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Description	一般講演要旨

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Option-games and Multi Criteria Analysis for Power Generation Investment Evaluation

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Abstract In this study, strategic decision-making models based on option-games and multi criteria decision analysis (MCDA) are proposed to assess the value of government based-risky power generation project. A high risk project requiring a significant financial investment must be evaluated to verify its economic feasibility and effectiveness before it is introduced. In the past, most energy project is only valued through its economic point of view and pay less attention to other non-economic perspectives. Most traditional valuation models fail to capture the full values created by a new project because they do not correctly capture the nature of the process of project development itself, such as the competitors and public reactions. The option-games model is designed at two-stage, which consider duopoly of leader and follower. The output from the option games will be considered as one of the input in MCDA framework as an economic aspect. Additionally, there is the problem of combining the results of economic analysis with the qualitative factors that are difficult to quantify in currency units, such as risks, time limits, and the distinctiveness of project effectiveness. While economic analysis in long term can be done with an option-games method, qualitative factors require multi-criteria analysis. One of the primary concerns in selecting energy projects is to integrate all these factors (sometimes competing with each other) and to come up with a decision model that can be used easily by project managers. The purpose of this study is to introduce an integrated framework that can improve the current feasibility assessment process in evaluating energy generation projects.

Keywords: *real options, game theory, power generation investment, multi-criteria decision making, analytical hierarchy process*

Introduction

Electricity policy in OECD countries over the past decade has been focused on the liberalization of electricity markets. In doing so, governments have shifted the responsibility for financing investment in power generation away from generally state-owned monopolies to private investors. No longer able to automatically pass on costs to consumers and with future prices of electricity uncertain, investors face a much riskier environment for power generation investment decisions.

Many factors such as policies, strategies, and economic feasibility must be considered in power generation projects. However, the process of developing and acquiring these projects requires extremely large investment costs and a long period of time. Moreover, once a government has committed to a decision, it is very difficult to change the course of action without enormous costs of money and time. This lack of flexibility is one of the common problems cited for traditional economic analysis. Recently, the real options model is the most commonly used technique for the valuation of a strategic investment project under significant uncertainty. This technique alleviates the limitations of the traditional methodology and actively manages the uncertain investment environment, giving strategic flexibility to postpone, extend, reduce, or abandon the project and reflecting all these factors in the investment valuation.

However, the main disadvantage of ROA is that it cannot take into account additional investments between an investor and its competitors. The investment decision of a policy maker also has an effect on the market. This means that the value of investment is uncertain not only with regard to demand and price but also in what additional investment an investor and its competitors make. To overcome this shortcoming, a combination of option games that intergrates real options (with demand and price uncertainties) and game theory (with a competitor's decision) has been presented as a hybrid investment valuation tool for analysis of the value of flexibility and commitment (Smit and Trigeorgis 2009).

We designed a numerical case study of power generation investment based on fossil fuel and renewable energy sources. The basic flow of investment in power generation business is represented by Figure 1 below. Two-stage option-games model of strategic investment will be used to analyze payoffs of power generation projects. On value creation of the firms, an innovation and high risky technology development such as energy industry of power generation projects involves uncertainty. But to deal with it, a concept of real option is very effective for a measurement of the flexibility value as the expanded NPV created by a flexible decision-making and for a model design of flexibility built-in decision-making. Meanwhile, game theory is a useful method to measure and ensure the strategic value. Thus, option-games, a further integrated framework between real-options and game theory for analyzing investments in a more rigorous fashion is suitable for competitive business faced by power generation investors. Investors in power generation are represented by independent power producers (IPP). IPPs are merchant developers and operators of power plants that sell wholesale power to utility and industrial buyers. Within limits they can sell power at whatever price the market will bear. IPPs face more financial risk. They do not have guaranteed service territories and can face intense competition for power sales.

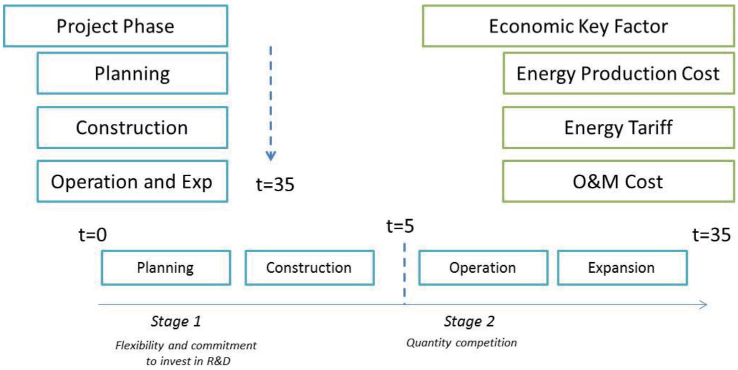
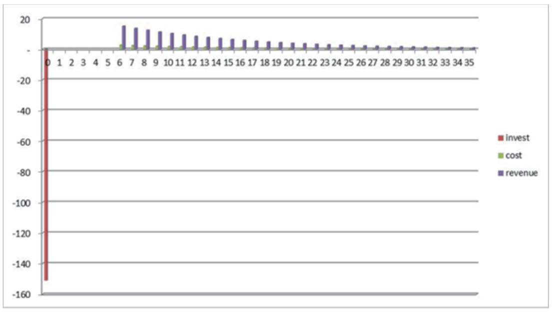


Figure 1 Two-stage approach for Power Generation Projects

Methodology

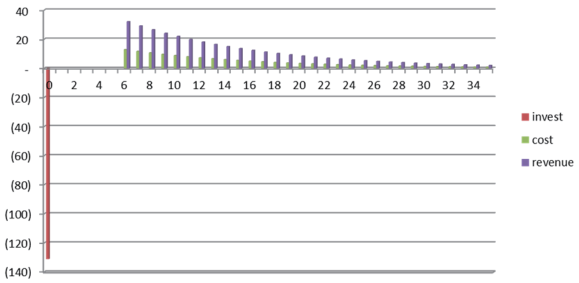
In an environment of high uncertainty, firms have an incentive to defer irreversible investment. However, early investment can be used to gain strategic advantages (Smit 2004). Pioneering strategies often involve a sequence of interdependent strategic investment decisions in early stage and subsequent commercial stages. If it decides to invest in commercialization, an early investment in R & D or a pilot plant in a new market may entail strategic value by improving the firm's competitive position. In each strategy, the incremental flexibility value from postponing irreversible investments from the base case is traded off against the incremental commitment value from pre-committing investments to gain the strategic advantages. The value of the strategy is based on the expanded or strategic NPV criterion that incorporates both the early commitment effect on value from a firm's ability to influence its future competitive position, and the flexibility effect from strategic investment.

We calculate the initial NPV for several power generation projects. The initial result by using discounted cash flow method is shown in Figures 2a, and 2b below. Based on this result alone, it is shown that coal-fired power plants is the most profitable investment compared to hydropower energy project.



NPV = -23 million USD

Figure 2a Cashflow for Hydropower Plant Project



NPV = 67 million USD

Figure 2b Cashflow for Coal-fired plant project

The basic setup is two-stage game with player A and B, in which player A is the pioneering IPP and player B is other IPPs which usually enter the market in the latter stage. At first stage (basic research), initial investment is made only by Player A as the pioneer which has the proprietary right to invest or not. During the second stage, the two players will make endogenous competition between them for the commercialization R&D investment. As the methodology for such game, the procedure is consisted of basically comparing both the value of flexibility by real options and the commitment value by game theory in a game tree and then, of utilizing both of them for the optimal strategic decision through the backward induction. An investment in earlier stage will provide a competitive advantage of cheaper production cost during commercialization in next stage. In this study, the analysis will be limited to no investment (scenario 1) and shared investment by both firms (scenario 2) from the perspective of Cournot quantity competition.

The illustration of this case study is as follows : firm A can make the decision to invest its first stage initial R&D investment that results in a deterministic operating cost advantage in the second stage in renewable energy projects. Its commercialization (second) stage investment and initial investment is USD 300 million. When they make endogenous competition during this stage, either firm A or B can invest in this commercialization projects, depending on subsequent random demand moves with its initial demand $\theta = 25$. Volatility is estimated using discounted cash flow and by utilizing Monte-carlo simulation, thus σ=14%. Binomial parameters up and down moves of $u = 1.15$ and $d = 1/u = 0.87$. The risk-adjusted discount rate, k is 17% while risk-free rate is 8%. If constant asset payout yield for perpetual project is:

$$\delta = \frac{k}{1+k}$$

risk neutral probability is

$$p = \frac{(1 + r - \delta) - d}{u - d} = 0.214$$

where $u = \exp\sqrt{\sigma \Delta t}$ and $d = 1/u$. As firm A choose not to make its basic R&D investment, the two firms would have the symmetric second stage operating costs based on first stage old technology, $c_A = c_B = 7$. The illustration of the base case is shown in Figure 3 below. The combination of competitive decisions (A or B) and market demand moves (θ) may result in one of the following market structure game outcomes:

1. C: Cournot Nash quantity / price competition equilibrium outcome
2. S: Stackelberg leader (S_L) / follower (S_F) outcome
3. M: Monopolist outcome
4. A: Abandon (0 value)

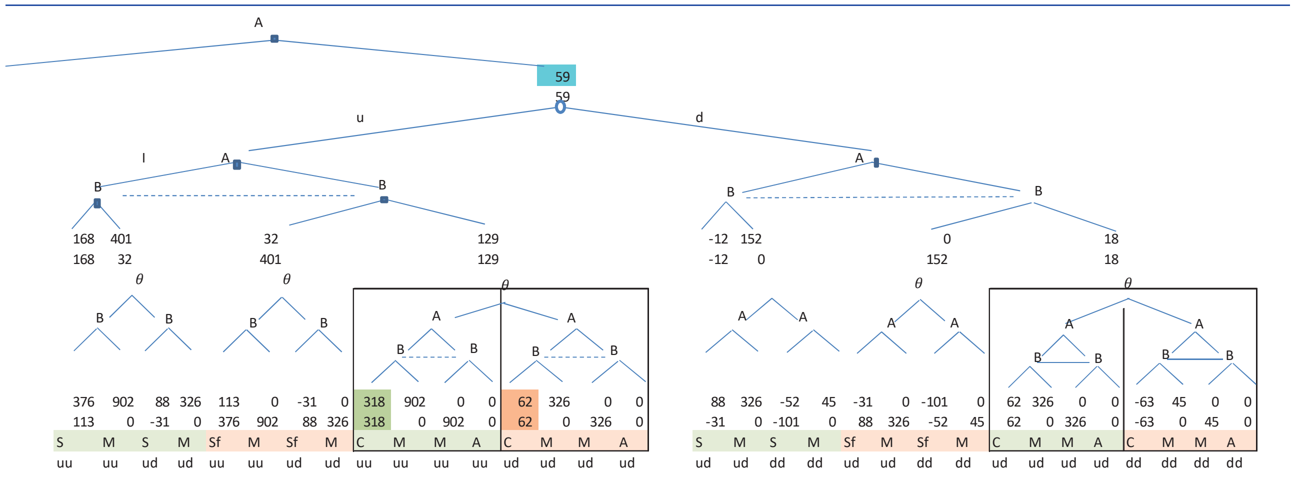


Figure 3 Base Case for Hydropower Project

In our second case, we consider a project in coal-fired energy plant project, since the coal fired plant is dependent to the volatility price of fuel, the risk in this project is higher although the generation cost is relatively lower (see Figure 4).

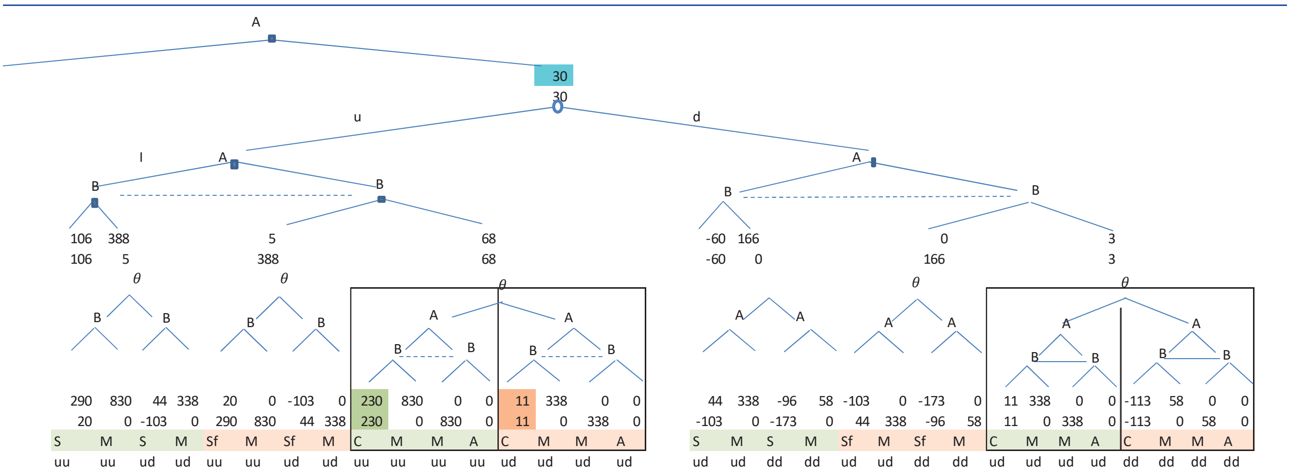


Figure 4 Base Case for Coal-fired Project

Discussion

The base case for each project is symmetrical for both firm, which means that no firm can gain an advantage by investing first. However, the interesting result is that coal-fired energy project offers quite similar result to the hydropower energy project by using the option-games approach. This base case will be used as an input for multi-criteria decision approach to evaluate the project feasibility. The evaluation of criteria for energy project is based on Analytical Hierarchy Process. Among numerous MCDA methods, Analytical Hierarchy Process (AHP) is the most popular technique and has been utilized in various areas for making the best decision with the available alternatives. A critical feature of AHP is that it creates a hierarchy which consists of criteria and sub-criteria as assessment elements and measures the level of relative importance of these criteria through pairwise-comparison. It helps decision makers in organizing their values and preferences to make effective decisions and transfer them into quantitative ratios to weight criteria. We determine the hierarchical structure of the decision model with the alternatives and criteria in Figure 5 below.

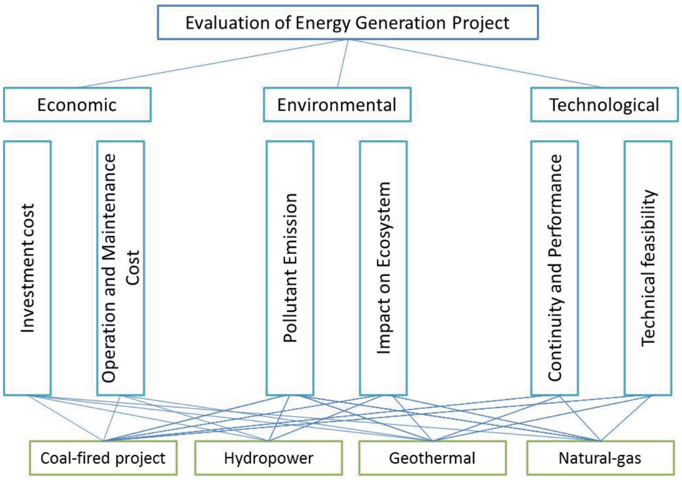


Figure 5 The hierarchy of the energy resources evaluation problem

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