Spatial Econometric Estimation of the Merit-Order Effect of Wind Penetration and its Implication on Wind Farm Investment Decisions in New Zealand

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Overview

The NZ government has proposed a net-zero carbon target by 2050. Agriculture contributes more than 50% to NZ's green house gases (GHG) emissions. To date there appears to be minimal scope for reducing methane emissions from livestock. Fossil fuel based energy sources contribute around 40% of total GHG emissions. Greater opportunities to reduce GHG emissions are possible with sector-wide improvements in energy efficiency, structural change, and electrification of transport. 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. Since the future expansion of hydro capacity is limited, as much as 20% of electrity may need to be generated by wind if this goal is to be achieved.

Expansion of wind generated electricity has important implications for electricity supply in New Zealand. First, because international trade in electricity is not feasible, the market response to sources of low cost wind generated electricity is conditional on the relative marginal cost of alternative sources, such as hydro, geothermal and gas. Second, given the intermittency of wind generated electricity, climatic conditions are significant in determining the merit-order of generation alternatives entering the market. When wind generation is low, base load capacity is typically hydro/coal/geothermal. When wind generation is high, wind displaces higher cost supply alternatives. Wind generated electricity is likely to be quite variable and may require expensive nautral gas backup since this ramps up faster than the alternatives. When more low cost wind generation is added, this shifts the merit-order curve to the right and pushes out the most expensive generators. This results in the reduction of wholesale electricity price at a given level of demand. Peak demand is satisfied by relatively more expensive sources of electricity, namely, natural gas. Consequently, the merit-order effect (MOE) of wind generation is relatively larger during periods of peak demand. Third, adding wind capacity at one grid injection node, contingent on hydro storage and demand, we expect to observe a reduction in the wholesale price at neighbouring nodes, provided transmission capacity exists. Departing from the current literature, we use a novel econometric approach to estimate the MOE and provide estimates of the temporal effects of wind generation on regional wholesale prices.

Our study contributes to the literature in three ways. First, our primary contribution is to extend the literature by employing spatial econometric methods to examine the MOE. We construct three spatial weight matrices, and evaluate different spatial models. Among the spatial models we evaluate, we select a spatial fixed effects bias-corrected (Lee and Yu, 2010) Durbin model (SDM) to examine the MOE of wind penetration. Second, this is the first study to examine the MOE in New Zealand and the first study to examine the hourly MOE. Third, we apply estimation results to forecast regional wholesale price reduction effects and use these to estimate net financial savings at each node. The evidence affords insight into expanding and integrating wind generation into the electricity system for the system operator and market participants.

Methods

Three spatial weight matrices are constructed:

1. Distance weight matrix- based on geographic distance
2. Contiguity weight matrix- 1 if connected by cable, 0 otherwise.
3. Transmission weight matrix- based on transmission capacity of cable connection

Using the pooled ordinary least squares and the panel fixed effects models as benchmarking models, we applied the classic Lagrange Multiplier (LM) tests proposed by Auselin (1998) and the robust LM-tests proposed by Anselin et al. (1996) to determine the need to add spatilal interaction effects into the benchmark models.

Results

- The negative and significant coefficients on wind penetration show the prices dampening effects of raising wind penetration. Statistically significant coefficients on both spatially lagged dependent and independent variables at the 1 percent level strongly support the hypothesis that a nodal price observed at node i is influenced by the price and other factors at neighbouring nodes.
- A 10% increase in the wind share has the highest price impact of $3.5 per MWh at 6pm, the lowest is $0.92 per MWh at 4am.
- According to 'net annual savings per MW', we identify the node where the highest value wind site should be built. We also identify the node where injecting a wind site has the least value. We quantify these values.

Conclusions

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 been 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. Results show that private investment in additional wind capacity leads to positive gains in economic value throughout the network. However, it's not clear if private investment is financially viable. Investing in capacity at a given node can reduce the return to a generator's assets in the network. Reaching the goal of 20% electricity from wind generation depends on growth in demand. One suorce of this growth may come electrification of transport.

References

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