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Optimal design of feed-in-tariffs to stimulate renewable energy investments under regulatory uncertainty — A real options analysis

Ingmar Ritzenhofen *, Stefan Spinler

WHU — Otto Beisheim School of Management, Kuehne Foundation Endowed Chair in Logistics Management, Burgplatz 2, 56179 Vallendar, Germany

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ABSTRACT

Feed-in-tariffs (FITs) are widely used as policy instruments to promote investments in renewable energy sources (RES). While FITs are often regarded as the most effective RES support scheme, regulators around the world continuously review their FIT schemes in the light of budget constraints and evolving policy goals. We assess the impact of adjustments to FIT schemes by quantifying the relationship between FIT levels, i.e., the guaranteed amount paid per quantity of electricity produced and the propensity to invest in RES. Through a regime switching model, we quantify the impact of regulatory uncertainty induced by regulators considering moves from a FIT scheme to a more market-oriented regulatory regime. Our focus is on market-independent, fixed FITs, the dominant scheme in Europe receiving increasing attention globally. We find that RES investment projects under market-independent, fixed FIT schemes become now-or-never decisions and derive FIT thresholds required to induce investment. We show that uncertainty regarding future regulatory regimes delays or even reduces investment activity for FIT levels near electricity market prices and high probabilities of an imminent regime switch.

1. Introduction

In 2011, renewable energy sources (RES) experienced an investment inflow of a total of 257 Billion USD globally, a sixfold increase over 2004 levels, with China, the United States (U.S.) and Germany being at the forefront of new investments (UNEP, 2012). This corresponds to an increase in renewable energy generation capacity by 100 GW in 2011, which is most pronounced in wind power as well as solar photovoltaic (PV) (REN21, 2012b). Many researchers attribute this investment boom to RES support schemes such as feed-in-tariffs (FITs) (Couture et al., 2010), through which governments attempt to achieve specific energy policy goals (IEA, 2011). RES support schemes have proliferated globally with more than 109 countries having adopted at least one or even multiple RES support schemes by early 2012 (REN21, 2012b). At least 65 countries and 27 states have adopted FITs, whereof 6 were newly enacted in 2011 and early 2012 (REN21, 2012b). This makes FITs the most widespread and a growing RES support scheme. Under a FIT scheme regulators offer guaranteed payments for electricity produced from RES for specified periods of time. These payments can take the form of market-independent guaranteed prices or market-dependent remunerations such as premia on spot market prices (IPCC, 2012). Other prominent RES support schemes include quota obligations or renewable portfolio standards adopted by 18 countries and 53 other jurisdictions (REN21, 2012b). Under such schemes, also denominated green certificate or renewable energy certificate (REC) schemes, regulators require producers, distributors, or consumers to produce or buy a certain amount of renewable electricity or corresponding certificates. Additionally, carbon emission allowance schemes such as the EU Emissions and Trading Scheme attaching a cost to carbon emissions contribute to supporting RES investments.

While numerous RES support schemes — in particular FITs — have proven effective in promoting RES investment (Shrimali and Baker, 2012), governments have continuously revisited existing RES support schemes, e.g., in order to adjust the speed and cost of RES investment. Held et al. (2006) show that many governments revised their RES support policies in the past to better achieve their initial goals of increasing RES capacity under cost efficiency while meeting strategic objectives such as high social acceptance of their policy. Prominent examples of such changes include the short-term-oriented production tax credits (PTC) system in the U.S., the revision of FITs for solar PV in Spain, as

* Corresponding author. Tel.: +49 261 6509 434.
E-mail addresses: ingmar.ritzenhofen@whu.edu (I. Ritzenhofen), stefan.spinler@whu.edu (S. Spinler).

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well as the current discussion of revising FITs in Germany. In all three cases, these (potential) modifications have a major impact on investment behavior as we show in Section 2.2.

The design features of RES support schemes, in particular FITs, and the regulatory uncertainty surrounding them have drawn increasing interest from researchers in recent years with numerous articles focusing on comparing FITs with other RES support schemes. For an overview, see Haas et al. (2004). While an increasing number of studies analyze specific design features of FITs from a policy maker perspective (Butler and Neuhoff, 2008), quantitative analyses of the impact of specific FIT design features on a firm-level are still lacking. Proven approaches to conduct analyses of RES investment decisions on a firm-level exist: real options are well-suited to capture the uncertainty inherent in these long-term decisions (Kumbaroğlu et al., 2008).

Our paper aims at quantifying the impact of FIT design features and regulatory uncertainty on the propensity of private investment into RES and at deriving policy design implications. We develop numerical solutions reflecting current and expected future revisions in FIT levels and potential changes in regulatory regimes. We conduct two numerical studies — one with FIT on the level of electricity market prices (Low-FIT Case), and a second with FIT levels significantly above electricity market prices (High-FIT Case). Thus, we contribute to explaining currently observed investment behavior and provide insights both to investors regarding optimal investment timing and regulators regarding the impact of specific FIT design features and changes to existing FIT schemes.

The remainder of this paper is organized as follows: In Section 2, we review related work both in the field of RES support schemes — in particular FIT and related regulatory uncertainty — as well as regarding real options applications to the energy sector. In Section 3, we describe the overall setting of the model and the detailed assumptions as well as introduce the modeling methodology. We then discuss numerical results for the Low-FIT Case in Section 4 and for the High-FIT Case in Section 5. Section 6 concludes and highlights areas for further research.

2. Theoretical background

2.1. RES support schemes and FITs

Since the first implementation of a RES support scheme in 1978 as part of the "National Energy Plan" of the U.S. government (Lesser and Su, 2008), researchers have been investigating the impact and functionality of different RES support schemes. REN21 (2012b), Butler and Neuhoff (2008) and Klein et al. (2007) provide an overview of the different policies in place. Haas et al. (2004) provide a survey of different RES support schemes employed in European countries, in which FITs are shown to be the preferable mechanism to promote RES investments. Couture and Gagnon (2010) summarize evidence that FIT schemes are considered the most effective RES support scheme. They compare different FIT design options and, on the one hand, find that market-independent, fixed FIT schemes increase investment security, lower cost of capital and thereby attract a diverse set of investors. On the other hand, market-dependent, premium price schemes increase market integration of RES capacity. Butler and Neuhoff (2008) compare RES support schemes in Germany and the United Kingdom (U.K.), assessing them based on two criteria: installed capacity and price of electricity. FIT schemes as employed in Germany are demonstrated to be significantly more effective in promoting the deployment of RES than the "Non-Fossil Fuel Obligation" and "Renewables Obligation Certificates" in the U.K..

Couture et al. (2010) and Mendonça et al. (2009) summarize the research around FITs and qualitatively provide an overview of FIT scheme design options. An increasing number of studies aim at analyzing specific design features from a policy maker perspective. On one hand, Kim and Lee (2012) investigate the investment speed into RES under different FIT payment structures such as fixed and premium FIT, finding that the optimal FIT payment structure depends on policy objectives and expected future electricity prices. Similarly, Shrimali and Baker (2012) find that under a standard FIT setting FIT policies should be either front- or back-loaded, depending on whether technology costs follow a "learning by doing" or "economies of scale" dynamic. Alizamir et al. (2012) investigate whether the amount paid per unit of electricity produced under a FIT regime should remain constant over time or monotonously increase or decrease. They suggest that FITs should be adjusted, so that the profitability of RES investments increases (decreases) over time for low (high) learning rates and RES penetration speeds. Lesser and Su (2008), on the other hand, emphasize the increasing pressure to review existing FIT schemes more drastically and qualitatively investigate the benefits of a new type of two-part FIT scheme. Overall, only few quantitative analyses of the overall impact of FITs on a firm level exist such as Boomsma et al. (2012). Comparing two RES support schemes, they find that under a fixed FIT scheme investment occurs earlier, while under a renewable energy certificate scheme bigger projects are realized. Analyses of specific design features of FIT schemes such as the FIT level and its impact on a firm level are lacking.

2.2. Policy uncertainty

When assessing investment in electricity generation capacity, correctly accounting for the risks[1] associated with these irreversible investments is crucial. As Jager et al. (2008) emphasize, regulatory risks are particularly relevant and have a major impact on project financing cost and thereby on the propensity to invest. This is in line with Yang et al. (2008), who suggest that policy risk has a significant impact on incentives for investments. In their discussion of different RES support schemes, Cleijne and Ruijgrok (2004) argue that "the largest risk a generator faces is the regulatory risk" (p. 61), as this can change market conditions fundamentally.

Recent developments in countries announcing to revise their RES support schemes, such as the U.S., Spain or Germany, confirm this assessment: in the case of the U.S., the regulator granted PTCs in most years since the establishment of the PTC scheme in 1992. However, in years without PTC support, RES capacity growth rates fell to less than 10% compared to a yearly average growth of 16% between 1981 and 2000 (Arent et al., 2011; EIA, 2009). In Spain, the sudden revision of the country's FIT scheme for solar PV in 2008 nearly halted the market, which had still added 2.6 GW of solar PV capacity in the previous year (Mendonça et al., 2009; Deutsche Bank, 2009). In Germany, ongoing discussions of a revision of the current FIT scheme have pushed the first investors to postpone RES projects (ICIS, 2013). In line with such observations, Wüstenhagen and Menichetti (2012) point to "the importance of risk in policy design" (p. 3) and highlight that "empirical evidence about how policies and their risk are actually perceived by investors and project developers has been limited so far" (p. 3). In this paper, we aim at addressing this gap by modeling the impact of FIT schemes on the propensity to invest. While these FIT schemes significantly reduce risk, policy uncertainty related to these schemes increases risks. We reflect this in our analyses through a regime switching model and thereby provide insights to investors and policy makers regarding the impact of such regulatory uncertainty and its implications for optimal policy design.

2.3. Real options in energy markets

Investments in power generation capacity are not only subject to regulatory uncertainty, but also future electricity price, investment amounts as well as commodity price uncertainty, amongst others. Given this uncertainty and the irreversibility of power generation investments, real options valuation represents a well-suited method to

[1] In line with current research in this field (see for example Yang et al. (2008) and Boomsma et al. (2012)), we use the terms "risk" and "uncertainty" interchangeably.