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Regulation and grid expansion investment with increased penetration of renewable generation

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ABSTRACT

The recent trend toward decarbonization led to crucial challenges for network operators and regulators in terms of network reliability and optimal grid expansion. In order to analyze the effects of rising shares of renewable energy sources on investment decisions in both, the generation and the transmission sector, the following article brings together the two sectors in a single real options framework. This allows us to derive the optimal timing of the production capacity expansion and the optimal transmission price which assures its connection. We find that an increasing penetration through renewables leads to investment postponement in both sectors, which goes along with increased systematic risk. However, we show that the negative effects on the transmission firm can be overcome by choosing an appropriate incentive system.

1. Introduction

Renewable energy generation is one of the most discussed topics in the recent European energy policy debate. Although, unbundling the electricity production from transmission and distribution allowed smaller companies to enter the market and helped boost renewable electricity investments, the European emission targets are still not reached. Based on the Kyoto Protocol and the EU's climate change package, the European leaders focus for the year 2020 on a 20% cut in emissions and a 20%

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increase in clean energy sources. However, this task is not trivial, as a major characteristic of renewable energy sources is that its output is hardly predictable and highly volatile. Hence, it challenges not only the owners of production facilities but also the downstream firms who have to handle the varying production output when transmitting or distributing the energy from the producers to the final consumers. In Northern Europe for example, the supply volatility from wind generation already causes significant grid management challenges that could be solved by further EU market integration and interconnector capacity investments (Pollitt, 2009).

The current debate on necessary investments into the transmission sector can be visualized by Germany for example. Here, the decentralized production, especially the distance between main producing and main consuming areas plays a crucial role for the investment needs as it draws the system towards its limit. Moreover, reduction in electricity produced via nuclear power plants and the increase in wind energy generation via offshore and onshore facilities (which will be even more distinct in the near future), underline the necessity of grid connecting points but also an overall improvement of the grid capacity in order to allow an adequate system operation in line with the quality standards established over the last few years. However, for most European countries, the situation is in a similar bad condition, such that it can be characterized by:

- the existing transportation facilities are close to the end of their economic lives and need to be replaced and
- the system needs to accommodate the growing amount of renewables that are often situated far away from the existing grid (Pollitt, 2008).

From the perspective of regulatory economics, the interdependency between the producing sector and the regulated transmission and distribution market as well as the impact of renewable energy sources (further denoted as RES) and the changing production mix on the efficiency and effectiveness of regulation are the most important questions that have to be addressed in the near future. Therefore, the interactions between producers and transmission or system operators as well as regulators lie the center of the following article. In particular, we focus on the interdependencies between investment decisions of producers and transmission or distribution operators when they are confronted with increasing shares of production coming from renewable energy sources. For this, we derive a dynamic real options model in which both investment decisions can be analyzed simultaneously, such that the overall electricity system is appropriately developed and supplemented. Based on this, we are also able to deduce optimal regulatory actions that assist sustaining the network security.

Our paper makes several contributions. First, we show that increasing shares of renewables within the market go along with increasing volatility and, thus, delay further investments in the production sector. This investment postponement can only be overcome by regulatory actions that set appropriate feed in tariffs or incentives. Additionally, we show that these uncertainties also transform into risk implications for the firm that my increase a firms' cost of capital and thus, further accelerate the previously mentioned consequences. Finally, our paper is one of the few real options applications that bring the transmission and production investment side via a regulated market framework together.

The article is organized as follows. Section 2 gives a detailed literature review on real options and its application for regulated markets. In the next section the regulations and the considered market framework are described in detail. Section 4 describes the model and derives the optimal timing of the production and transmission investments. This section furthermore computes the optimal transmission price and also sheds light on the value and risk implications of these investments. Section 5 analyzes the case of discrete production capacity expansion by offshore wind power and is based on European data. Finally, Section 6 summarizes the findings and concludes.

2. Literature

The article in hand is one of the first studies that bring the investment into grid and generating facilities together. Hence, we can distinguish two different strands of real options literature: studies dealing with energy production facilities, and studies related to transmission, solely. Invest-