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The impact of Norwegian-Swedish green certificate scheme on investment behavior: A wind energy case study

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ABSTRACT

In order to encourage investments in the most cost-effective renewable energy projects, Norway and Sweden have implemented a joint green certificate subsidy system, where the certificates are traded on a common market. The policies applied in the two countries, however, are not identical and differ most notably by the deadlines for receiving the subsidy. From the policy perspective, the important question is how these differences affect investment behavior in the renewable sector. This paper investigates the impact of the green certificate subsidy scheme on the value of renewable energy investments from the perspective of both Norwegian and Swedish investors based on a wind energy case study. We find that the impact of the policy is greatest when the distinctive Norwegian investment deadline is approaching, making investment optimal for the Norwegian investor for a larger range of prices. The Swedish investor, having no deadline to meet, will be more reluctant to investing. Furthermore, we find that the possibility of a collapse in the green certificate price reduces the values of the investment options. Being able to learn about the likelihood of such a price collapse leads to a small increase in the values of the options.

1. Introduction

Investments in renewable energy are an essential part of a sustainable energy future. *At least 179 countries had targets for an increased share of renewable energy by the end of 2017* (REN21, 2016). *The European Union has a goal of covering 27% of the energy demand from renewable sources by 2030* (European Commission, 2017). *Furthermore, on 14 June 2018 the European Commission, the European Parliament and the Council agreed upon a new ambitious renewable energy target for 2030 of 32% with a clause for an upwards revision by 2023***.** In order to attract sufficient investments in renewable energy to meet these goals, various incentive schemes are implemented by individual governments. These policy schemes can have vastly different characteristics, depending on what the governments deem suitable. The goal of this paper is to assess how the differences in regulations in Norway and Sweden impact the investors' decisions.

The green certificate market is an example of a renewable energy incentive scheme, which entails that qualified renewable energy producers receive certificates from the government per MWh produced. Energy consumers, often in the form of utility companies, are obliged by law to purchase certificates corresponding to a certain percentage of total energy consumed over a year. Norway and Sweden, who are committed to the EU goal to increase renewable production, have both implemented a green certificate scheme where the certificates from both countries are traded on a common market. However, the regulations associated with the green certificates are different in the two countries. Most notably, projects must be operating before the end of 2021 in order to receive green certificates in Norway, while there is no such deadline in Sweden.

This paper presents a case study of a wind energy project eligible to receive green certificates, which is used to analyze the investments opportunities in Norway and Sweden. With uncertainty in both future electricity and green certificate prices, the investor must decide the optimal time to invest in the project. We analyze the investment decision from the perspective of both a Norwegian and Swedish investor, and investigate how the regulatory differences in the green certificate schemes affect the investment opportunities. Furthermore, we examine the effect of a possible collapse in the green certificate price, and how learning about the likelihood of the price collapse affects the investors.

In this paper, we apply the real options theory to analyze investment behavior in renewable energy projects. Such investments typically entail large and irreversible up-front costs. Additionally, the revenues generated are highly dependent on the electricity and green certificate prices over the lifetime of the project. The investment is thus exposed to considerable market risk (Fernandes et al., 2011). Being able to delay the investment enables the investor to wait for more information before

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undertaking the investment. This creates an additional value of managerial flexibility.

The net present value (NPV) approach, which treats the investment as a now-or-never decision, is commonly applied in capital budgeting. However, this approach fails to capture the dynamic nature of the investment problem and thus disregards the value of flexibility. Managerial flexibility implies that the investment can be undertaken at any time, where an irreversible cost is paid to receive the profit streams generated by the project. As a result, the characteristics of this investment opportunity resemble those of a time-dependent American call option. Therefore, it is more appropriate to value investments under uncertainty as financial options by applying real options methodology (Dixit and Pindyck, 1994).

The contribution of this paper is threefold. First, we analyze the implication of different subsidy policies in Norway and Sweden by explicitly accounting for the limited time of the policy scheme and country specific regulations. Second, we consider a perpetual option with a complex time-dependent value function, where changes occur at given dates. We find that neglecting the time-dependent features of the model, can have a large impact on investment behavior and option values. Third, we develop an algorithm to solve the real options model, using least-squares Monte Carlo simulation.

The following section presents the overview of the relevant literature. Section 3 provides background on the electricity and the green certificate market. Section 4 formulates our real options model. Section 5 quantifies the parameters used in the case study. Section 6 discusses the results of the case study and compares the Norwegian and Swedish investment opportunities. Section 7 concludes.

2. Literature

An increasing number of recent contributions study the effect of various support schemes on investment behavior. *Real options analysis has been demonstrated as a useful tool in the attempt to quantify the impacts of different policy schemes on power investment. When making policy recommendations it is important to understand the effect of firms' expectations about future framework conditions on their investment behavior. The strength of the real options approach compared to larger system analysis models, which consider energy systems from a society point of view, lies in the ability to address the actual decision makers' perspective. Focusing on central mechanisms and ignoring many of the secondary factors allows to develop smaller, more business relevant and transparent models. In the following we mention publications studying the effect of various support schemes taking a real options approach, that are most relevant to our study.*

Adkins and Paxson (2016) use a real options approach to derive the optimal investment timing for a renewable energy project with a subsidy. Different subsidy schemes are evaluated, where the subsidy is proportional to a stochastic price and/or a stochastic quantity. The occurrences of a sudden introduction or retraction of a subsidy are modeled by a Poisson process. Adkins and Paxson (2016) find that the type of subsidy scheme has a large impact on the optimal time of investment, where a retractable subsidy gives the strongest incentive for early investments.

Boomsma and Linnerud (2015) analyze how investors respond to market and policy risk, and consider several different support schemes. Market risk refers to the uncertainty in electricity and green certificate prices, while policy risk is defined as a possible change of the subsidy scheme, modeled as a Poisson process. Correlation between electricity and green certificate prices results in risk diversification, which speeds up investments. They find that the possibility of a retroactive termination of the subsidy scheme encourages later investments, while a non-retroactive termination encourages earlier investments.

Kitzing et al. (2017) evaluate a wind energy project under different support schemes using a real options model. They include different correlated factors in one stochastic process to model the gross margin. The investment threshold and optimal capacity is then found for a offshore wind energy case study in the Baltic sea. They find that there is a difference in profit margins and project size when evaluating the various subsidy schemes, where green certificates may lead to a higher profit margin and capacity.

Fleten et al. (2016) consider perpetual investment opportunities in hydropower projects before green certificates were introduced in Norway. They use a real options model to find the implied level of subsidies in each project, and investigate whether the investors base their decisions on the traditional net present value approach or the real options approach by conducting interviews. Even though the investors claimed to use the NPV criterion, their decisions were consistent with the real options approach. Their analysis shows that investors follow real options thinking, but the option values are not explicitly quantified.

Closest to our work here is Boomsma et al. (2012), who examine investment behavior under different policy schemes using a case study of a wind energy project in Norway. They employ a real options approach to analyze the optimal investment timing and capacity choice, with steel price, electricity price and subsidy price as the sources of uncertainty. The policy schemes they examine are feed-in tariffs and green certificates. In addition, they analyze the case where the support scheme employed can change with time, using Markov switching. Boomsma et al. (2012) find that both the timing and capacity choice differ with the various support schemes. Implementing a feed-in tariff encourages an earlier investment, while certificate trading encourages a larger project capacity.

This paper models investments in renewable energy in Norway and Sweden as an American option with a time-dependent value function. This is because the duration for which subsidies will be received depends on the time of investment. In addition, we consider a project with a finite lifetime. Close to this issue is Gryglewicz et al. (2008), who study the effects of uncertainty on finite-life projects. They find that uncertainty in some cases accelerates investments for finite-life projects. Testing the robustness of this finding, they also consider the case with a finite option life similar to our model. They conclude that their result proves robust to the finite life option case.

In most cases, there is no closed form solution to options with time-dependent values, therefore numerical methods must be applied (Moreno and Navas, 2003). *There is extensive literature on numerical methods to value of American options. Examples of well recognized approaches are among others* Schwartz (1977), Cox et al. (1979), *and* Boyle (1977). Schwartz (1977) *evaluates American options for discrete times and discrete stock prices, by approximating the partial derivatives in the Black-Scholes equation using finite differences. The boundary conditions at the investment deadline of the option are known, and the option value is calculated for a range of stock prices by backwards iterations.* Cox et al. (1979) *introduce a model where the underlying stochastic process starts at a given value, and follows a binomial process. The value of the option is then derived by iterating backwards using arbitrage arguments, i.e. risk neutral valuation.* Boyle (1977) *uses Monte Carlo simulation to estimate the value of an European option. This is done by simulating a series of stock price trajectories, which is used to determine the distribution of terminal option values. He finds that this is a simple and flexible method. The underlying variables can, for example, follow different types of stochastic processes. Also a jump process can easily be incorporated into the model.*

This paper follows the approach of Longstaff and Schwartz (2001) to estimate the value of the time-dependent option. Longstaff and Schwartz (2001) propose the least-squares Monte Carlo method to approximate the value of an American option numerically. The advantage of using this method is its flexibility. The Monte Carlo model captures the complexity caused by the regulations of the policy scheme, and allows to incorporate different features, such as, for example, learning effects in the investment cost and correlation in the underlying stochastic variables.