# Renewable Energy Technologies and Electricity Forward Market Risks

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This paper analyses how the introduction of the same renewable technology at different parts of the electricity supply chain has different price formation effects on wholesale power markets. Across the world, the integration of renewable energy sources in power systems is taking place in various ways and paces, resulting in a fierce ongoing political combat between the various technologies. The forces at play are driven by the decarbonization of generation portfolios, moving conventional power plants toward intermittent renewable technologies, as well as the decentralization of demand and control. Digital advances in the form of smart meters and IoT devices have created opportunities for tech-savvy end-consumers and prosumers to become increasingly, but not entirely, independent from the grid.

This paper studies how the integration of renewable technologies at different parts of the supply chain may result in information asymmetries between retailers, where distributed production behind the meter may complicate prediction accuracy, and producers, who are confronted with uncertainty over intermittent production profiles. We thereby focus on the forward risk premium between short-term forward and spot electricity markets, rather than the spot market processes by itself, as the premium reveals the balance of risk-averse behaviour between producers and retailers.

We propose a multi-stage competitive equilibrium model, modelling the supply and demand side in a closed system with intermittent production capacity at both sides of the market. We find that forward prices are biased predictors of spot prices, with the emergence of risk premiums accounted to heterogeneous hedging needs of producers and retailers in relation to uncertainties from demand, intermittent production profiles and distributed production by end-consumers. We for a multi-factor propositional framework, relating the behavior of the forward premium, next to the role of technology as specified in our model, to fundamental, behavioral and dynamic market effects.

We validate the model by analyzing data in short-term forward and spot power markets in California and the Great Britain. Both markets have recently experienced a technology shift from conventional to respectively large-scale renewable energy production (e.g. wind and solar farms) and distributed renewable energy sources (e.g. rooftop solar). The results show evidence for large-scale and distributed renewable energy technologies to oppositely affect the forward premium, as asymmetries in the ability to predict and gather information on renewable energy supply heterogeneously influence risk preferences of producers and retailers.

Providing important insights on the distinctly different market price effects of renewable technologies and the role of prediction accuracy in short-term power markets, this study suggests a need for awareness by policy makers in evaluating the role of both large-scale and distributed energy sources on price formation. To the extent that the different effects of distributed and large-scale renewable facilities are due to intermittency risks being carried by retailers and generators

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respectively, at different ends of the supply chain, improved information transparency would help efficiency, but that would only be part of the matter. More crucially, the structural effect of small scale installations influencing retailer demand and large scale farms influencing generator production remains, and may well be a motivation in the future for increased vertical integration in the market. As competition authorities monitor the causes of mergers, technological insights from this study may therefore add a new awareness to their deliberations.