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Real options analysis for renewable energy investment decisions in developing countries

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ABSTRACT

Renewable energy projects in developing countries should provide clean energy supply as well as support sustainable economic development. To this end, risks arising from uncertainties such as rapidly changing technologies and host government conditions should be carefully addressed. However, traditional methods for economic assessment are not adequate to support decision-making regarding investments in renewable energy. This paper proposes a real options analysis framework as a tool to assess renewable energy investment in developing countries. A case study involving a hydropower project in Indonesia was conducted to validate and verify the proposed framework. This framework is expected to help host countries and investors assess renewable energy projects with high volatility and risk.

1. Introduction

Due to global climate change, developed countries have continued to reduce their use of fossil fuels and increase their use of renewable energy (RE). By 2012, as a result of the Kyoto Protocol, RE production reached an estimated 22.1% of global electricity production [1]. Total new investment in renewable power was at least US$249.4 billion in 2013 [1]. Since 1990, RE generation worldwide has grown by an average of 3.3% per annum: 2.3% among countries in the Organization for Economic Co-operation and Development and 4.5% among other countries [2].

The RE industry has expanded more quickly in developing countries facing rapid economic growth and severe energy shortages. The continual decline in prices of RE material and equipment caused by technological advancements have improved the applicability of RE in recent decades. Governments of developing countries have played a role in the growth of the RE market by attracting foreign investors for RE business opportunities, by means of new energy policies such as feed-in tariffs, renewable portfolio standards, deregulation, incentive programs, and public–private partnership models. The RE business has created an energy industry boom and has filled a gap in the electricity supply in emerging economies including developing countries in Asia, Africa, and South America.

Despite the positive aspects of RE markets, it is difficult to make decisions regarding RE investments in developing countries. Risks arising from changeable policies, loan rate fluctuations, foreign exchange rates, and inflation are typical examples that illustrate the difficulty of decision-making in RE investment. This paper proposes a real options analysis (ROA) framework for the assessment of investments in RE projects of developing countries. RE projects in this study are defined to include electricity-generating power plants powered by hydropower, solar, geothermal, bioenergy, wind, or marine (tide and wave) energy sources. The two objectives this paper attempts to achieve are the accurate estimation of uncertainties arising from investment in RE projects of developing countries and the accurate assessment of economic feasibility of such investments. This paper first identifies the key variables to assess the uncertainties that have a direct influence on the project profit. ROA is then conducted to yield the option value to decide whether or not the project is economically feasible. The proposed framework enables investors to accurately evaluate RE projects with regard to the major risks associated with these projects. The entire process of planning, designing, constructing, and operating RE projects in developing countries is covered in this framework.

2. Literature review

Developers, financial institutions, and government agencies commonly assess investments using the net present value (NPV) technique under the condition of definite cash flow. The NPV technique is the most widely used decision-making tool for various investment projects. This traditional approach is known to be quite useful in many projects, but not in the case of highly volatile and uncertain investments. Because RE projects in emerging markets entail considerable risk influenced by rapidly changing RE technologies and global climate

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change, the traditional method for economic assessment does not adequately meet the requirements of RE projects in developing countries. NPV has long been authorized as an investment decision technique for energy projects; however, it is considered inappropriate for highly uncertain investment projects because it intrinsically carries the assumption of definite cash flows. The limitations and weak points of NPV have become more obvious when NPV is compared with ROA. Amram and Kulatilaka [3] and Copeland and Antikarov [4] applied ROA to highly volatile investment projects in the areas of oil, gas, mining, research and development, aviation, telecommunication, pharmaceuticals, and semiconductors.

Recently, ROA has been more frequently applied for valuation of RE projects. ROA has been used for various types of RE, including hydropower [5–7], wind farms [8–12], and solar energy [13,14]. Studies have been conducted to improve ROA methodology for RE [15–18]. Policy issues for RE have also been addressed [19–25]. The Clean Development Mechanism (CDM) for RE projects is another important issue that has been studied [26–29]. Additionally, investment in RE projects in developing countries has also been explored [30–33]. Particularly, Kurbatova and Khlyap [34] and Kaygusuz [35] argued that political and economic factors encourage developing countries to develop RE projects and new energy policies, and that RE strategies be changed with consideration to the increasing levels of future energy consumption. Huenteler [36] suggested the role of donor countries in helping developing countries ease the high uncertainty of feed-in tariff.

The volatility of project cash flow is much more important in RE projects than in traditional energy projects. Systematic and comprehensive analysis is increasingly useful for investigating the volatility arising from uncertainties of RE projects. Bøckman et al. [5] developed a real options model for a small hydropower project in Norway, to find the unique trigger price for investing and the optimal size of the hydropower plant. Kjærland [6] applied the real options model framework for potential hydropower investments to quantify the option value based on different timing and investment behaviors in Norway. Abadie and Chamorro [8] developed a real options model to investigate a wind farm project considering the three uncertain factors of electricity price, wind generation quantity, and subsidy in the UK. Lee [37] demonstrated the effectiveness of ROA for a wind energy project in Taiwan and argued that the value of RE investment increases when underlying price, time to maturity, risk-free rate, and volatility increase. Martinez-Cesena and Mutale [11] proposed a real options methodology to assess the value of small wind power projects. Venetsanos et al. [12] developed an evaluation method for uncertainties associated with wind energy projects after deregulation of the electricity market in Greece. Kumbaroğlu et al. [38] presented a policy planning model integrating learning curve information on RE technologies into a dynamic programming formulation featuring ROA in a Turkish case.

Many researchers evaluated RE projects by taking into account volatility within economic, environmental, and technical factors. Kim et al. [39] identified three key variables (energy production, tariff, and O & M costs) to understand uncertainty in hydropower projects in Korea, and forecasted the future energy production derived from the projected future precipitation. Zhang et al. [40] suggested a ROA model for evaluating solar photovoltaic (PV) power projects in China, by considering variable factors including CER price, non-renewable energy cost, investment cost, and tariff. Detert and Kotani [41] compared coal-based power and renewable energy by considering the sole uncertain cost of coal in Mongolia. Jeon et al. [42] proposed a real option model to estimate optimal subsidy in PV investment, reflecting uncertainties such as tariff, energy production, interest rate, risk premium, risk free rate, and the exchange rate in Korea.

Table 1 summarizes the relevant literature that used the real options approach, and classifies it according to countries, RE type, and uncertainties. It illustrates the lack of literature that profoundly analyzes the uncertainties of RE projects in developing countries.

Table 1
Summary of real options literature.

Authors	Country	RE type	Year	Uncertainty	Ref.
Batista et al.	Brazil	Hydropower	2011	CER price	[26]
Zavodov	China	Hydropower	2012	CER price	[29]
Zhang et al.	China	PV	2016	Non-renewable energy cost, Tariff, CER Price, Investment cost	[40]
Yang et al.	China	Wind	2010	CER price	[28]
Weibel and Madlener	Germany	Hybrid	2015	Energy production, Tariff, Investment costs	[46]
Reuter et al.	Germany	Wind	2012	Tariff	[18]
Kroniger and Madlener	Germany	Wind	2014	Energy production, Tariff, Capacity	[47]
Venetsanos et al.	Greece	Wind	2002	Tariff	[12]
Lee et al.	Indonesia	Hydropower	2013	CER price	[27]
Kim et al.	Korea	Hydropower	2016	Energy production, Tariff, O & M cost	[39]
Jeon et al.	Korea	PV	2015	Tariff, Energy production, Interest rate, Risk free rate, Exchange rate	[42]
Kim et al.	Korea	PV	2016	Energy production, Tariff	[48]
Kim et al.	Korea	Wind	2014	Non-renewable energy cost	[49]
Detert and Kotani	Mongolia	Wind, PV	2013	Non-renewable energy cost	[41]
Boomsma et al.	Nordic region	Wind	2012	Tariff	[16]
Kjærland	Norway	Hydropower	2007	Tariff, Investment cost	[6]
Bøckman et al.	Norway	Hydropower	2008	Tariff	[5]
Lee and Shih	Taiwan	Wind	2010	Tariff, Costs	[23]
Lee	Taiwan	Wind	2011	Underlying price, Exercise price, Operation Time, Risk-free rate	[37]
Kumbaroğlu et al.	Turkey	Wind	2008	Tariff	[38]
Martinez-Cesena et al.	UK	PV	2013	Tariff	[14]
Abadie and Chamorro	UK	Wind	2014	Tariff, Energy production, Subsidy	[8]

Previous studies were primarily carried out for developed countries such as the UK, Greece, Germany, Korea, and Norway. However, there are few studies that analyze RE investments in developing countries such as China, Brazil, Indonesia, and Mongolia.

A RE project includes uncertainties influenced by costs during the development phase and cash flow during the production phase. Typical development costs include site survey, feasibility study, design, and construction. These costs are subject to private risk, as opposed to market (public) risk. Cash flow during the production phase is typically calculated as the net of expected revenue minus production costs [43]. Cash flow is usually influenced by market risk only [43]. The marketed asset disclaimer (MAD) approach is applicable to both market and private risks [44]. This approach presents the practical challenge of developing a cash flow model and associated subjective input variables. However, because the MAD approach is applicable to any investment [45], it was adopted in the ROA framework for RE projects developed in this study.

The issues addressed in previous studies on the application of ROA for RE projects can be categorized into applicability of ROA to a

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