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Market and policy risk under different renewable electricity support schemes

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ABSTRACT

Worldwide, renewable electricity projects are granted production support to ensure competitiveness. Depending on the design of these support schemes, the cash inflows to investment projects will be more or less exposed to fluctuations in electricity and/or subsidy prices. Furthermore, as renewable electricity technologies mature, there is a possibility that the current support scheme will be terminated or revised in ways that make it less generous or more in line with market mechanism.

Using a real options approach, we examine how investors in power projects respond to such market and policy risks. We show that: (1) due to price diversification, the differences in market risk between support schemes like tradeable green certificates, feed-in premiums and feed-in tariffs are less than commonly believed; (2) the prospects of termination will slow down investments if it is retroactively applied, but speed up investments if it is not; and, (3) this policy uncertainty may add a substantial risk to investments, especially in the first case where investors expect future curtailment of subsidies to affect new and old installations alike. We conclude the paper by discussing the division of risk between investor and government.

1. Introduction

At present, many renewable electricity projects are granted production support to ensure competitiveness. These support schemes can be either quantity-driven (the government sets the quantity of new renewable electricity production and lets the market determine the subsidy level) or price-driven (the government sets the subsidy level and lets the market determine the quantity). An example of a quantity-driven scheme is a quota system, in which green certificates are issued to producers in proportion to the volume of renewable electricity generated and traded to satisfy a quota for renewable electricity. Other common terms for the same concept are "renewable portfolio standard" and "renewables obligation". A feed-in scheme is an example of a price-driven scheme, and it can be implemented as either a tariff that replaces the electricity price or as a price premium paid on top of this price. As of 2013, 71 countries had implemented price-driven support schemes and 24 countries had implemented quantity-driven schemes.[1]

Depending on the design of these support schemes, the cash inflows to investment projects will be more or less exposed to fluctuations in electricity and/or subsidy prices. In addition to this market risk is the risk that the policy will change in the future. As renewable electricity technologies mature, governments may eventually want to terminate these support schemes or revise them in ways that make them less generous. The prospect of revised renewable electricity support schemes in the EU post 2020 may serve as an example. Most EU member states support the production of electricity using renewable energy sources by offering fixed feed-in tariffs for a given number of years. Because these feed-in tariffs have systematically exceeded the marginal costs of renewable electricity production, in 2012 the tariffs for new plants were cut significantly (e.g., Germany) or removed (e.g., Spain). Moreover, Spain, Belgium, the Czech Republic, Bulgaria and Greece have recently enacted retroactive adjustments to their feed-in tariffs,

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[1] Source: REN 21 Renewable Energy Policy Network for the 21st Century, GSR Policy Table. [http://www.ren21.net/RenewablePolicy/GSRPolicyTable.aspx, 16th of February 2014.].

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thereby reducing the profitability of already installed plants [7]. Furthermore, a greater influx of intermittent renewable electricity funded by fixed feed-in tariffs challenges the functioning of power markets. In a communication on the internal energy market published in November 2012, the EU Commission suggests that the support schemes are revised to better reflect market mechanisms.

We examine how such market and policy uncertainties affect investment decisions in the renewable electricity sector. The benchmark case is a situation in which investors expect the current support scheme to stay the same indefinitely. We assume that investors receive an electricity price and a subsidy payment for each unit of electricity produced. We allow for different combinations of deterministic and stochastic, geometric Brownian motion diffusion processes. The resulting models can be used to evaluate support schemes of tradable green certificates (both prices are stochastic), feed-in premiums (a stochastic electricity price and a deterministic subsidy payment) and feed-in tariffs (only a deterministic subsidy payment). We further assume that at some random point in time, the subsidy payment will be terminated, and that investors either expect or do not expect that this decision will be retroactively applied. This is modeled by including a Poisson jump process.

We formulate the investment decision as a real option problem in which the option to delay an irreversible investment decision has a value [8]. Our optimization problems are solved analytically using dynamic programming. The essence of this method is to compare the value of immediate investment with the expected value of delaying the investment decision. In our case, finding the optimal timing of an investment implies identifying the sum of the electricity price and the subsidy payment—the threshold revenue—that defines the border between the continuation region (in which the optimal decision is to wait) and the stopping region (in which the optimal decision is to invest). Uncertainty will affect the value of the option to wait and therefore this threshold.

Taking the perspective of an energy firm, real options theory has been used to derive the optimal investment and operative decisions under uncertain policy conditions. Most studies aim at correctly modeling the market-driven sources of uncertainty under specific policy schemes, like the carbon price process under the EU emission trading scheme (e.g. Refs. [10,12,15,19,26,29–31]. Some studies acknowledge that policy uncertainty could be modeled more drastically. This can be done by including stochastic jumps in the prices of policy instruments reflecting sudden changes in the policy target (e.g. Refs. [28,11], or by modeling the risk that a scheme will be introduced (e.g. Ref. [16], or that an existing scheme will be replaced (e.g,. Ref. [4] and Ref. [23] or simply removed (e.g. Refs. [2,3,24]. analyze policy uncertainty from a different perspective. They examine the uncertainties arising from public support for renewable energy and show how these uncertainties generate real regulatory options, not in the hands of the project's promoter, that reduce the net present value of the project. Finally, a few studies have used project-level data to test whether energy firms time their decisions as predicted by real options models under uncertain policy conditions [16,25]. These empirical studies find that uncertain policy and regulatory conditions significantly affect the pattern of development in the electric power industry.

The nearest papers apparently to ours are Boomsma et al. [4] and Ref. [2]. Boomsma et al. [4] examine investment timing and capacity choice under uncertainty in capital costs, electricity price and subsidy payments under different renewable electricity support schemes, and the possibility of a change from one support scheme to another. Using simulations they find that feed-in tariffs encourage earlier investments than feed-in premiums and green certificates [2]. derive the investment timing for a renewable energy facility with price and quantity uncertainty, where there might be a subsidy proportional to the quantity of production. Including the possibility that the subsidy is retroactively terminated, they conclude that a subsidy, even one having an unexpected withdrawal, will hasten investment compared to a situation with no subsidy. Like Boomsma et al. [4] we allow for more than one stochastic price process in order to realistically model the support schemes in use. We extend their analysis by allowing for correlation in prices to better investigate the risk of green certificates under different assumptions of price dependencies. In order to more clearly convey how individual price and policy uncertainties are related to the threshold revenue, we choose to derive the solution analytically following an approach developed in Ref. [1] and applied in Ref. [2]. Like [2] we examine the prospects of scheme termination; but we reach a somewhat different conclusion than Ref. [2] because we compare and contrast situations where investors believe this decision will be retroactively applied or not.

Real options studies that have derived analytical solutions for cases with two, possibly correlated, geometric Brownian motion diffusion processes include the classical reference by Ref. [20]. They examine the perpetual American option to pay a stochastic cost I against a project of stochastic value S. The option value function is homogenous of degree one and thus the investment rule is simplified to wait until S/I reaches a constant threshold value [1]. extend this model to a two dimensional real options problem where the option value function is not homogenous of degree one and, as a consequence, it is not possible to reduce the dimensionality down to one. More specifically, they examine the perpetual American option to pay a constant cost I against the net cash flow $S-K$ where both cash flows follow, possibly correlated, geometric Brownian motion processes. They develop an implicit representation of the investment boundary as the solution to a set of n simultaneous equations in $n+1$ unknown variables and parameters. By fixing one of the random variables, say S, they derive a threshold value for the other random variable K as a function of the first. We use their approach to examine a similar problem; to pay a fixed cost I against the sum of two, possibly correlated, price processes $S+K$. We show that the optimal threshold provides a non-linear relation between these two random variables.

Merton, (1976) [22] was the first to construct an option pricing formula where the value of the underlying asset is generated by a mixture of both jump and diffusion processes. Later real option studies have applied Merton's jump-diffusion model to processes involving sudden death, birth and change of the value of the underlying asset (e.g. Refs. [2,5,8,27]. Our study builds upon Ref. [8] who examine the prospects of an introduction or termination of an investment tax credit. In contrast to Ref. [8]; we assume that policy change is permanent; that is, once the support scheme is terminated, it is never altered. This is the same set-up as in Refs. [2,27]. However, by assuming that investors either expect or do not expect that these changes will be retroactively applied, we show that including jump mechanisms may increase but also decrease the value of waiting.

Our choice of price processes results in a threshold revenue with important characteristics. In cases where both prices are random, such as tradable green certificates, the optimal threshold revenue is a convex function of the observed electricity (subsidy) price. Consequently, as long as the electricity and subsidy prices are not perfectly correlated, part of their individual risks will be diminished through diversification when they are combined. One may argue that the electricity and certificate prices are negatively correlated (see Refs. [13,17], in which case the gains from risk diversification may be substantial. It follows that the market risk and therefore the threshold revenue may be higher but also lower under a quantity-driven scheme as compared with a price-driven scheme. By including a Poisson jump process, we add further characteristics to the optimal investment threshold. The prospects of termination