What happens to electricity prices when the wind and sun supply half the electricity market?

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Overview

Over the last six years, the South Australian (SA) electricity market has changed remarkably. Production from wind and solar increased to 48% of demand, the last coal-fired power station closed (520MW accounting for 16% of the region's supply in 2013), and gas prices almost doubled.

This conference paper describes our analysis and modelling of how the half-hourly wholesale electricity price in South Australia has changed over the last six years. The modelling method distinguishes the contribution of gas prices, coal closure, demand and renewable electricity production by regressing six years of 30-minute time-series market data. The analysis uses satellite irradiance data and PV uptake to model the 30-minute rooftop photovoltaic (PV) profile; missing from past studies (Bushnell & Novan, 2018) (Cludius, Forrest, & MacGill, 2014). The analysis extends the past the merit order effects literature by distinguishing seasonal effects. The analysis shows that wind and solar reduced the average wholesale price by $38 AUD /MWh in 2018 from what they otherwise would have been. The paper examines price reduction and compares them to the cost of subsidy and examines the relative merits of subsidies to extend coal generation life relative to renewables.

Methods

We solve the regression for Equation (1) for each half-hour period of the day, h (where $h \in \{0, 0.5, 1, \dots, 23.5\}$), and season to provide the $\beta_{h,s}$ regression coefficients. This model formulation is particularly influenced by the approach in (Bushnell & Novan, 2018) and is also consistent with (Cludius, Forrest, & MacGill, 2014) and (Würzburg & Linares, 2013). Our work extends the work of (Bushnell & Novan, 2018) by including rooftop PV, solving the model for 30-minute intervals and for each season, S (where $S \in \{Summer, Autumn, Winter, Spring\}$. This methodology provides additional insight into the seasonal trends in the wholesale market at half hourly intervals. The data used in the model covered the date range from 1st July 2012 to 30th June 2018.

$$P_{h,s} = \beta^0_{h,m,s} + \beta^w_{h,s} \cdot W_{h,s} + \beta^{PV}_{h,s} \cdot PV_{h,s} + \beta^g_{h,s} \cdot G_{d,s} + \beta^D_{h,s} \cdot D_{h,s} + \beta^c_{h,s} \cdot C_{h,s} + \varepsilon_{h,s} \quad (1)$$

Where,

$P_{h,s}$, is the half-hourly (h) spot in a season (S), and is measured in \$/MWh, $W_{h,s}$ is the half-hourly gross wind generation in MWh, $PV_{h,s}$ is the half-hourly gross rooftop PV generation in South Australia in MWh, $D_{h,s}$ is the state demand plus exports and before rooftop solar in MWh $G_{d,s}$ is the daily gas spot price in \$/GJ, $C_{h,s}$ is the available coal capacity. $\beta^0_{h,m,s}$ is used to account for monthly seasonal fixed effects. $\beta^g_{h,s}$ is the gas price coefficient and describes the \$/MWh change in wholesale price for a \$1/GJ change in gas spot price. $\beta^w_{th,s}$ is the wind generation coefficient and describes the \$/MWh change in wholesale prices per MWh change in wind generation. $\beta^{PV}_{h,s}$ is the solar coefficient and describes the \$/MWh change in wholesale prices per MWh change in solar generation. $\beta^D_{h,s}$ is the demand coefficient measured in \$/MWh per MWh change in hourly demand. $\beta^c_{h,s}$ describes the fixed affect in \$/MWh when coal generation was available in South Australia. We do not use gas production directly in the model since this correlates strongly with demand as will be shown in the paper.

Results

The linear model in (1) fitted with an R^2 error of 0.54. Figure 1 shows the summer and winter wind and rooftop solar generation coefficients and the 95% confidence interval. It shows that increasing the average wind generation by 100MW would reduce the wholesale price by $8/MWh in summer and winter, though the precise value varies around the day, with summer price impacts most significant (but also most variable) around 3-6pm. The wider variability in summer between 3 pm and 9 pm can be attributed to the higher volatility of wholesale prices in summer and low generation output for PV. The final paper will present the results for coal capacity, gas price and demand.

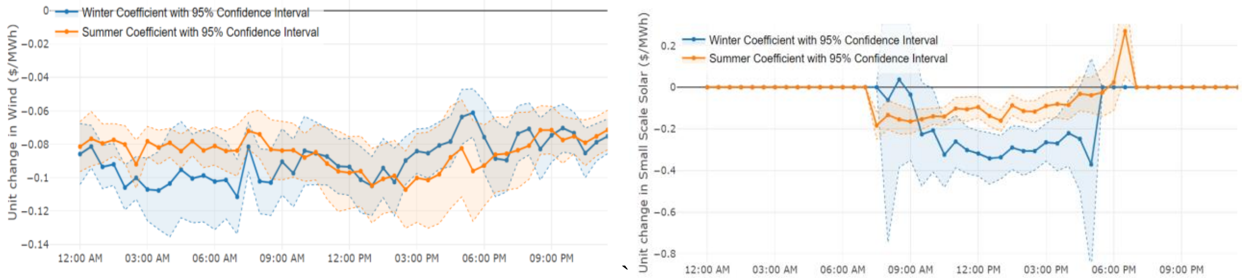

Figure 1- Solar and wind model coefficient for summer and winter

To quantify the impact on wholesale electricity prices attributable to gas prices, wind generation, coal closure, solar generation and demand, we used the regression model to decompose the half-hourly SA spot price into each component. Figure 2 shows that by 2018, the price of meeting SA demand and exports and excluding the other factors was $74 AUD per MWh. Additionally, SA's extraordinarily high gas prices explained an increase of $61 per MWh. The 1,110 GWh of solar and 5,550 GWh of wind generation reduced prices by $10 AUD/MWh and $28 AUD MWh respectively. Adding these together our model predicts 2018 average annual prices of $89.9 AUD per MWh, compared to the actual average of $90AUD per MWh, in both cases excluding Settlement Period prices greater than $1000 AUD per MWh.

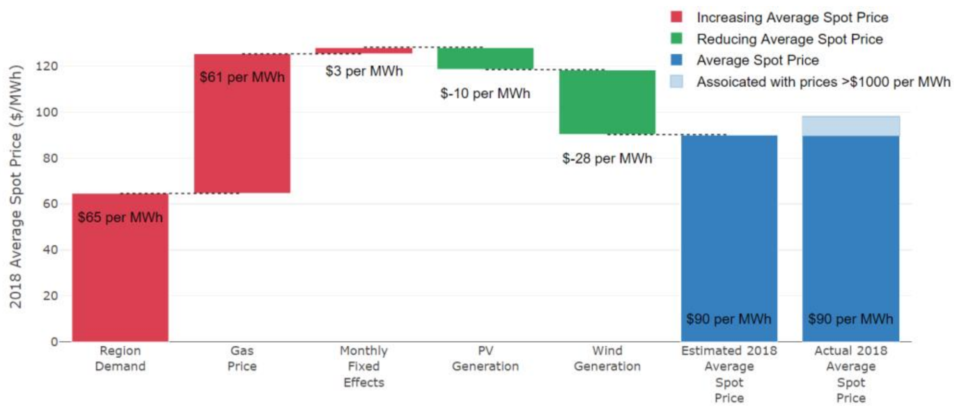

Figure 2 - The average individual on wholesale (spot) price

Conclusions

The results show that the transition to a 48% renewable energy market had a more significant impact in reducing wholesale prices than gas prices have had in raising them since 2013. Coal generation closure raised prices, but the closure was inevitable: a market increasingly dominated by variable renewable production has increasingly less tolerance of inflexible "base load" conventional generation. The cost of the renewable generation subsidy paid by customers in South Australia is a third of the wholesale market price reductions associated with that renewable generation.

References

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