Quantile merit order and network upgrade effects: evidence on Italian wholesale power prices

Effetti dell'ordine di merito e di un nuovo cavo sui quantili: evidenze sui prezzi della borsa elettrica italiana

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Abstract This paper estimates the effects on the Italian wholesale electricity prices of the increasing penetration of renewables and new interconnection links. Quantile autoregressive models, augmented with explanatory variables accounting for the supply of renewables and the inception of a new cable (SAPEI, linking Sardinia with the Italian peninsula), are estimated on daily data about the Italian zonal electricity prices in the 2005-2015 time window. The results confirm the merit order effects detected in the existing literature, but only for wind power, mainly in market conditions characterised by moderately low levels of demand, and with an implied increase in volatility. The new cable, instead, has apparently challenged the ability of power generating companies to extract value through price spikes, and mitigated volatility. Some differences across zonal markets are nonetheless detected.

Key words: Electricity prices; renewables; merit order effect; electricity transmission; quantile regression.

1 Introduction

In this paper, quantile regressions are estimated in order to assess the effects of two potentially pro-competitive changes in the Italian electricity market: the increasing penetration of renewables and the new transmission cable SAPEI, linking Sardinia with the peninsula. Quantile regression models are estimated on daily zonal electricity prices in the 2005-2015 time window. The results confirm the merit order effects detected in the existing literature (Ballester and Furio' 2015), according to which renewables crowd out more expensive units and therefore put a downward pressure on market-clearing prices. In the sample, this is only true for wind power, in market

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conditions characterised by moderately low levels of demand, and with an implied increase in volatility. The new cable, instead, has apparently challenged the ability of power generating companies to extract value through price spikes, and mitigated volatility. Some differences across zonal markets are nonetheless detected.

Through quantile regressions one can disentangle the contribution of each electricity price driver at quantiles of the conditional price distribution that are more relevant than the mean vis-a-vis policy goals and risk measurement. In fact, the full profile of quantile regression coefficients across quantiles is informative on how the variance and skewness of the outcome variable respond to marginal changes in the explanatory variables (Capasso et al. 2013). Applications to electricity prices include Bunn et al. (2015), Hagfors et al. (2016), Paraschiv et al. (2016), who found stronger autocorrelation and stronger effects of reserve margins in the right tail, presumably due to market power, with however some exceptions in night-time auctions. Also, stronger effects of fuel prices were detected in the body of the price distribution, an evidence that has been interpreted in light of fuel switching. Less clear in the cited works was the effect of renewables across price quantiles.

The layout of the paper is the following. Section 2 describes the data, the variables and the econometric model. The main findings are summarized in Section 3, before the concluding remarks offered in Section 4.

2 Materials and methods

Data on the wholesale day-ahead zonal electricity prices (in Eur/MWh) have been collected from the IPEx website (www.mercatoelettrico.org) for the period Jan 1, 2005-Jul 31, 2015. The econometric analysis has been performed on daily average prices. The zones in the Italian electricity market are North, Center-North, Center-South, South, Sicily, and Sardinia. Our sample does not include more recent years, such as 2016 and 2017, due to a structural break occurred after the precautionary shut down of 18 nuclear plants in France in 2016, that upset the usual import-export patterns leading Italian prices to soar in early 2017. Also, due to very high prices in Sicily, thermal plants on the island with capacity above 50 MW are supplied compulsorily and remunerated at an administered tariff.

Until 2009, Sardinia was only connected to the Italian peninsula through the Sardinia-Corse-Italy (SACOI) cable, with a transmission capacity of 300 MW. The Sardinian wholesale price was often above the average national price, signalling a chronic supply shortage in a region characterised by scarcity of hydropower sources. The Sardinian electricity system was fully integrated with the Italian grid on March 17, 2011, through a new HVDC interconnection, called SAPEI (SArdegna PEnisola Italiana), linking Sardinia with the Center-South market zone, with a total capacity of 1,000 MW.

The set of explanatory variables, aside from lagged log-prices as customary, includes: the daily supply from intermittent renewables (wind and photovoltaics, separately considered) and the inception of a new cable linking Sardinia with the Italian mainland. The SAPEI cable is accounted for by a dummy taking unit value from March 17, 2011 onwards. We focus on the sign and significance of the coefficients associated to these variables, quantile by quantile. Moreover, we include daily gas prices (PSV), sourced from Eikon / Thomson-Reuters, in order to capture cost fundamentals; the daily average of the Residual Supply Index (RSI) published by GME to account for market power; as well as monthly, weekend, and holiday dummies.

For each variable, 3864 data points are available at a daily frequency.[1] Unit root tests (Augmented Dickey-Fuller, Phillips-Perron) performed on the time series of zonal electricity prices reject the null of non-stationary mean, whereas also the null of stationarity tested through the KPSS is rejected. We can thus estimate time series model specifications in (log-)levels.

Let $Q_p(y|X)$ denote the p-th quantile of y conditional on the matrix of explanatory variables X, with $p \in (0,1)$. A quantile regression model to be estimated for electricity log-price y_t at time t (omitting zonal subscripts) reads

$$Q_p(y_t|X) = \beta_0^p + \beta_1^p y_{t-1} + \beta_7^p y_{t-7} + \beta_g^p g_{t-1} + \beta_{rsi}^p rsi_{t-1} + \beta_s^p s_t + \beta_w^p w_t + \beta_c^p c_t + \mathbf{d}_t \beta_d^p \quad (1)$$

where g_t is gas price on day t, rsi_t is the residual supply index, s_t stands for log-supply of photovoltaic energy, w_t is wind power in-feed (in logs), and c_t is the SAPEI cable dummy. Matrix $\mathbf{d}_t$ collects all monthly, weekend, and holiday dummies. Coefficients are denoted by a subscript, indicating the variable it is associated with. The p superscripts indicate that the model coefficients are allowed to vary across quantiles of the conditional log-price distribution. Our focus is on coefficients β_s^p and β_w^p, measuring merit order effects, and on β_c^p taking up the effect of market integration.

The model has been estimated, for each electricity market zone, at percentiles separated by 5% intervals. Confidence intervals are computed by means of bootstrapping.

3 Results

Estimation results are displayed by means of 6 subplots, one for each electricity market zone (Fig. 1). Each plot includes the quantile regression profile - and the associated bootstrapped confidence intervals - for a set of 3 coefficients, associated to photovoltaics (β_s^p), wind (β_w^p), and the cable (β_c^p). The other coefficients are not reported for the sake of brevity. The focus is on the sign of the estimated coefficients as well as on the shape of the coefficient profile across quantiles. A rising (declining) pattern of coefficients across quantiles is indicative of a positive (negative) effect of the explanatory variable on the variance of the dependent variable (Capasso et al. 2013).

[1] The descriptive statistics are available upon request.

Let us start from the two zones that are immediately affected by the new cable. Concerning the Center-South (mid-right panel), interesting results are found for renewables. Photovoltaics positively affect electricity prices, although confidence bands in the tails are rather wide. Wind power in-feed exercises a downward pressure on prices, with coefficients between -0.7 (lower tail) and -0.15 (upper tail). Remarkably, the increasing profile of coefficients across quantiles indicates that the spread of the electricity price distribution increases with wind power outputs. Also, the coefficient at the 95% quantile is not statistically different from 0. Lastly, the new cable appears to have allowed for lower prices, as testified by negative coefficients, but only from the 70% quantile and there is no significant impact around the median. In other words, the new cable has shaved the price peaks without affecting the main body of the electricity price distribution. Expectedly, autoregressive coefficients are positive at all quantiles, albeit following different patterns. First order autoregressive coefficients decline across quantiles, meaning that lower prices are more persistent. Seventh order coefficients, instead, depict an inverse U-shaped pattern: very low and very high prices do not exercise a lasting effect, as their impact diminishes within a weekly horizon. Gas price and RSI coefficients are positive as expected as well (not reported in Fig. 1 for the sake of space).

The mid-left panel is dedicated to Sardinia. Results about autoregressive, gas, and RSI coefficients are confirmed as regards signs, but patterns slightly change. Closer to our focus, one spots negative solar power coefficient, following an increasing profile up to the 60% quantile, when they turn slightly positive. Wind power coefficients are negative at all quantiles, hence increasing wind outputs appear to have challenged price spikes in Sardinia, which was not the case in the Center-South. Cable coefficients are negative as expected, and rather constant across quantiles, yet lacking significance at the 95% quantile.

Another zone that is partly influenced by the new cable is the Center-North one, where SACOI is not in competition with SAPEI. The top-right panel shows results in line with the Center-South ones as concerns autoregressive, gas, and RSI coefficients. Similarly for wind output results. However, photovoltaic output and the cable fail to exercise any significant impact. The latter result may be due to the limited capacity of the SACOI cable.

The top-left panel displays evidence about the North zone. The only result departing from the previous ones regards the effects of the new cable, which are positive and significant up to the 60% quantile, then losing significance. Concerning the South (bottom-right panel), again one finds unclear effects from solar power, negative but fading impacts of wind power (more able to depress price when it is already low, less so when it is peaking), and a beneficial impact on the new cable at the upper quantiles. The plots on Sicily (bottom-left) are consistent with this picture.

[Figure 1 (Appendix)]

Robustness checks are then performed (available upon request), showing that results are robust to controlling for the share of congested hours and to structural change over time. Finally, interacting the cable dummy with all regressors helps detect complementarities between network upgrades and renewables.

4 Conclusion

This paper has assessed, through quantile regressions on data between 2005 and 2015, how the probability distribution of wholesale electricity prices in Italy changed in response to potentially pro-competitive transformations of the industry, such as an increasing penetration of renewables and a new transmission cable. The estimates show that both have delivered the expected reduction in wholesale electricity prices, yet through different channels. The network upgrade has reduced prices by shaving the price peaks, as shown by the negative and relatively large coefficients at the highest quantiles. Robustness checks suggest that the cable mostly delivered its price reduction effects in conjunction with renewables. Conversely, the penetration of renewables in some important zones (such as Sicily, which was frequently congested out, and Center-North) has not challenged the ability of power generating companies to extract value through price spikes. When controlling for congestion, wind power in the Center-South appears to reduce the upper tail of the price distribution more clearly.

The merit order effect is detected mainly in the body of the electricity price distribution and in the lower quantiles, i.e. in market conditions when prices were already moderately low. This is consistent with theoretical predictions (Acemoglu et al. 2017, Milstein and Tishler 2011) and previous empirical results (Ballester and Furio' 2017) according to which conventional units can partly offset the merit order strategically. Moreover, only wind power has triggered a merit order effect, while photovoltaics have probably delivered their price savings directly to prosumers exploiting distributed generation technologies.

A richer picture will be attained through further steps in this research programme, which involve accounting for cross-zonal correlations, endogenous market power and congestion patterns, and regime switches, or performing estimates on different hourly auctions, with a view to overcoming the present limitations of the analysis.

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Appendix

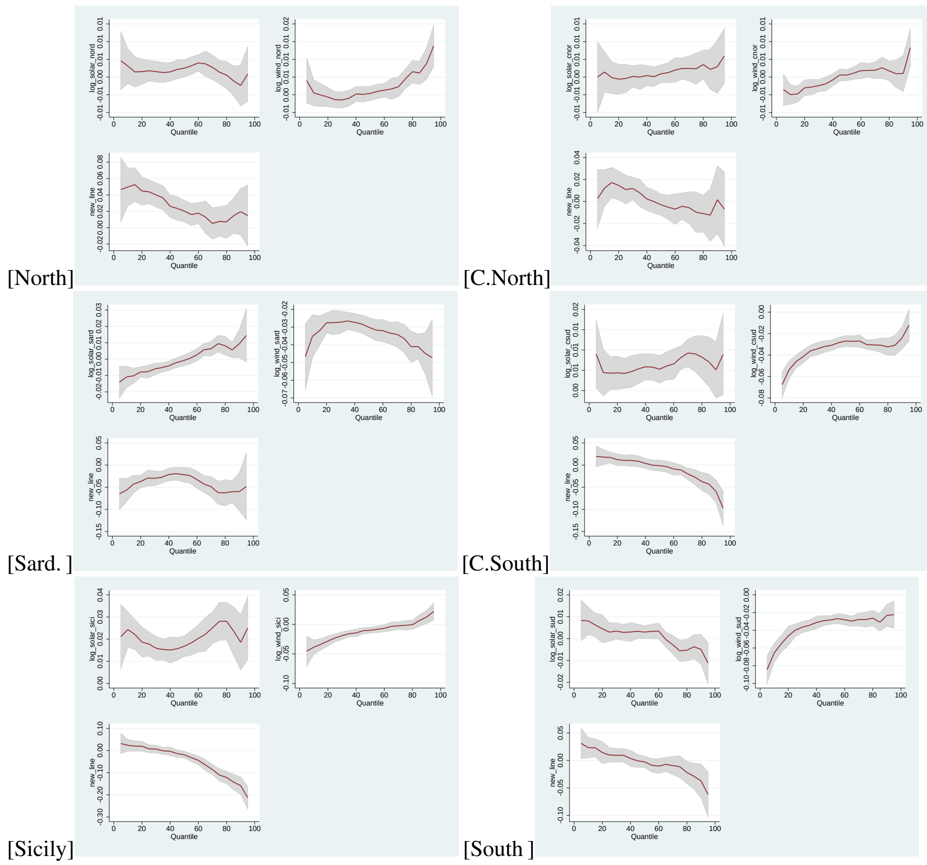

Fig. 1 Quantile regression estimates: Italian day-ahead electricity prices (daily averages), 1 Jan 2005-31 Jul 2015. Variables: (log-)solar power supply, (log-)wind power supply, SAPEI cable dummy.