Energy Economics 90 (2020) 104849

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Competitive and risk-adequate auction bids for onshore wind projects in Germany

Chris Stetter *, Jan-Hendrik Piel, Julian F.H. Hamann, Michael H. Breitner

Information Systems Institute, Leibniz Universität Hannover, Königsworther Platz 1, D-30167 Hannover, Germany

ARTICLE INFO

Article history:
Received 23 August 2019
Received in revised form 28 May 2020
Accepted 1 July 2020
Available online 10 July 2020

Keywords:
Renewable energy auctions
Competitive bidding
Adjusted present value
Debt service cover ratio
Risk analysis
Onshore wind energy

ABSTRACT

In recent years, auction mechanisms have gained in significance in the context of renewable energy deployment. An increasing number of countries have adopted auctions for the allocation of permits and financial support for renewable energy projects, thereby increasing competition among project developers. As a result, profit margins have decreased significantly while sensitivity to risks and uncertainty has increased. The adequate quantification of bid prices is a key challenge. We present a modeling approach to determine competitive and risk-adequate auction bids. The contribution of this paper is an improved method for quantifying marginal cost, which is the minimum sales price per unit of electricity through which the investment criteria of all project stakeholders are fulfilled. In our financial model, the risk-adequateness is determined through the investment criteria of equity investors by means of the adjusted present value, and those of debt investors by means of the debt service cover ratio, through Monte Carlo simulations. The resulting marginal cost serve as the starting point for strategic bidding optimization, regardless of the pricing rule in the contemplated auction design. To demonstrate the integrability of our mathematical model with strategic bidding optimization, we check its applicability in a case study, which shows how a German project developer should bid to realize an onshore wind farm project. We show that our model enables the quantification of bid prices that are both competitive and risk-adequate.

1. Introduction

Policymaking in various countries has focused, in particular, on accelerating the deployment of renewable energies through extensive investment incentives and financial support policies that have low market exposure (Abolhosseini and Heshmati, 2014). These support policies provide favorable investment and financing conditions due to high revenue certainty and stability (del Ro and Linares, 2014; Huntington et al., 2017). The consequential expansion of deployment has led to a highly competitive situation for wind turbine manufacturers and, therefore, rapid technological efficiency improvements (Butler and Neuhoff, 2008). However, these policies have also led to costly market distortions and significant subsidy costs resulting from the high level of remuneration induced by a lack of competition in project markets (Huntington et al., 2017). While technology improvements have constantly reduced the prices of wind turbines and solar systems (Taylor et al., 2015), these support policies have been ineffective in appropriately translating the cost reductions into lower financial support (del Ro and Linares, 2014). Thus, today, policymaking is shifting toward more market-based support policies, for example, feed-in premiums, auctions, quota obligations, and investment aid (Adib et al., 2016; European Commission, 2013). In particular, auctions have been implemented increasingly in recent years (Winkler et al., 2018).

Auctions introduce competition among project developers for procurement rights or remuneration contracts and are intended to manage the expansion of deployment via predefined tender volumes (del Ro and Linares, 2014). Increasingly, auction mechanisms determining feed-in tariffs or premium levels are the focus of policymaking (del Ro and Linares, 2014), for example, in Germany (Hake et al., 2015), Brazil (Ellabban et al., 2014), Mexico (Alpizar-Castro and Rodrguez-Monroy, 2016), and South Africa (Eberhard and Naude, 2016). Under these mechanisms, project developers compete by specifying their desired level of remuneration and only the most competitive projects are granted funding (del Ro and Linares, 2014). When correctly implemented, this prevents the overcompensation of project developers (del Ro and Linares, 2014; Abdmouleh et al., 2015; González and Lacal-Arántegui, 2016) and is likely to result in comparatively low

---

Abbreviations: **APV**, Adjusted present value; **CAPEX**, Capital expenditures; **CAPM**, Capital asset pricing model; **CDF**, Cumulative distribution function; **CVaR**, Conditional Value at Risk; **DEP**, Depreciation; **DSCR**, Debt service cover ratio; **DSC**, Debt service capacity; **EBIT**, Earnings before interest, and taxes; **EBITDA**, Earnings before interest, taxes, depreciation, and amortization; **EEG**, Renewable Energy Sources Act; **FCF**, Free cash flow; **INT**, Annual interest payment; **KPI**, Key performance indicator; **LCOE**, Levelized cost of electricity; **MC**, Monte Carlo; **MCP**, Market clearing price; **NPV**, Net present value; **OPEX**, Annual operating expenditures; **PDF**, Probability density function; **PERT**, Project evaluation and review technique; **TAX**, Taxes on EBIT; **VaR**, Value at Risk; **WACC**, Weighted average cost of capital.

* Corresponding author.
E-mail address: stetter@iwi.uni-hannover.de (C. Stetter).

https://doi.org/10.1016/j.eneco.2020.104849
0140-9883/