The Effect of Wind and Solar on Fossil Plant Revenues and Prices: A Case Study of Australia's National Electricity Market

[Arash Taheri, University of New South Wales, +61435759671, z5341617@ad.unsw.edu.au]

Overview

A quick transition of electricity markets toward high shares of variable renewable energy (VRE) could undermine power system security and reliability by inducing earlier than expected exits of fossil fuel-fired power plants. Accordingly, the impact of increased electricity generation by VRE technologies on the latter is of importance to policy makers attempting to oversee a secure transition of the electricity market. This study explores the short-run relationship between wind and solar PV capacity on the one hand and the wholesale market revenues of coal and gas-fired power plants and electricity prices on the other in Australia's National Electricity Market (NEM) throughout the 2020 to 2022 period. Structural estimates indicate that, all else the same, an additional MW of wind (solar PV) capacity lowers average prices and the average daily revenues of coal-fired plants, combined cycle gas turbines, and open cycle gas turbines by \$0.07 (\$0.04), 0.05% (0.02%), 0.14% (0.06%), and 0.08% (0.03%) respectively. Despite the negative marginal revenues and continued growth in the capacity of VRE in the NEM, the revenues of fossil fuel-fired plants are shown not to have declined over the sample period. Evidence is provided that suggests this to have been a consequence of rising prices, in turn resulting from upward shifting and steepening fossil plant supply curves over time. Inflation in the international prices of coal and natural gas over the sample period and the advanced age of most of the coal-fired plants in the NEM suggest these changes have been due to increased generation costs. The results of this study cast doubt on the prediction that continued growth in VRE capacity will lower prices in the medium to long term: while such growth exerts downward pressure on prices by reducing residual demand, this pressure can be more than offset by tightening supply conditions that result from increasing fossil fuel-fired generation costs.

Methods

This study uses a simple equilibrium model of the electricity market to structurally identify the short-run relationship between wind and solar PV capacity on the one hand and the electricity market revenues of coal and gas-fired power plants and electricity prices on the other. According to this model, the wholesale electricity price is pinned down as the minimum price which equates aggregate dispatchable (i.e. fossil fuel-fired) electricity supply with residual demand (i.e. electricity demand less available wind, solar PV, and hydroelectric generation). The corresponding equilibrium equation in turn allows for the derivation of analytical expressions that quantify the short-run relationships of interest. These quantities are then estimated using Australian Energy Market Operator (AEMO) data on wind and solar PV capacity factors, electricity prices, and plant-level power output, as well as supply function estimates derived from regressions on plant-level bid schedule data from the same source.

The methods outlined above, as well as the detailed nature of the data used, allow for the estimation of the effect of a marginal increase in the capacity of wind/solar PV on average electricity prices and the average daily revenues of coal-fired power plants, combined cycle gas turbines, open cycle gas turbines, and gas-fired steam turbines. These estimates are obtained for each of the four main regions of the Australian National Electricity Market (NEM) and each month of the January 2020 to December 2022 period.

Results

In the short-run, increases in the capacity of both wind and solar PV were found to lower average electricity prices and the daily revenues of coal and gas-fired power plants in all regions and month-years in the sample period. Specifically, a 1MW increase in wind (solar PV) capacity was estimated to lower average electricity prices and the average daily revenues of coal-fired plants, combined cycle gas turbines, open cycle gas turbines, and gas-fired steam turbines by \$0.07 (\$0.04), 0.05% (0.02%), 0.14% (0.06%), 0.08% (0.03%), and 0.29% (0.14%) respectively. As evident, the negative impact of an increase in wind capacity on prices and fossil plant revenues was found to be larger in magnitude than that of an increase in solar PV capacity. This is because, unlike solar PV which only operates during daylight hours, wind is available throughout all hours of the day: the revenues of coal and gas-fired technologies are vulnerable to competition from cheap wind throughout more hours of the day relative to solar.

Despite the negative effect of VRE capacity on prices and fossil plant revenues in the short run, and even though VRE capacity (residual demand) was observed to have increased (decreased) over the sample period in all the regions studied, prices and revenues of fossil plants were observed to have increased over the same period in every region. These increases were verified to have been driven by tightening supply conditions: the estimated supply curves of coal and gas-fired power plants shifted up and become steeper throughout the sample period. These upward shifts were shown to be partially driven by inflation in the prices of coal and natural gas on the international market throughout the sample period. As for the observed steepening of supply curves, this was, in the case of coal-fired power plants, likely a result of the increasingly costly operation and maintenance of ageing plant equipment.

Conclusions

This study uses a simple equilibrium model and data from Australia's National Electricity Market throughout the 2020 to 2022 period to structurally identify and estimate the short-run relationship between wind and solar PV capacity on the one hand and the revenues of coal and gas-fired power plants and electricity prices on the other. The results show that, all else the same, an increase in the capacity of both wind and solar PV lowers electricity prices and the revenues of both coal and gas-fired power plants. This finding is consistent with those of the 'merit order effect' literature which indicate that increases in the generation share of renewables lead to declines in average electricity prices in the short-run[1].

On the other hand, observed increases in prices and fossil plant revenues in the NEM throughout the sample period, which coincided with falling residual demand, suggest that the extrapolation of the estimated negative short-run relationship to the medium and long-run is not necessarily warranted. This is because, even if VRE capacity continues to grow over the next decade, whether this growth will result in a decline in electricity prices and the revenues of fossil fuel-fired generators in the market will depend on the evolution of the latter's generation costs: if fossil fuel-fired generation costs rise sharply enough, the downward pressure on prices and revenues resulting from rising (falling) VRE capacity (residual demand) will be more than offset by an upward pressure exerted by tightening supply conditions. An important implication of this possibility is a potential delay in the 'self-cannibalisation' of VRE technologies: VRE capacity (residual demand) will continue to grow (fall) without lowering prices and therefore VRE revenues for a longer period than if supply conditions did not tighten.

References

Clò, S., Cataldi, A., & Zoppoli, P. (2015). The merit-order effect in the Italian power market: The impact of solar and wind generation on national wholesale electricity prices. *Energy Policy*, *77*, 79-88.

Cludius, J., Hermann, H., Matthes, F. C., & Graichen, V. (2014). The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: Estimation and distributional implications. *Energy Economics*, *44*, 302-313.

Csereklyei, Z., Qu, S., & Ancev, T. (2019). The effect of wind and solar power generation on wholesale electricity prices in Australia. *Energy Policy*, *131*, 358-369.

Woo, C. K., Horowitz, I., Moore, J., & Pacheco, A. (2011). The impact of wind generation on the electricity spot-market price level and variance: The Texas experience. *Energy Policy*, *39*(7), 3939-3944.

[1] Woo et al. (2011), Cludius et al. (2014), Clò et al. (2015), and Csereklyei et al. (2019) are among the many studies in that literature that uncover such a negative relationship in the short-run.