Impact of intermittent supply on tail fatness of electricity prices

Ronald Huisman, Erasmus School of Economics, Erasmus University Rotterdam, +31 613 267 474, rhuisman@ese.eur.nl
Cristian Stet, Erasmus School of Economics, Erasmus University Rotterdam, +31 616 536 077, stet@ese.eur.nl
Evangelos Kyritsis, Norwegian School of Economics, Bergen, Norway, +47 55 95 99 53, evangelos.kyritsis@nhh.no

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Overview

The shift towards an increasing share of intermittent electricity has a significant impact on the electricity prices and enhances the need for flexibility in the power systems. A better understanding of the impact that intermittent generation has on the electricity prices can help both managers and policy makers in taking short and long term decisions on operating and designing electricity markets. If we consider the case of the German power market, as shown in Kyritsis et al (2017), both solar and wind power influences electricity prices by inducing a merit order effect. The merit order effect has been widely researched and a consensus seems to be present among researchers, that electricity prices are reduced when the share of renewables in the power system increases. One question that remains unanswered and, a natural next step for better understanding electricity prices, is to what extent and in which way the increasing share of intermittent renewable also affects the probability distribution functions electricity prices. In the literature there is a weak and contrasting evidence on electricity price tail fatness in relation to wind and solar output. Power prices are well known to have a fat tailed probability distribution function. These fat tails represent the probability of sudden high and low prices that occur as a result of sudden changes in supply and/or demand due to inelastic demand and the absence of sufficient storage capacity. Although the existence of fat tails is well established, it is not known what actually explains the level of tail fatness and what causes the level of tail fatness to change over time. In our paper we focus on German power prices for which it is known that wind and solar supply explains changes in their standard deviation. Expanding on Kyritsis et al (2017), this paper contributes to the literature by investigating impact that the penetration of intermittent renewables in the German power supply mix has on the tails of German electricity prices. The output of intermittent renewable generation has increased greatly in the last few years in Germany and, there is an increasing need to better understand how the tails of electricity prices are affected. Focusing on the distribution of the tails, we show that the level of wind and solar supply do cause significant changes in the tail fatness of power price distribution functions. Knowing this, brings a better understanding on how price uncertainty changes and on risks caused by it. The results of this research can be later expanded and are of importance also for other geographies, since many of the developed electricity markets are moving towards an ever increasing share of intermittent renewables in the generation mix.

Methods

This research links the occurrence of extreme electricity prices to intermittent wind and solar output using an extreme value theory approach. Tail fatness estimates for the German day-ahead spot electricity prices are analyzed using price data from 1st of January 2010 to 30th of June 2015. The paper calculates the tail index in order to investigate the impact that intermittent renewables output level has on the right tail, on the left tail but also on both tails combined of the electricity prices. For the average daily price we make use of Phelix Day Base data which calculates the daily prices based on the average of over the 24 hourly prices of the day; peak hour prices are based on Phelix Day Peak prices which are calculated as the average hourly prices for the hours 9-20; the off-peak hour prices are calculated based as the average price for the 21-8 hours. Separation between peak and off-peak prices allows observing the magnitude of the impact of wind and solar penetration on the German electricity prices in moments with high (peak) and low (off-peak) demand. This delimitation is useful as different levels of electricity demand exhibit different price patterns and require different flexibility measures. The paper further separates the data into samples with low to high wind, solar or intermittent (wind and solar) penetration into the German supply mix and calculate the tail index for each subsample. To separate between different levels of penetration of wind and solar in the total electricity generated, the article follows two approaches. The first one builds on the sampling used of Kyritsis et al (2017), making our results directly comparable with what is already know in the literature. The second one splits the data into 3 equal samples: low, medium and high penetration of wind, solar or intermittent (wind and solar joint) supply. Data used for the levels of wind and solar output are taken as per Kyritsis et al (2017) and Nicolosi (2010), using actual power generation data for the total output, wind output and solar output. The main reasons behind this choice are the fact that data for predicted solar and wind output is limited, creating own predicting models is prone to errors and the fact that if we analyze the actual market then the actual generated output should be used. To differentiate between left and right tail of the distribution of electricity prices, for each subsample, the values below the median are placed into the left tail observations and the values above the median into the right tail observations. Calculations of tail index estimators are based on the methodology proposed by Huisman et al. 1998, which recommends a variation of the Hill tail index estimator suited for small samples. This methodology is the most suited to this research since some of our samples are relatively small. In determining the thresholds used for the Hill estimations, we rely on Paraschiv et al. (2015) which offers an in depth investigation on the thresholds to be used German electricity prices. Their conclusions show that tail index stays relatively stable between 10% and 15% of the observations. Additionally we also investigate the tail index at 20% tail threshold to better understand if the tail index estimates are sensitive to threshold selection.

Results

The results of this paper show clearly that intermittent renewables supply level generates changes in the electricity price probability distribution function and leads to tail asymmetry. The more intermittent renewable electricity is supplied into the German power network the fatter the left tail and the thinner the right tail of the distribution of electricity prices. When intermittent renewables output is very low right tail tend to be statistically significantly fatter than the left one. In contrast, when intermittent renewables output is very high, the left tail of the electricity price distribution function tends to be statistically significantly fatter than the right tail. This effects are seen when we look at all hours combined, peak hours and off-peak hours but they occur with have different magnitudes. Wind output impacts the tails in both peak and off-peak hours, with the highest impact being seen in the off-peak hours when electricity demand is generally low. In such times, high inflow of wind increases greatly the probability of having low electricity price spikes. This happens because in such periods there is not enough demand for the extra wind electricity produced and because there is lack of flexibility to ramp down production from the marginal producers (coal power plants). In peak hours periods when demand is high, marginal producers (gas power plants) are more flexible in reducing production and therefore also the impact that intermittent renewables output has on the electricity prices is lower. Looking at the solar output during peak hours, the hours that match generally the daylight hours, we observe the same pattern that the more solar output the fatter the left tail and the thinner the right tail of electricity price distribution. When investigating both tails, there is evidence that intermittent renewable output is increasing the fatness of the tails of electricity prices in Germany. More specifically, if we move from low to high intermittent output level, the distribution of electricity prices moves from a few high spikes to many low spikes. This effect takes place when we look individually at wind or solar output but also when we look and wind and solar output combined. What is also important to mention is the fact that results are robust across the three selected tail thresholds 10%, 15% and 20% showing the fact that there is not much sensitivity towards the selected threshold.

Conclusions

What this paper shows and adds to the literature, is the fact that the level of solar and wind output, besides impacting the volatility and the absolute values of the electricity prices, it has also a major role in shaping the tails of the distribution of electricity prices. This paper introduces evidence that intermittent renewables have an important impact on the probability distribution function the electricity prices in Germany. Wind and solar output decreases the probability of having extreme high electricity prices and increases the probability of having extreme low electricity prices. As we show in the previous section, increases in both or each of wind and solar output leads to a fatter left tail and a thinner right tail of electricity price distribution. This pattern leads to tail asymmetry with fatter left tail than right tail when wind and solar output is high and thinner left tail than right tail when wind and solar output is low. Additionally, for wind output, it is important to distinguish between the peak and off peak hours. In off-peak hours when wind production is high, there is also higher probability of experiencing low spikes in the electricity prices than compared to peak hours with high wind power production. The results of this research help in better understanding the flexibility needs of an electricity market with significant intermittent renewables capacity. Therefore, these results have important implications for managers operating in electricity markets but also for policy makers as they show that different measures of flexibility are needed at different moment in times (different level of intermittent renewable production but also different demand levels – peak vs off-peak hours –).