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Green electricity investment timing in practice: Real options or net present value?

Stein-Erik Fleten [a], Kristin Linnerud [b], Peter Molnár [a, *], Maria Tandberg Nygaard [a]

[a] Norwegian University of Science and Technology, NO-7491 Trondheim, Norway
[b] Center for International Climate and Environmental Research - Oslo, NO-7491 Oslo, Norway

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ABSTRACT

Using data from 214 hydropower projects in Norway we study whether investors in renewable energy projects exert discretion about the timing of investment decisions. We know from interviews with these investors that they do not use the real options model; however, we would like to learn whether they act consistently with this approach. These investments were expected to be supported financially through renewable policy schemes, but were not during the time period we consider. We calculate subsidies implied by investors' decisions using both real options and net present value models and compare these expected subsidies with subsidies observed in a very closely related market (Sweden). Our analysis indicates that our assumed real options model implies expected subsidies that align well with the ones observed. If we assume investors used a net present value model, the corresponding implied subsidies are close to zero. However, we know from interviews with investors that they did expect subsidies. We therefore conclude that the real options model is a meaningful descriptor of the observed investment behavior.

1. Introduction

A range of policies has been proposed to promote green investments [10]. In this context it is important to know how investors in green projects make investment decisions. This section provides insights into how such investors exercise discretion about investment timing. Specifically, we examine investment timing and subsidy expectations among investors in 214 small hydropower plants in Norway. By varying assumptions regarding their investment timing decision rules, we are able to infer an implied level of expected subsidy per project. In addition we also interview some of the investors about their expected subsidies. Combining this implied data with observed data and the fact that interviews indicate that subsidies are counted in project assessments we conclude that a real options model is meaningful in explaining actual investment behavior.

Investments in small hydropower plants in Norway are subsidized. There have been political discussions about subsidies since 2001. Small hydropower plants are characterized by a maximum installed power of 10 MW. Subsidies (certificates) were supposed to be given through a common market for Norway and Sweden, but it was not until 2011 that the subsidies were passed by law in Norway. The market in Sweden was up and running from May 2003. The subsidies are a response to the EU directives 2001/77/EC and 2009/28/EC promoting the use of renewable energy sources, where only the latter directive was binding for the Norwegian government. In 2010, Norway and Sweden agreed to increase the amount of new renewable energy by 26.4 TWh per year by 2020 using a common market for certificates Ministry of Petroleum and Energy (2010). By investigating licenses granted between 2001 and 2008 we precede the introduction of this market in Norway, which did not become active before 1 January 2012. The motivation for a common market, instead of two separate ones, was to achieve a more cost-effective development through higher liquidity, lower price volatility and lower political risk.

All those years of political discussion led to policy uncertainty for green energy investors. Dixit and Pindyck [11] state that "If governments wish to stimulate investments, perhaps the worst thing they can do is to spend a long time discussing the right way to do so". The Norwegian Minister of Petroleum and Energy promised a transitional agreement in a press release indicating that all who invested after 1 January 2004 would be included in the subsidy scheme once introduced [30]. However, a few years later

* Corresponding author.
E-mail address: peto.molnar@gmail.com (P. Molnár).

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negotiations with Sweden broke down. In December 2007 negotiations were restarted. In 2009, a second transitional agreement was promised by the Minister of Petroleum and Energy whereby only plants built after 7 September 2009 were allowed to receive certificates.

During this period, investors in Norway had varying expectations as to whether they would receive subsidies or not. Some were sitting on the fence waiting for a final confirmation. Others invested knowing that their projects would be profitable regardless of any subsidy scheme. Others again invested believing they would receive subsidies based on the promised transitional arrangement.

To model the investment decision when investors face two sources of uncertainty (the price of electricity and the amount of subsidies), a two-factor model is required. We use a real options model by Ref. [7]; who in turn rely on Refs. [2,19]. The advantage of this model is that, despite including two-factors, it can be solved quasi-analytically.

Even though investors may not be familiar with real options theory, they might behave in accordance with it. Over time, investors can develop decision rules which can be similar to what is predicted by theory. Kellogg [24] states that the real options theory is consistent with the existence of a strong incentive for firms to behave optimally. In his study of oil well drilling he finds that the cost of failing to respond to changes in the volatility of the price of oil can be substantial. Thus, there is good motivation for taking a rational approach to exercising one's options.

Real options theory, which is rooted in the financial options pricing theory of Merton, Black and Scholes [5, 28], was first introduced by Ref. [42]. McDonald and Siegel [27] discuss the value of waiting to invest in irreversible projects. There are numerous applications of real options to the energy industry. Tourinho [52] examines the option to wait in valuing natural resources. Brennan and Schwartz [9] use real options theory to evaluate natural resource investments and stress the importance of treating output prices as stochastic when there is considerable price variation. This feature distinguishes many natural resource industries, including electricity. Fernandes et al. [13,14] summarize research involving real options theory applied to renewable energy resources.

Previous work on policy uncertainty includes, amongst others [26,48] and [21] who examine investor behavior under an uncertain reform or tax law change. [6,12,53] discuss climate policy uncertainty and its implications for the choice of power generation technology. These studies generally find that uncertainty acts as a hefty tax on investment or as a risk premium for investors. Boomsma et al. [8] analyze investment timing and capacity choice for renewable energy projects under different support schemes, namely feed-in-tariffs and renewable energy certificate trading. They analyze a three-factor contingent claims (real options) model applied to a wind power case study. Adkins and Paxson [2] derive the optimal investment timing and real options value for a renewable energy facility with price and quantity uncertainty, in the presence of an uncertain government subsidy proportional to production. Boomsma and Linnerud (2015) [7] analyze the risk of a change in the current support scheme at some random future point in time, using a case study for an onshore wind power project. Fleten et al. [15] study decisions to shutdown, startup and abandon power plants and find that these decisions are consistent with the real options theory.

We apply our real options model to data obtained from a regulatory database[1] verified or updated through interviews. This data set was originally gathered in 2011 and used by Ref. [25]. We updated and extended it by contacting the license holders that had not previously responded or had not made an investment decision in 2011. The overall response rate was 99% (211 of 214 plants).

Empirical research on real options began with [44]. Further work includes Quigg , Moel and Tufano [40,46]. They all find empirical support for a model that incorporates the option to wait. Case studies on real options in the Nordic electricity market include Bøckman et al., Fleten et al. and Fleten and Ringen [4,16,17], which focus on investment timing and optimal capacity choice for small hydropower projects. Secomandi [51] provides empirical evidence in support of the use of the real options approach to price natural gas pipeline capacity. The effect of regulatory uncertainy on investment in renewable electricity generation under feed-in tariffs is studied by Ref. [47]; who find that uncertainty regarding future regulatory regimes delays or even reduces investment activity.

We take advantage of recent progress in analytical and quasi-analytical solution methods developed by Refs. [1,19,49] and [7]. However, to the best of our knowledge, there is almost no empirical research based on multi-factor real options models. Our main contribution is therefore the execution of an empirical study. The work closest related to this paper is [25]. We apply a simple analytical solution whereas their solution approach relies on least squares Monte Carlo simulation.

This paper is organized as follows. Section 2 explains the types of subsidies for renewable energy production that we study. Section 3 describes the investor's decision problem and the real options framework. Section 4 presents our data set. Section 5 discusses our findings. Section 6 concludes.

2. Tradable green certificates

The governments of Norway and Sweden have agreed to increase their countries overall renewable power production by 26.4 TWh per year by 2020. This amount equals more than half of the current consumption of all Norwegian households [43]. Certificates, a particular subsidy mechanism, address this goal by giving a financial incentive for investment. A detailed description of consumer-based tradable green certificate systems can be found in Refs. [3,22,23,41,50] and [18].

The market for certificates was established in Sweden in May 2003. From the beginning (2001), the intention was to have a common market for Norway and Sweden. However, negotiations broke down. Consequently, the market only included Sweden for many years. Subsequently negotiations with Sweden were restarted. A common market was finally agreed to in 2009, with a planned start-up in 2012. On 1 January 2012 Norwegian power producers and distributors joined in and a common market was formed. Table 1 presents a summary of publicly available information published by the Norwegian government during this period. It is reasonable to assume that investors were familiar with these statements, as they were debated extensively in parliament and in the media.

All Norwegian producers of new renewable energy are eligible to receive certificates, as long as they invest in new or upgraded small hydropower plants with initial development date between 1 January 2012 and the end of 2020. These investors receive certificates throughout 15 years.

3. Modeling the investment decision

The most prominent factors affecting the profitability of small hydropower plants are the revenues from selling electricity and certificates. Investing in a power plant requires a large up front construction expenditure. It consists of the plant's operational and maintenance costs. The revenue stream is therefore approximately determined by the selling price of electricity and certificates, and

[1] http://www.nve.no/no/Konsesjoner/.