The effect of hydro and wind generation on the mean and volatility of electricity prices in Spain

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Overview

Wind power generation has two important characteristics. First, it has zero marginal cost, which leads generators to bid at close to zero price in wholesale markets. This in turn contributes to a decrease in the average level of wholesale electricity prices, as has been extensively documented in the literature. Second, wind is an intermittent resource. This characteristic contributes to an increase in the volatility of electricity prices – see Woo, Horowitz, Moore, and Pacheco (2011) for evidence on the Texas market, Ketterer (2014) for the German market, or Pereira and Rodrigues (2015) for the Portuguese market.

Hydropower is different: while it still has zero marginal cost, it is not intermittent in the sense that wind or solar are. Dams with large reservoirs can act as a storage of electricity in the form of water's potential energy. This allows hydro plants to postpone energy production if future prices are expected to be higher than the current price. Therefore, the optimal bid for such hydro plants will take in consideration the opportunity cost of selling the electricity now as opposed to later, considering both future expected prices and the local hydrological conditions. In other words, hydropower is dispatchable and can behave strategically.

In situations of high water levels, hydropower can thus wield considerable market power. Gas-fired power stations are usually the marginal producers, but they must always bid at least at fuel cost. Because hydropower has no such costs, it can always underbid gas-fired power stations, driving them out of the market, and thus contributing to limit the increase in electricity prices. Huisman, Stradnic, and Westgaard (2013) show that higher reservoir levels lead to lower prices in the NordPool. EIA (2012) documents a similar effect for the Pacific Northwest. Kilic and Trujillo-Baute (2014) show that hydropower contributes to stabilize intraday NordPool prices.

This paper investigates the effect of wind generation and hydro reservoir levels on the electricity price in Spain. Power prices in Spain have become more volatile due to the increasing penetration of intermittent wind and solar. At the same time, Spain has a large share of hydropower, which makes it an ideal setting to test the interaction of these different types of renewables.

Methods

We collect day-ahead hourly prices for the Spanish market from the Iberian market operator (OMEL) for the period 1/Jul/2007-20/Dec/2014. For each day, we compute an average price from 00h00 to 08h00 and denote this series as "Night". The average from 08h00 to 20h00 is denoted as "Peak". Weekends are removed from this series. Generation and demand load quantities are obtained from Spain's national TSO (Red Electrica de Espana).

Data on the water stored in Spanish dams is available from the "Ministerio de Agricultura, Alimentacion y Medio Ambiente" at http://eportal.magrama.gob.es/BoleHWeb/. The data shows the total amount of water stored in all dams already converted to the MWh of electricity that it can generate. The data are available at the weekly frequency, so we interpolate to daily frequency.

We fit the following ARX-EGARCHX model to each series of electricity prices:

$$p_t = \mu + \sum_{i=1}^{k} \phi_i p_{t-i} + \psi_1 \frac{W_t}{D_t} + \psi_2 H_t + \varepsilon_t$$

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] + \delta_1 \frac{W_t}{D_t} + \delta_2 H_t$$

where p is the deseasonalized log electricity price, W/D is the ratio of Wind generation to total Demand, and H is the available hydro energy stored in dams as a fraction of the maximum storage capacity. Note that H is exogenous to the price as it depends mostly on precipitation.

Results

The following table shows the main results:

	Night Coef.	Peak Coef.
Mean Equation		
μ	0.0461	-0.0105
ϕ	0.9047***	0.9456***
Wind/Demand	-0.0838**	-0.054*
Hydro	-0.0493	0.0101
Variance Equation		
ω	0.0088	-0.0682
β	0.9342***	0.9271***
γ	-0.1919***	-0.4793***
α	0.4387***	0.2982***
Wind/Demand	1.0171***	0.5629***
Hydro	-0.0047***	-0.0048***
R2	0.476	0.3349
Adj R2	0.4741	0.3315
Log Likelihood:	465	582
AIC	-908	-1143
BIC	-844	-1082

First, we find that wind generation, as a fraction of demand, reduces the average price level, but increases the volatility.

Second, we find that Hydro availability has a negative impact on the volatility of electricity prices.

Conclusions

The results show that different renewables have different impacts on electricity prices. While intermittent resources like wind increase the volatility, dispatchable hydro reduces it. This result suggests that hydropower plants behave strategically and, given their zero marginal cost, dampen the otherwise higher price increases.

One implication of this work is that electricity price modelling can benefit from including information on the different renewable resources available on a particular market area.

References

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