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A real options valuation of Chinese wind energy technologies for power generation: do benefits from the feed-in tariffs outweigh costs?

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ABSTRACT

In order to assess the viability of wind energy projects in China, this paper takes a real options approach by accounting for flexibility over deployment of the technology in response to a stochastic non-renewable energy cost. The difference between the latter and the R&D-enhanced cost of renewable energy operation may be thought of as a benefit from using wind. On the other hand, the Chinese government provides feed-in tariffs to encourage further adoption of wind, which should be included as a cost. This work, thus, shows that there is substantial options value to China's wind energy program, which is bolstered if the cost of carbon dioxide emissions is internalized. Moreover, by varying the rate of feed-in tariffs, the model may be used to show plausible ranges for the feed-in tariffs, which could be a useful policy insight. Furthermore, the study hypothesizes that with the likelihood of renewable energy to replace non-renewable energy, wind power in China can potentially reduce CO_2 emissions by approximately 6.4% by 2020 comparing to the 2005 level and highlights the significant role of wind power in China's emission targets and energy security. This is a relevant paper, especially given the importance of a sustainable energy transition for China. More generally, using the real options approach from a policy perspective could provide insights about the viability of renewable energy programs and robustness of feed-in tariffs rates.

1. Introduction

Conventional energy production relies heavily on fossil fuels like oil, natural gas and coal. Hence, there emerges as by-product carbon dioxide which is the most important greenhouse gas since a very high concentration in the atmosphere accelerates climate change and causes environmental damage. Renewable energy (RE) like hydro, solar and wind do not generate greenhouse gases and as such do not harm the environment. In order to fulfill the emissions reduction commitment of the Kyoto protocol and to contribute to the mitigation of climate change, a large number of countries have implemented policy measures for promoting renewable energies. For instance, as of 2009 more than 60 countries worldwide including China use feed-in tariffs (FITs) which guarantee suppliers of renewable energy a price that lies above the market price, implying an implicit subsidy on renewable energy. Other widely used policy measures are RE Portfolio Standards (used in many U.S. states), tax incentives or direct R&D subsidies (used mainly in European countries).[1]

China's energy consumption also relies heavily on fossil fuels and domestic carbon emission has grown considerably following the country's rapid economic growth.[2] In 2010, fossil fuels accounted for 91.4% of total energy consumption in China, of which 68% came from coal (NBSC, 2011; Lin and Wesseh, 2013a). This implies that using the cost of coal to represent the cost of fossil fuels as is the case in this study is reasonable. Given the rapid increase in China's energy consumption in recent years coupled with a coal-dominated energy mix, the Chinese economy has high carbon intensity. The Netherlands Environmental Assessment Agency on

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[1] A comprehensive survey of policy instrument promoting renewable energy is given in the CESifo database DICE under http://www.cesifo-group.de/portal/page/portal/ifoHome/a-winfo/d3iiv.

[2] This is because energy serves as a vital input to national development (Wesseh and Zoumara, 2012; Wesseh et al., 2013; Lin and Wesseh, 2014; Lin et al., 2014).

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June19, 2007 announced that China's 2006 CO_2 emissions had surpassed those of the United States, making China the largest carbon emitter. In fact IEA (2009) documents that the share of China's emissions over the world's total increased from 12.9% in 2000 to 22.3% in 2008. In 2011 China was estimated to emit more CO_2 than the US and Canada together, an increase of 171% since the year 2000.[3]

As pressure and global clamor for carbon emission reduction mounts, China finds itself in a state of predicament and has to properly determine its future energy policies. It is obvious that the issue of low carbon would be the bedrock for these policies. In its 12th Five-Year Plan, the Chinese government has committed to reducing carbon emission per unit of GDP by 40–45% by 2020 compared to the 2005 levels. To help achieve the goal of carbon reduction and to provide energy security, Chinese policy makers and scholars have shown a growing interest in the development of RE and its substitution for fossil fuels, especially coal. Indeed, China has rapidly moved along the path of RE development and RE energy has played a major role in helping China meet its rising energy demand, improve its energy structure, reduce environmental pollution, stimulate economic growth, and create job opportunities.

Notwithstanding, the development of RE is affected by many uncertainties, such as natural conditions, varying fossil fuel prices, advancing electricity generation technology as well as national policy planning. Zhang et al. (2009) identifies several disadvantages associated with Chinese RE policy development including lack of coordination and innovation, unhealthy and incomplete investment and financing system, inadequate investment in technical R&D, etc. Indeed, RE development technology is constrained by high cost and difficulty of investment recovery, long and deferrable planning processes, high investment risks and uncertain returns, and the liberty of decision-makers to invest at their own timing. Hence, it is important for policy-makers to employ flexibility to adjust their policies as appropriate so that RE development policies meet policy targets. Flexibility here refers to the real options for making decisions about real assets. These decisions can involve adoption, abandonment, exchange of one asset for another or modification of the operating characteristics of an existing asset. This cannot be taken for granted in China since RE is still unable to compete with fossil energy and its development is well dependent upon the government's support. In order to overcome the investor inertia brought about as a result of difficulty in assessing investment risks as well as failure of many critical technologies to achieve success, the Chinese government continues to employ measures necessary for the development of RE. This makes it necessary for a study of this nature that would not only investigate the impact of these support schemes but also take initiatives in trying to quantify the value of the RE policy program in an attempt to find the optimal FIT solution. In so doing, it becomes imperative for an appropriate policy benefit evaluation model to be developed so as to measure the benefit produced by various policies and plans.

This contribution adopts a real option pricing approach to model the benefit of RE policy for wind power in China. Real options come in handy for the purpose in this study given that they "provide good evaluation model for assessing flexibility" (Martins et al., 2014). One must not also forget the uncertainties regarding demand, capital costs and construction costs inherent in RE development. According to Cruz and Marques (2013), flexibility in RE contracts would allow for tackling these uncertainties. The present study builds on the approach in Wesseh and Lin (2015) by considering the case of China and incorporating grid expansion costs of renewable energy into the model. This is important since the Chinese government target for wind energy will require expansion of the power grid.[4] A comprehensive review of real options application to the energy sector is presented in Fernandes et al. (2011).

It would be useful to mention game theory and draw on insights from game theoretical modeling given that an important aspect of negotiating towards environmentally friendly energy sources involves the selection of appropriate strategies. However, this goes beyond the scope of the present paper and is left for future research and model development. A discussion of these issues are documented in Perc and Szolnoki (2010) and Nax and Perc (2015).

The remainder of the manuscript proceeds as follows: Section 2 provides a brief description of China's RE potential and wind power tariffs. In Section 3, the model framework is described. Section 4 presents the scenario analysis and parameter estimation while Section 5 concludes the paper.

2. China's renewable energy potential and wind power tariffs

China is one of the world's fastest growing countries in multiple aspects and the government has recently set targets to be reached by 2020 for installed generating capacity. The two main sources of RE for China will be from hydropower and wind power. This section will provide a brief synopsis on the potential of Chinese RE as well as render some discussion on the government's support for wind power development; with focus on FIT and VAT reduction.

2.1. Renewable energy potential

China has an enormous untapped RE potential, and the government has recently realized these resources and is beginning to introduce measures to take advantage of that potential. This potential is against a backdrop of significant need for renewables. Following the adoption of the Renewable Energy Law in 2005 (which became effective on 1 January 2006), China's RE sector boomed, resulting in China taking a leading position globally, particularly in small hydropower, wind power, and solar water heating. By the end of 2008, China's annual RE use totaled some 250 million tons of coal equivalent (tce), excluding traditional biomass energy (including large hydropower). This represented 9% of total primary energy consumption, two percent more than in 2005. Hydropower use amounted to 180 million tce, and solar, wind, and modern biomass energy use totaled 70 million tce. (Ren21, 2009). A study by Research and Markets Ltd showed that between 2005 and 2030, China is planning to spend approximately 23% of global investment, about $1.2 trillion on RE. In the year 2006, a target was set by the Chinese government for RE to account for 15% share of total primary energy by 2020, up from 8% in 2006. There has been a revision of the target from two angles. First, recent target calls for a 15% share of final energy consumption. This adjustment has placed Chinese target on the same accounting benchmark as the European Union (EU), whose 2008 target calls for a 20% share of final energy by 2020. In a broader sense, the recent target of 15% final energy represents a higher amount of renewables relative to the 15% primary energy target. Notwithstanding, one needs to understand clearly that the second revision actually changed the scope from 'renewables' to 'non-fossil-fuel sources' including nuclear. In China, nuclear currently accounts for less than 3% share of final energy but is expected to increase by 2020. This puts a lot of complications on assessing the net impact on total renewables by 2020 of the target

[3] Simon Rogers and Lisa Evans, World carbon dioxide emissions data by country: China speeds ahead of the rest, The Guardian, 31 January 2011.

[4] For a comprehensive review of the literature on the application of real options to the energy sector, interested readers are referred to Fernandes et al. (2011) and Martins et al. (2015).