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A real option model for renewable energy policy evaluation with application to solar PV power generation in China

Mingming Zhang [a,b,*], Dequn Zhou [a,b], Peng Zhou [a,b]

[a] College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China
[b] Research Centre for Soft Energy Science, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China

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ABSTRACT

This study proposes a policy evaluation model from the perspective of government and investors. The proposed model, which integrates American option method and two-factor learning curve method, can be used to evaluate the unit decision value and save-path rate for renewable energy development and examine the existence of balance point of interest. Several uncertain factors including non-renewable energy cost, carbon price, renewable energy cost, and price subsidy are all considered in this model. The model has been applied to evaluate the solar photovoltaic (PV) power generation in China. Our empirical results show that real option analysis (ROA) is more effective than net present value analysis (NPV) when handling uncertainty. Under current level of subsidy, the government would suffer loss and the investors could benefit so that it is difficult to achieve the balance of interest during the planning period. With the reduction of subsidy rate, they can achieve the balance of interest.

Contents

* Corresponding author at: College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing 211106, China. Tel.: +86 25 8489 6261; fax: +86 25 8489 2751.
E-mail address: zmmsdutgl@163.com (M. Zhang).

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1. Introduction

When energy shortage and environmental issues increasingly become the bottleneck restricting the social and economic development, more and more countries take steps to develop renewable energy. The development of renewable energy in the world shows a increasing trend. In 2012, the global renewable energy investment reached 24.4 billion dollars. However, the promotion of renewable energy is affected by its dispersion and instability which will result in high research & development (R&D) cost, difficulty of investment recovery, long and deferred planning processes, and high investment risks. Therefore, supportive policies and statutes are essential. Currently, a lot of policies like feed-in tariff (FIT), renewable portfolio standard (RPS), and tax rebates have been formulated and implemented to promote the use of renewable energy in the world.

China as a big country of energy production and consumption in the world faces more serve situation of increasing energy supply. China has great potential to develop renewable energy and has made great progress after years of promotion. To lower investment costs and attract more investments, Chinese government has implemented some policies, like equipment investment subsidy, tax relief and FIT. Supported by these policies, Chinese government also made a series of development plan for renewable energy. The Middle and Long Term Programme of Renewable Energy Development states that renewable energy should reach more than 15% of the total energy consumption in 2020. Regarding solar PV, the Opinions of State Council on Promoting the Healthy Development of the PV Industry proposed the installed capacity of solar PV power generation reach 35,000 MW and above by 2015. The 12th Five-year Plan of Chinese renewable energy also posed that installed capacity of solar PV reach 50,000 MW by 2020. Under current development plan, whether the current level of subsidy is favorable for government and investors as well as what is the appropriate level of subsidy are worthy of attention.

Some scholars [1–3] have established model to evaluate the policy benefit of developing renewable energy for government. The factors they considered contains non-renewable energy (NRE) cost, renewable energy cost, and carbon mitigation cost. However, most of the studies did not consider the benefits of both government and investors, whereas policy evaluation considering the benefit of government and investors seems to be more meaningful. In addition, some studies just only considered the economic value and concluded that government has always been at a loss. These are inappropriate. The value of developing renewable energy means not only the economic benefit but a kind of comprehensive benefit. This paper proposes a renewable energy policy evaluation model that integrates the American opinion and two-factor learning curve. The uncertain NRE cost, carbon price, renewable energy cost, and price subsidy are all considered. According to this model, we can derive the unit decision value and save-path rate for government and investors during the planning period. The existence of the balance point of interest can also be examined, based on which the applicability and effectiveness of policy can be assessed.

The remainder of this paper is organized as follows: Section 2 provides a literature review. Section 3 describes methodology which contains the factors involved in analysis and the real option model. Section 4 presents the empirical analysis including parameter estimation and scenario analysis. Section 5 concludes the study.

2. Literature review

2.1. The real option theory

Due to its characteristic of time-consuming, large scale and high cost, the development of renewable energy is constrained by high investment risks and uncertainty. The uncertainties lie in volatility of energy price and the speed of technological progress. Recently, the disadvantages of traditional techniques including NPV and discounted cash flow approaches (DCF) proposed by Fisher [4,5] are increasingly recognized [6–8]. Real option is an effective tool on resolving uncertainty. Real option could effectively analyze the investment opportunities combining the present and the future. If real option approach is used to assess the benefit of renewable energy development policies, managerial flexibility neglected by traditional assessment methods can be quantified. The possibility of underestimating policy value can also be minimized [9]. Therefore, real option is more and more used in renewable energy investment and policy evaluation.

Real option was originally developed in the 1970s by Black and Scholes [10] and Merton [11] to evaluate financial options. Myers [12] found their similarities and applied the option pricing methods to determine the value of physical assets firstly. He called it real option. After that, some scholars proposed a few basic concepts about real option. Trigeorigis and Mason [13] referred to the investment value of an options value with managerial flexibility obtained as “expanded” or “strategic” NPV. This value is the sum of the traditional NPV and managerial flexibility value. Sarkar [14] indicates that the increase of uncertainty could raise the probability of investment in a given environment. Copeland and Antikarov [15] established a unified model based on real option and put forward five solving steps which could be used to option evaluation and project valuation. They thought option was one important part of expected value of project in future.

For the numerical solution method of real option, Cox et al. [16] proposed the binomial model and its extension based on dynamic programming approach. Brennan and Schwartz [17], Majd and Pindyck [18] used partial differential equation to solve their option pricing models. The method used by Boyle [19] was Monte Carlo simulation. He [20] also demonstrated how to deal with the situation of two random variables. Longstaff and Schwartz [21] proposed Least Squares Monte Carlo method (LSM) which is one kind of American option solving method based on Monte Carlo simulation and least squares.

2.2. Application of real option to renewable energy investment

A number of studies focused on the area of renewable energy investment. Venetsanos et al. [22] analyzed the impact of uncertain factors on renewable energy investment and how to choose optimal investment time. The factors considered in their study contain fuel price, environmental regulations, initial capital investment, technology, and market structure. Davis and Owens [23] developed a real option model which uses a binomial lattice structure. The authors argued that a binomial lattice reveals the economic intuition underlying the decision-making process, while a numerical example illustrates the option components embedded in a simplified representation of current US Federal renewable energy research, development, demonstration and deployment. By analyzing the option value of power plant, Kiriyama and Suzuki [24] thought, with the arrival of carbon emission limiting age, nuclear power would become more and more important. Gollier et al. [25] compared the one-time investment of large nuclear power project and flexibly sequential investment of small nuclear power project with application of real option and considering uncertain electricity price. Yu et al. [26] focused on evaluating the flexibilities associated with switching tariff in Spanish electricity markets. Using the real options framework, they implemented numerical techniques to evaluate switching tariff for different wind generation assets, and identified optimal switching policies and values. Siddiqui et al. [27] examined the strategy for renewable energy R&D in the United States. Kjaerland [28] applied real