Varying impact of intermittent supply on hourly day-ahead electricity prices

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Overview

In the context of increasing concerns surrounding the climate change debate and having most power system going through a transition phase from fossil fuels to renewables, understanding the impact of renewable intermittent output on wholesale electricity prices captured the attention of researchers in the energy markets over the past decade. There is a vast energy economics literature which demonstrates that the output of wind and/or solar supply impacts the wholesale electricity prices by influencing their volatility, by changing the tails fatness of their distribution function and by reducing their average levels. This present piece of research builds on the previous literature by showing that the speed with which intermittent supply output is reducing the day-ahead electricity prices is not constant across the quantiles of the electricity prices, being more pronounced on the lower and the higher day-ahead price quantiles. Using a model based on fundamentals and a quantile regression approach, we investigate the German and the Spanish hourly day-ahead electricity prices and supply mix between January 2015 and June 2019, showing that the share of intermittent output is decreasing faster the day-ahead electricity prices at the very low and at the very high day-ahead price quantiles than elsewhere on the distribution of day-ahead electricity prices. This result enriches the energy economics literature on electricity markets as it is acknowledging that intermittent supply has a varying impact on power prices. This result has also an important practical value for market players (especially for storage facility operators) that are using price prediction intervals in their bidding strategies. As we show in the paper, including in the prediction interval models the information that intermittent supply decreases electricity prices with a different rate in the extreme low and extreme high price quantiles then elsewhere, leads to price interval forecasts that better resemble the actual distribution of day-ahead prices. When compared to ordinary least squares models, the proposed quantile regression approach allows for a greater variation in the size of the forecasted price intervals and, in the same time, it also permits for more extreme prices to be comprised in the predicted intervals. This pattern stays constant regardless of the choice of using a linear or a non-linear model. Such a variation predicted by the quantile regression approach is in line with what we observe in the Spanish and the German day-ahead markets past data. The evidence acquired throught the analysis leads us to conclude that, when predicting day-ahead electricity price intervals, using a quantile regression model is a more suitable approach compared to ordinary least squares models.

Methods

The analysis proposed in this paper covers two main areas. The research starts with an initial part where the varying effect of the intermittent supply on day-ahead electricity prices is demonstrated and is followed in the second part with an analysis and discussion of the implication of this result. For both parts of the paper we make use of quantile regression models. First introduced by Koenker et al. (1978), a quantile regression model as we know it today can locate the effect that independent variables have on the dependent one not only on average level but also at each quantile of the distribution of the dependent variable. This aspect provides important advantages for models where one or more independent variables do not have a constant impact on the dependent variable. While the use of quantile regression in electricity markets is not new, to our knowledge this technique was not used specifically for looking at the varying impact of intermittent supply on electricity prices. The present analysis uses a quantile regression model that is based on the fundamentals of day-ahead electricity prices. Due to the space restrictions of this abstract, we limit ourselves to mentioning that the model used takes into account as independent variables the share of the intermittent supply (wind and solar share) along with proxy variables for total demand (total load) and for the marginal cost of non-intermittent supply (lagged price). Demand and the marginal cost of non-intermittent supply (or the level of the underlying fuel prices) are the two variables that are alone contributing the most to wholesale electricity price formation. Therefore, not including them in the model would lead to the model not being able to isolate the effect of intermittent supply on electricity prices. Detailed explanation on each model choice is presented in the full version of the paper. Using this model, we investigate the day-ahead price behaviour at each day-ahead price quantile. Through this approach we are able to observe if the impact of intermittent supply is constant or not across all day-ahead price levels. Before concluding the first part of the analysis, we disicuss and run robustness checks aimed to investigate if the results represent a generalizable truth regarding the impact of intermittent supply on day-ahead electricity prices or if those results can be dependent on structural changes in the supply mix, market selection or model selection. In the second part of the paper, once the varying impact of the intermittent supply on the day-ahead electricity prices is

proven, we test the practical utility of this information and we discuss the general implications of it. The application that is investigated in the paper focuses on forecasting day-ahead electricity prices intervals (with a 95% confidence level). Accurate electricity price intervals forecats can help storage providers in signaling moments when price levels are expected to be very low (best moments to charge storage facilities) and moments when prices are expected to be very high (best moments to discharge storage facilities). If the impact of the intermittent supply on power prices is not constant, when looking to forecast day-ahead price intervals, models that assumes a constant effect of the independent variables across the distribution of the dependent variable, models such as ordinary least squares, should generate less accurate estimates. With this in mind, the paper forecasts day-ahead hourly price intervals using the quantile regression approach and compares them to price interval forecasts obtained by using the ordinary least squared approach. To check how well these two approaches predict day-ahead hourly price intervals, we compare the forecasts with the price confidence intervals that can be observed in the actual past data on Spanish and German day-ahead markets. In the process of comparing among the selected models,we choose to separate the observations in a matrix of subsamples categorized by the level of total demand and by the share of intermittent supply. This subsampling method allows us to isolate moments in time that exhibit similar load and intermittency characteristics and to examine how the predicted price intervals behave in comparison to the actual data in each subsample.

Results

The results of this paper confirm the fact that intermittent power supply has a varying impact on the day-ahead electricity prices. In both the Spanish and the German markets, the results show that at the higher and the lower day-ahead price quantiles an increase in the share of wind and/or solar supply lowers much more the day-ahead prices than in the other price quantiles. Through our robustness checks, we show that regardless of the market chosen or the model chosen the aforementioned result still holds. When looking into the potential applications of this information on forecasting price intervals, the results suggest that quantile regressions forecasts, as opposed to ordinary least squares forecasts, resemble more the patterns observed in the actual distribution of day-ahead historical price data. Through the subsampling method chosen, we can see in the actual price data that in moments with very high demand and very low share of intermittent output, the average size of the price intervals is very high (compared to moments with an average load). The higher size of the price confidence interval in those moments is driven mainly by the occurance of frequent extreme high price spikes. The same high average size of the price intervals is seen in the actual data when the markets are situated in the opposite state: moments with very low demand and very high share of intermittent supply. In this situation, the higher price interval size is driven by the frequent extreme low price spikes. When employing quantile regression and ordinary least squares approaches to predict price intervals in these extreme moments, the results clearly show that only the quantile regression models are providing for the required flexibility. Even when considering non-linear models, ordinary least squares methods are rigid in forecasting price intervals as they do not allow for higher price interval size when extreme are expected to occur. The flexible size of the price prediction intervals forecasted by quantile regressions is apprearing because the quantile regression models allow in their forecasts for more extreme prices (both high and low spikes) to be included in the predicted price intervals. As day-ahead electricity prices exhibit frequent price spikes, the quantile regression model replicates better this pattern. While we do not aim through this paper to provide a perfect price intereval forecast model, the results show that by considering into a price forecasting model the differentiated impact level of intermittent supply on power prices, the price interval forecasts are resembling more the actual patterns of historical day-ahead prices.

Conclusions

With the rise of wind and solar output in most markets, the share of intermittent supply becomes an important element in establishing electricity prices. Thus, a better understanding of the impact that intermittent supply has on electricity prices has an important value. This present paper builds upon the knowledge that we already have from the literature by proving that the intermittent supply output has a varying streght in reducing the day-ahead electricity prices. Thinking beyond the academic relevance, the information that this paper provides can help market players in better forecasting electricity price intervals. While for traditional suppliers and retailers, the technique of forecasting day-ahead prediction intervals might not play a central role in their bidding strategies, for owners of storage units, such forecasting strategies can be essential. Players in electricity markets using storage facilities are undertaking a unique role in the power system, the role of providing flexibility to the market, by shifting load from moments with too much available supply compared to demand to moments with too much demand compared to available supply. In order to be profitable to play this role, the storage facility owners can make use of strategies that signal the moments when, with a certain confidence level, electricity prices are expected to be very low (in order to charge the batteries) or very high (in order to discharge the batteries). Using the information that this paper provides, the fact that wind and solar output is decreaseing with different speeds the day-ahead electricity prices at the extreme low and high price quantiles, we show that quantile regression models present a more adequate tool than ordinary least squares approaches when forecasting electricity price intervals. This approach can help storage facility operators in optimizing their bidding strategies.