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Interfaces with Other Disciplines

The paradox effects of uncertainty and flexibility on investment in renewables under governmental support

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ABSTRACT

Given that companies have the flexibility to decide about size and timing of a renewable electricity investment, the existence of four paradox effects is proven: Only the type but not the amount of governmental support has an influence on the optimal capacity of a renewable electricity generating system. A decrease of governmental support over time may result in higher capacities of renewables installed on an industry level, at least on the short term. Likewise, higher uncertainty may encourage an expansion of these capacities. In contrast, technological progress may hamper the expansion of capacities. Finally, these four paradox effects are exemplified in a Germany-based case study regarding a photovoltaic project.

1. Introduction

The production of renewable electricity - at least today - is still more expensive than the production of conventional electricity. For example, the production of electricity in a lignite-fired power plant on average created costs of 0.0455 Euros per kilowatt hour in Germany in 2013 while the production of electricity from onshore wind power created costs of 0.076 Euros per kilowatt hour (Fraunhofer ISE, 2013).[1] Hence, in the short term governmental support is needed to give private investors or companies the incentive to invest into renewable electricity generating projects which may lead to learning curve effects, so that renewable energy technologies can become competitive in the long-term (Kumbaroğlu, Madlener, & Demirel, 2008).

Consequently, how to design an optimal support scheme for renewable electricity is a crucial question with great economic, environmental and social impact (Dinica, 2006). In particular, methods of multi-criteria decision-making will be needed as the governmental support of renewables does not only have an influence on the carbon emissions but also on the electricity price (and thereby on the economic competitiveness of a country), on the energy networks (Klessmann, Nabe, & Burges, 2008), on the landscape (Meyerhoff, Ohl, & Hartje, 2010) and on the speed of technological development (Davis & Owens, 2003). Furthermore, an optimal support scheme cannot be static but has to adapt to changes in the economic development as well as on technological progress to be able to meet its policy targets (Lee & Shih, 2010). For example, by decreasing the fixed feed-in tariff of renewable electricity over time the technological progress is taken into account in Germany (Klessmann et al., 2008).

Obviously, to determine an optimal governmental support scheme the decision-maker in a first step needs to know the investor's reaction on governmental support. Following economic intuition it should be expected that higher governmental support leads to a higher incentive to invest in renewable electricity projects as it increases the expected net present value of the project. Consequently, it is usually taken for granted that investors in countries with higher governmental support of renewables ceteris paribus implement more as well as bigger renewable electricity projects (Jacobsson & Lauber, 2006). Furthermore, due to risk-aversion uncertainty is generally seen to be a major investment barrier (Meijer, Hekkert, & Koppenjan, 2007).

However, only recently Linnerud, Andersson, and Fleten (2014) could empirically show that regarding renewable electricity investments under uncertainty only private investors decide according to the classical net present value rule while institutional investors act in accordance with the implications of the real option theory.[2]

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[1] The cost difference between conventional electricity and electricity from solar power or bio mass is even higher.

[2] In the following we will use the term "net present value" exclusively with the meaning of a static NPV, where the investor has only the choice to invest immediately or never. The dynamic net present value, i.e. a situation where an investor has the flexibility to wait with the investment but uncertainties are not considered, is seen as a special case of the real option approach. In particular, it is equal to the real option perspective in absence of any uncertainty.

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In particular, real options theory predicts that under uncertainty the possibility to wait with an investment until some of the uncertainty has resolved contains a flexibility value and can be valued analogously to financial options (Dixit & Pindyck, 1994; Trigeorgis, 1999).

So far, there exists already a small strand of literature which uses the real option framework to evaluate investment possibilities into renewable electricity projects under uncertainty.[3] In particular, investment possibilities in renewables are modeled, where the investor faces uncertainty - for example on the sales price of electricity- and can choose the optimal investment timing (Muñoz, Contreras, Caamaño, & Correia, 2011; Sarkis & Tamarkin, 2008). In Bøckman, Fleten, Juliussen, Langhammer, and Revdal (2008) investors can additionally choose the optimal investment size. The results show that it is optimal to invest as soon as the sales price of electricity meets a certain trigger value and that the optimal investment size is a function of the electricity price at the investment time.

In contrast to the literature discussed so far Boomsma, Meade, and Fleten (2012) focus on the influence of governmental support on renewable electricity investments. In particular, they analyze the investment decision of a risk-neutral investor under three different support schemes: renewable energy certificates, feed-in tariffs and no governmental support. Their results show that the choice of a governmental support scheme has a crucial influence on the investment behavior. In particular, they find that feed-in tariffs lead to earlier investment while renewable electricity certificates lead to larger investments. In accordance with previous results they furthermore show that investors should wait with their investment until a certain trigger is met and that the optimal investment capacity is a function of the earnings of the renewable electricity generating system, of its investment costs, and of the amount of governmental support. However, in the case of feed-in tariffs it is shown that the optimal capacity does not depend on the fixed feed-in tariff as long as immediate investment is not optimal.

In the following we will build on the model of Boomsma et al. (2012) but deviate in several points. First, we consider a price premium support scheme and governmental support on the investment costs instead of renewable electricity certificates. Second, we include the possibility of a reduction or an increase of governmental support over time but do not allow the government to switch from one support scheme to another. Third, we model the functional relationship of the investment level and the produced electricity as general as possible. Finally, we drop two assumptions of Boomsma et al. (2012) as we allow for a finite life-time of the renewable electricity generating system and for a correlation of the investment costs and earnings of the system.

As a result we can generalize the findings of Boomsma et al. (2012). As long as immediate investment is not optimal the optimal capacity of the system does neither depend on the ratio of the cost level and the electricity price at time of investment nor on the amount of governmental support. This holds for all governmental support schemes taken into account, i.e. for feed-in tariffs, for a price premium, for no governmental support and for a subsidy on the investment costs as well as for any combination of these support schemes. Furthermore, we can show that in contrast to the predictions of the net present value rule a decrease of the governmental support over time can lead to a higher propensity to invest and thus to a higher cumulated investment on the short term. Likewise, the influence of uncertainty on investment is ambiguous, too, i.e. higher uncertainty may also lead to more investment activity.

The rest of the paper is structured as follows. In Section 2 we set up the net present value and the real option model of an investment opportunity in a renewable electricity generating project under uncertainty and governmental support. Furthermore, the implications of the paper are proofed and summarized in eight propositions. In Section 3 the results of the net present value approach and the real options approach are compared and the effect of an increase of several model parameters is discussed. A focus is placed on four effects that seem paradoxical at first glance. In Section 4 those paradox effects are exemplified with the help of a case study regarding a possible investment in a photovoltaic project in Germany. Section 5 concludes and gives suggestions for future research. Finally, a list of all variables and parameters used in this article is provided in the Appendix.

2. Renewable electricity investments under uncertainty

We consider an investor who beginning in t_0 has the possibility to invest in a renewable electricity generating project – for example a wind park or a solar power plant – with a finite life time of $T > 0$ time periods. He has the flexibility to choose the size x of its investment, i.e. the maximum capacity installed. Certainly, the project will not generate its maximum capacity year round. For example solar power systems produce almost no electricity at night and less electricity in the winter than in the summer. Let $Q(x) \geq 0$ denote the expected amount of electricity produced per time period. Obviously, $Q(0) = 0$ and Q is strictly monotonic increasing in x. However, each additional unit, i.e. each additional wind turbine of a wind park or each additional photovoltaic cell, produces less electricity as the location of each additional unit of the investment project is getting worse, because under the assumption of optimality all better locations should already be used. Consequently, $Q(x)$ is concave and $\lim_{x\to\infty} Q'(x) = 0$. Furthermore, we assume Q to be continuously differentiable with respect to x.

The necessary investment costs are a multiple of the requirement $I(x) > 0$ of inputs, i.e. land rent, labor costs, material costs, as well as planning costs (all measured in the cost level of t_0), and the cost level $c(t) > 0$ of these inputs which varies stochastically over time. In particular, we assume that it follows the geometric Brownian motion

$$dc(t) = \alpha_c c(t)dt + \sigma_c c(t)dW_c(t), \;\; c(t_0) = 1, \tag{1}$$

with $\alpha_c \in \mathbb{R}$ as the expected exponential growth rate of the cost level, $\sigma_c \geq 0$ as its volatility and $dW_c(t)$ as the increment of a standard Wiener process with mean zero and variance equal to $\sqrt{dt}$. Obviously, the requirement of inputs increases with the project size, i.e. with the maximum capacity installed. Hence, we have that $I(x)$ is strictly monotonic increasing in x. Due to fix costs, i.e. $I(0) > 0$, and as each additional unit is getting cheaper, $I(x)$ is concave. However, as the material costs per unit cannot become lower than the producer price, we have that $\lim_{x\to\infty} I(x)' > 0$. Further, we assume that I is continuously differentiable with respect to x and that $\frac{Q'(x)}{I'(x)}$ and $\frac{I'(x)Q(x)}{I(x)Q'(x)}$ are monotonic in x.[4]

The earnings of the investment depend on the sales price $p(t)$ of each energy unit produced, which also varies stochastically over time. Again, we assume that it follows the geometric Brownian motion

$$dp(t) = \alpha_p p(t)dt + \sigma_p p(t)dW_p(t), \;\; p(t_0) > 0 \tag{2}$$

with $\alpha_p \in \mathbb{R}$ as the expected exponential growth rate of the cost level, $\sigma_p \geq 0$ as its volatility and $dW_p(t)$ as the increment of a

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[3] A good review is given in Martínez Ceseña et al. (2013).

[4] We need this condition to ensure the existence of the inverse function of $\frac{Q'(x)}{I'(x)}$ and $\frac{I'(x)Q(x)}{I(x)Q'(x)}$. Due to $\lim_{x\to\infty} Q'(x) = 0$ we get that $\frac{Q'(x)}{I'(x)}$ is strictly monotonic decreasing in x and that $\frac{I'(x)Q(x)}{I(x)Q'(x)}$ is strictly monotonic increasing in x.