Strategic Trading and Hedging in Sequential Electricity Markets with Increasing Renewable Energy

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The liberalization of electricity markets and the ongoing integration of renewable energy sources have a dramatic impact on power prices. The integration of wind and solar power introduced more low marginal costs suppliers to the market, as no fuels are needed to produce electricity, and power prices decreased as a result. On the other hand, intermittent supply from wind mills and solar panels in combination with the non-storability of electricity and price inelastic demand cause spot prices to fluctuate heavily. Increased competition, lower prices and more price volatility have drastically changed operations in electricity markets.

The above motivates power agents to use forward contracts to mitigate risk. Pricing forward contracts, however, is tedious, relating back to notions of risk related hedging pressure, strategic behavior and market technology set-up. Moreover, the economics of wind and solar power are very different from conventional power. Applied to markets operating under such heterogeneous operational constraints, empirical literature has presented mixed findings without clear economic interpretations with respect to the behavior and sign of the forward premium. In this work, an experimental design allows us to implement variations with a high degree of control and test decision making in sequential markets with a varying production technology mix under truly ceteris paribus conditions. We validate our findings empirically for the German power market, recently experiencing a sharp increase in intermittent production capacity. Analyzing these systems, relationships between market participants, technology adaption and changes to market behavior provide key ingredients for devising a robust well-functioning electricity market, its design and its governing policies.

Sequential Power Market Simulation

We conduct a series of experiments in order to evaluate the influence of a varying renewable technology mix on hedging and strategic trading in sequential power markets. We set up a market in which participants can trade the commodity electricity in a simulated wholesale environment for a sequence of 20 trading sessions. Each session covers two periods: a forward and a spot market. Participants represent single agents, acting as power producers selling electricity on the wholesale market while hedging against risks from demand uncertainty and variable output. We distinguish between 3 different market set-ups. First, “non-intermittent” (NI), with exclusively producers that bear increasing marginal production costs when their output increases, reflecting the more traditional set of power producers. Second, “low market share intermittent” (LI), with both non-intermittent and intermittent producers. The latter guarantee 33% of the market capacity and do not bear any marginal costs for producing electricity, representing renewables power sources that are dependent on weather conditions like solar radiation or wind speed. The production capacity of zero-cost producers is represented by a random variable, and can be interpreted as a production constraint by nature. Lastly, in “high market share intermittent” (HI) the share of high- and zero-cost producers is inverted, simulating future markets which aim to implement a large share of renewable energy sources. The 3 market structures or treatments were presented in a counterbalanced order over the set of 5 experiments, each consisting out of 25 simulation rounds. Subjects were recruited amongst energy finance experts and energy management students of the Erasmus University Rotterdam, Netherlands with a thorough understanding of energy markets.

Results indicate the well-known negative effect of renewable energy on forward (day-ahead) prices. Mean spot prices vary across markets but we find evidence for significantly increasing volatility in spot markets with a higher renewable capacity share. We observe a clear difference between non-intermittent and intermittent producers’ trading behavior, most significantly represented by the fact that non-intermittent producers (are forced to) move from the forward market to the spot market when the share of intermittent producers increases. We find evidence that the merit order effect negatively pushes profits in the forward market of conventional power plants. Non-intermittent producers, however, do seem to gain from trading in the spot market, with higher profits made with more intermittent sources on the market. This indicates that there is a demand for flexible spot production with more intermittent production in the market, i.e. a convenience yield for flexibility in the producer’s portfolio. Figure 1 visualizes this effect, showing density distributions of non-intermittent producers’ profits in forward and spot markets for all market treatments and experiments. The figure indicates that in all HI forward markets, lower and more similar profit profiles are obtained but there is also less room for strategic behavior. Contrarily spot market profits increase drastically and follow smoother profiles than in NI and LI, indicating lower risks for non-intermittent producers strategically trading in the spot market.

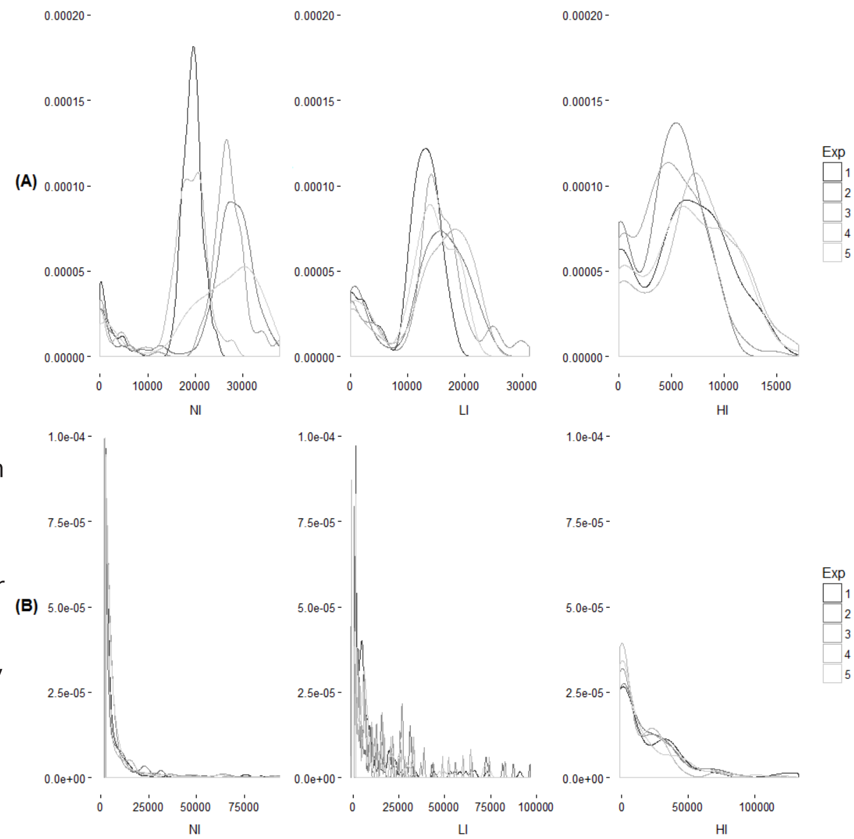

Figure 1: Profit distributions of non-intermittent producers in non-intermittent market (NI), low intermittent market (LI) and high intermittent market (HI) for the forward market (A) and spot market (B).

Empirical Validation in German Short-term Sequential Markets

In electricity markets with increasing intermittent capacity, risk-sharing becomes more important and short-term financial instruments gain liquidity. In the context of the German power market, new short-term market constructs have been put into place to accommodate this transition. As weather dependent intermittent production can only be accurately predicted for a limited time horizon, we compare the effect of high shares of renewable energy on trading in day-ahead, intraday and real-time imbalance power markets.

Results indicate the merit order effect of a negative effect of intermittent power sources on day-ahead power prices. As closer to real-time the time granularity of the traded product increases, intraday and real-time prices experience a pronounced hourly jump with a recurrent hourly fluctuation around the day-ahead forward price. We indicate that where the day-ahead auction may allow traders to anticipate average hourly variations for the next day, the intraday and real-time markets give an opportunity to trade into the within-hourly differences. As such, with prediction accuracy on both production and demand increasing closer to real-time, the hourly jump effect is propagated through markets moving closer to real-time.

Next to this microstructure effect, the real-time imbalance market shows evidence for the strategic effect indicated above. For the German imbalance market, prices are determined and known to market participants ahead of real-time gate closure. Indeed, bidding for the reserve market takes place day-ahead and as such, prices are subject to day-ahead predictions of intermittent production levels. Controlling for imbalance, we find that real-time imbalance prices exhibit larger spikes, i.e. negative prices become more negative and positive prices become more positive, at those moments when day-ahead predictions indicate high shares of intermittent production. This strategic behaviour of price setting in real-time imbalance markets indicates evidence for the above discussed convenience yield for flexibility.

Concluding Remarks

With the growing share of sustainable energy sources, electricity markets experience increasing uncertainty and volatility. Key in the transition process is to ensure that markets provide adequate price signals for assets and investments, ensuring security of supply in an efficient and sustainable way. Future market design must be inherently robust, as markets and financial stakeholders may create instabilities, potentially leading to huge losses and black-outs, while the bill is eventually paid by the customer.

The technology varying risk-premium influences policy practices for current market structures, which aim to integrate renewable energy in an efficient way. Influenced by market conditions as flexibility, producer set up and risk aversion, relative performance of spot and forward markets is bound by the markets' operational constraints. We find that the various operational characteristics of producer technologies affect commodity trading and thereby affect market prices, often not desirable from a sustainable efficient market point of view. This work paves the way for policy makers to examine the implications on existing market structures and their participants' strategic space, considering alternative market designs both from market and individual perspective in order to not only integrate large shares of renewable energy in existing electricity markets but also achieve it in a sustainable manner.