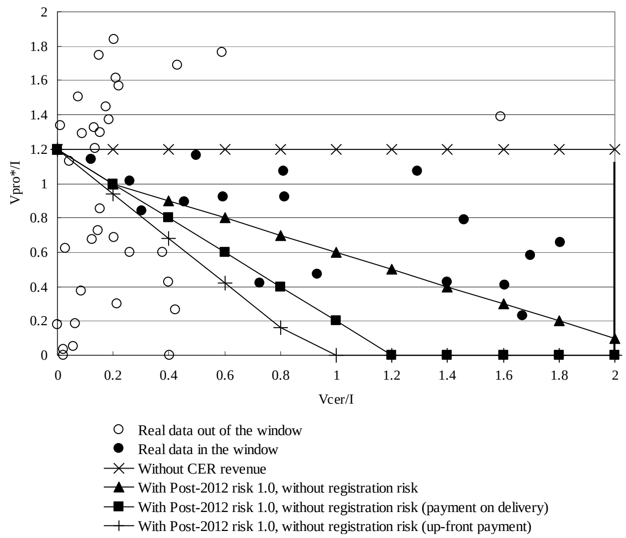

Figure 5. The window in the up-front payment with the post-2012 risk and without registration risks and actual data.

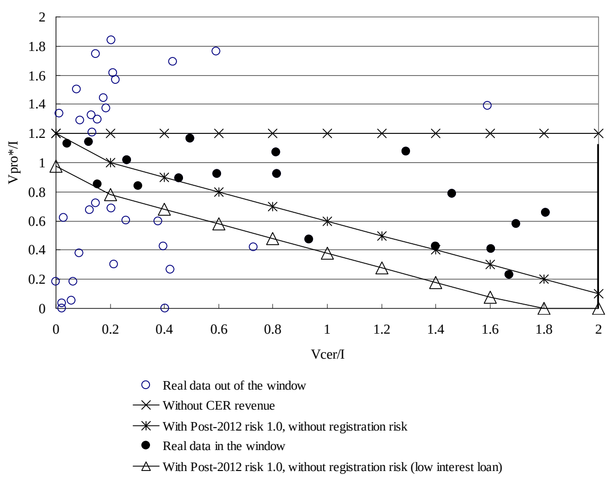

Figure 6. The windows with Post-2012 risk and in the low interest loan.

4. Conclusions

In this paper, we first investigated how to evaluate risks in CDM. The real option theory is applied to quantify project risks in CDM so that we could estimate the option values. A mathematical model of CDM was represented with a compound rainbow option, which includes continuous procedures from registration to investment.

The evaluated results identified the condition of CDM in which investment as projects are feasible. We quantified how the registration risk and the post-2012 risk make investment more difficult. As our conclusion, registration risk could have a stronger adverse impact on investment in CDM projects than the post-2012 risk does.

We then investigated how to activate CDM projects. For this purpose, two options were considered: low interest loans by official financial institutions and the procurement of CERs by governments. The former relates to low interest loans similar to environmental ODA, which certainly eases the financial burden of initial investments in CDM projects. On the other hand, the latter aims at lowering risks through the secure purchase of CER by governments. We also surveyed actual data on CDM, investigating how the above-mentioned risks and governmental policies influence the number of executable CDM projects.

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