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 systems going through a transition phase from fossil fuels to renewables, understanding the impact that variable renewable energy (VRE) output has 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 upon the previous literature by showing that the speed with which the share of VRE supply is reducing the day-ahead electricity prices is not constant across the quantiles of the electricity prices, being significantly stronger in the moments when the power markets are challenged the most, at the lowest and highest price quantiles. This conclusion was reached by employing a quantile regression with fixed effects approach on hourly German and Spanish day-ahead electricity data between January 2015 and June 2019. Besides enriching the energy economics literature, the results of this paper can have also an important practical value for market players, especially for storage facility operators, that are using price intervals forecasts in their bidding strategies. As the paper shows, including in the price interval prediction models the information that the share of VRE supply has a varying effect on day-ahead electricity prices, leads to price interval forecasts that better resemble the actual distribution of day-ahead prices.

Methods

To test the changing effect of VRE supply on day-ahead electricity markets, a quantile regression (QR) with fixed e ects model is used. The research starts with an initial part where the varying effect of the intermittent supply on day-ahead electricity prices is demonstrated and follows with an analysis and discussion over the implication of this result. 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 and it is the first time when it is used in a panel data structure. 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 VRE 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 various day-ahead price quantile. Through this approach we are able to observe if the impact of intermittent supply is constant or not across day-ahead price levels. Further, the paper tests the practical utility of this information and discusses 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, 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 share of VRE supply 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 towards the extreme low 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. Also on the higher end of the day ahead quantiles, we observe a similar effect but less pronounced, especially on the Spanish market. When looking at applying 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 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 higher 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. Those moments, moments when the electricity prices are challenged the most, are also the moments when storage facilities could help the system the most. When employing quantile regression and ordinary least squares approaches to predict price intervals in these extreme moments, the results 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 prices are expected to occur. 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 VRE 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 many power markets, the share of VRE supply becomes an important element in establishing electricity prices. Thus, a better understanding of the impact that VRE 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 share of VRE supply has a varying strength in reducing the day-ahead electricity prices, with significantly higher strength in the moments when the power markets are less flexible than otherwise. When total load is high and the share of VRE supply is low or when the total load is low and the share of VRE supply is high, extreme low, and respectively, high power prices are expected to occur. This paper proves that in those moments, a change in the share of VRE supply has a much higher impact in lowering electricity prices than in other moments in time when a power system is more flexible. It is worth mentioning that both in the Spanish and in the German day-ahead market, with the introduction of more VRE supply, the market becomes more inflexible on the low end of the power price distribution, when an increase in the share of VRE is having the strongest negative impact on the day-ahead 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 power 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 (from batteries to hydro pumped), 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). The paper shows that models that incorporate the information that the share of VRE output is decreasing with different speeds the day-ahead electricity prices at the extreme low and high price quantiles compared to the average level, perform better at signaling price extremes in the moments when the power markets are challenged the most.