Spatial Analysis of the Merit-Order Effect of Wind Penetration in New Zealand

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Overview

The expansion of wind generation in New Zealand potentially provides an important contribution to achieving the goal of having 90% of electricity generated from renewable resources by 2025. Due to the limited expansion of hydro capacity expected in the future, as much as 20% may need to be generated by wind if this target is to be achieved. Understanding the behaviour of nodal prices when adding wind is crucially important for valuation and risk management of real assets and financial claims. The non-storability of electricity, the characteristics of demand and supply and the structure of the market and the market power of the generators all contribute to the observed high volatility of electricity prices (Escribano et al., 2011). Electricity generation in New Zealand is hydro-dominated, with around 60% of electricity generated by hydro. New Zealand lacks significant capacity for water storage to provide reliable hydro generation. This makes the New Zealand electricity system vulnerable to dry periods. During dry periods, HVDC provides the South Island consumers with access to the North Island's thermal generation capacity. During wet periods, HVDC transfers surplus South Island hydroelectric power northwards to the North Island.

The impact of wind generation on electricity prices via the merit-order effect (MOE) has been examined in Germany (Ketterer,2014), Spain (de Miera et al.,2008) and Denmark (Munksgaard & Morthorst, 2008). However, policies in these countries directly support renewable energy sources, see Haas et al. (2008). Moreover, both Nicholson et al. (2010) and Pöyry (2010) found that the MOE is stronger during the day than in the night. The impact on price depends on the generation mix and the availability of flexible conventional capacity.

To the best of our knowledge, no studies have examined the MOE of wind penetration in the New Zealand electricity market. In addition, there are not any studies that have applied spatial models to MOE studies. We hypothesise that the nodal price is influenced not only by factors at the grid injection point but also by factors at its neighboring nodes. We also estimate the MOE by season and demand segments. The findings are expected to provide important evidence for acquiring security of supply management to stabilise the balance between wind capacity and conventional capacity, the balance between electricity supply and demand.

Methods

(1) Non-Spatial model

Price=$F_{1\_OLS/FE}$ (wind/load, hydro/load, thermal/load, load, weekday, spring, summer, autumn)

(2) Spatial model
a. Spatial fixed effects Durbin Model
Price=F_{2_SDM} ((price, wind/load, hydro/load, thermal/load, load) in neighbour region, wind/load, hydro/load, thermal/load, load, weekday, spring, summer, autumn)
b. Spatial fixed effects Durbin Model by demand segments
Price=F_{3_SDM} ((price, wind/load, hydro/load, thermal/load, load) in neighbour region, wind/load, hydro/load, thermal/load, load, weekday, spring, summer, autumn)
c. Spatial fixed effects Durbin Model by season and demand segments
Price=F_{4_SDM} ((price, wind/load, hydro/load, thermal/load, load) in neighbour region, wind/load, hydro/load, thermal/load, load, weekday)

Results

- First, we estimate the MOE of wind penetration on nodal prices, both directly and indirectly. Importantly, the results are based on an electricity supply system that receives no subsidies and no grid access priorities.
- Second, estimates of the direct effects (the main diagonal elements) indicate that a 10% increase of wind penetration in node *i* is associated with a reduction of 0.3$ to 0.5$ per MWh in nodal price in node *i*. The indirect effects for wind generation are that a 10% increase in wind penetration at neighbouring node is associated with a price drop of 1.4$ to 2.6$ per MWh. The total effects of a 10% increase in wind penetration on nodal prices are a reduction of 1.7$ per MWh at night, 2.3$ per MWh at shoulder, and 3.1$ per MWh at peak. These effects are statistically significant.
- For each season and each demand segment, we find negative and significant direct and indirect effects associated with changes in both types of neighbourhood wind penetration, suggesting the existence of spillovers and scalability of wind farms.

- In spring, summer, and autumn, we find the strongest MOE of wind penetration on nodal prices during peak times, and the weakest MOE occurs during the night. In winter, the strongest MOE is found during the shoulder period, the medium MOE during the peak period and the weakest MOE during the night. This indicates that the magnitude of MOE depends on the extent of the difference in marginal cost of generation technology.
- With regard to the statistically significant coefficients for load support, our hypothesis is that rising loads raise nodal prices. The magnitude of the effects of load on prices is uneven over the four seasons. A relatively small effect in winter may indicate that there are small variations in load, or low elasticity of demand in winter.
- Our results show that ignoring spatial spill-overs leads to an underestimation of the MOE of wind penetration on nodal prices. The ability of spatial regression models to provide quantitative estimates of spill-over magnitudes and to allow statistical testing for the significance of these represents a valuable contribution of spatial regression models to understanding electricity prices.

Conclusions

- The study has examined the MOE of wind penetration on nodal prices in the NZEM based on the centralised dataset. The study addresses the heterogeneity that is important for electricity price analysis, and it extends the literature as follows. First, a spatial econometric model estimates the direct and indirect MOE of wind penetration on nodal prices. Second, we provide estimates of the impact of other types of generation on nodal prices. Third, we evaluate nodal price effects during dry periods and wet periods because the NZEM is hydro-dominated and hydro storage affects the MOE. Fourth, the MOE is further examined in different demand segments using a spatial econometric model.
- More wind injected into the grid lowers the nodal price, and this result is not sensitive to the electricity demand. The spatial regression results have re-assured our statistical analysis. Wind speed in one wind site is complementary with wind speed in another wind site. Surplus wind generated electricity can be exported to neighbourhood nodes, which reduces nodal price. The results provide evidence that the benefits of wind farms constructed at sites with a good wind resource, at scale, are distributed through the network, provided that network capacity is not a limiting factor. On the other hand, smaller scale wind farms should be located close to communities rather than more distant from main load centres avoiding transmission costs.
- With an average load factor of around 45% it is highly likely that wind generation will expand in the near future, particularly if demand grows. Adding more intermittent wind generation into the electricity system will create challenges for the system operator and market participants. On the one hand, electricity generated by wind is independent and non-adjustable with respect to electricity demand. Our results show that high levels of variable renewable electricity production can be balanced by adjusting the output from hydro and thermal power plants. Unlike Norway, for example, New Zealand cannot achieve balance by adjusting imports/exports. The entry of load balancing investments into the market will depend on the cost of alternative technologies relative to existing sources of supply. The magnitude of MOE depends on the extent of the difference in marginal cost of generation technology.

References

Escribano, A., Ignacio Peña, J., & Villaplana, P. (2011): "Modelling Electricity Prices: International Evidence," Oxford Bulletin of Economics and Statistics, 73(5), 622-650.

Haas, R., N.I. Meyer, A. Held, D. Finon, A. Lorenzoni, R. Wiser and K-I. Nishio (2008): Promoting electricity from renewable energy sources -- lessons learned from the EU, U.S. and Japan, in: F.P.Sioshansi (Ed.), *Competitive Electricity Markets: Design, Implementation, Performance,* Elsevier: Amsterdam.

Ketterer, J. C. (2014). The impact of wind power generation on the electricity price in Germany. *Energy Economics, 44*, 270-280. http://dx.doi.org/10.1016/j.eneco.2014.04.003

Munksgaard, J., & Morthorst, P. E. (2008). Wind power in the Danish liberalised power market—Policy measures, price impact and investor incentives. *Energy Policy, 36*(10), 3940-3947. http://dx.doi.org/10.1016/j.enpol.2008.07.024

Nicholson, E., Rogers, J., & Porter, K. (2010). Relationship between Wind Generation and Balancing Energy Market Prices in ERCOT: 2007-2009. NREL Report SR-5500-49415. National Renewable Energy Laboratory (NREL).

Pöyry (2010). Wind Energy and Electricity Prices. Exploring the 'merit order effect'The challenges of intermittency in North West European power markets. European Wind Energy Association (EWEA) 2010. Summary Report (http: //www.poyry.co.uk).

Sáenz de Miera, G., del Río González, P., & Vizcaíno, I. (2008). Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain. *Energy Policy, 36*(9), 3345-3359. http://dx.doi.org/10.1016/j.enpol.2008.04.022