ENERGY ONLY MARKETS: ARE THEY EFFICIENT WITH LARGE AMOUNTS OF INTERMITTENT GENERATION?

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Overview

The New Zealand government has signalled an intention to reduce carbon emissions by 50% by 2050. By 2025 the aim is to have 90% of electricity generated from renewable resources including between 20-30% generated from wind (Electricity Authority (EA), 2010). Electricity generation expansion scenarios that would achieve these targets also include significant geo-thermal build which is classed as "must run" base load and offered into the spot-market at a price of zero, as is wind and must run hydro such as run of river. Thus the renewable electricity generation scenarios for New Zealand will likely include large amounts of electricity offered into the spot market at a price of zero much of which is intermittent. The New Zealand Electricity Authority models generation expansion scenarios based on: expected demand; fuel and carbon prices; a merit order using long run marginal costs; combined with various constraints including security of supply constraints. However the Generation Expansion Model (EA, 2010) does not model actual price formation. The first aim of this work is to model price formation to understand the impact of large amounts of intermittent wind on the electricity market. Prices are expected to become much more volatile as thermal plants can only recover their fixed costs by capturing higher prices when they are running. There are some suggestions that market power will exacerbate this (Green and Vasilokas ,2010). Volatile prices change the risk profile and investment incentives for new generation especially for capital intensive generation such as wind. A further consideration for a market such as New Zealand, which has locational pricing, is the impact of wind and intermittency on the grid. In particular attractive wind farm sites tend to be geographically proximate which may lead to line congestion and large variations in nodal prices. Thus we also investigate the incentives to site wind in places where the power is needed (rather than where it can be generated most efficiently). Spot prices may well be zero for a significant fraction of the time. It is not clear that the generation scenarios with large amounts of renewable generation will result in market prices that allow for cost recovery. There may well be a missing money problem which means less investment and a lower than desired security of supply security – a trend which may be exacerbated by change in the risk profile discussed above. The rise of intermittent generation in electricity markets has given rise to a renewed interest in capacity markets for security of supply, driven by the underlying assumption that the increased price volatility caused by intermittent generation will not provide sufficient revenue to incentivize construction of peaking generators sufficient to ensure security of supply. The growth of intermittent generation such as Wind and Solar in electricity markets requires increased investment in peaking capacity to ensure security of supply. In 'Energy Only' electricity markets such as New Zealand's, these investments are made on the basis of the expected revenue peakers generate on the spot market in periods of high demand. It is well known that in the short term at least the merit order effect will depress average prices. Hence an ongoing concern is that energy only markets cannot guarantee sufficient investment in peak capacity to ensure security of supply. However, this assumption has not been well tested in the academic literature with any degree of rigour. Another issue that is starting to emerge is the ability for firms to exercise market power during periods of low wind. In this paper, we use an agent-based model combined with a generation expansion model of the New Zealand (energy only) electricity market to determine a long run equilibrium capacity mix and examine the interaction between long run capacity mix, the merit order effect and market power as wind penetration increases dramatically.

Methods

To model electricity prices realistically we use a computer agent based model developed by Young et. al. (2011) which uses a modified Roth and Erev algorithm and applies it to a 19-node simplification of the New Zealand electricity market. The computer agents have a portfolio of generator assets and bid into the market. Profits are computed, using a simplified dispatch model of the New Zealand market, which are fed into the learning algorithm. New bids are constructed and the process is repeated until prices converge. The NZ Electricity Authoritie's Generation Expansion Model (EA, 2010) is used to generate a number of different scenarios for 2025 with varying amounts of intermittent wind generation. The demand projections from the Statement of Opportunity (EA, 2010) are used as well as expected line upgrades. Simulated wind data was obtained from National Institute of Water and Atmosphere. We simulate wholesale electricity prices for a number of years with different wind profiles.

Results

The New Zealand electricity market is a unique market for testing the merit order effect as large amounts of generation is likely to be required to bid into the spot market at zero price, much of which is intermittent. Unlike many countries wind is not subsidised. Furthermore the electricity network is stand-alone with no interconnection to other electricity grids. The results here suggest that the existing grid with planned line upgrades to 2025 is viable for our central scenario of 20% wind penetration. Wind siting decisions have important implications for the network. Locational pricing does give the right incentives for firms to have the right mix of wind farm sites as there is an advantage to having wind sites that have a less correlated generation profile even if some of these sites are less windy. As expected price volatility increases with market power and with higher wind penetration. Our results support Twomey and Neuhoff's (2010) theoretical result that with market power thermal plants are able to exercise market power more than the intermittent wind generators. With large amounts of wind prices are much more volatile with extra wind pushing down returns on existing wind farms (the merit order effect) As the amount of wind penetration increases it skews the price duration curve with large amounts of zero price hours combined with more higher price events.

We find the degree to which peakers are able to exercise market power depends critically on the ratio of capacity to peak demand. When capacity is low relative to peak demand we find that peakers can persistently exercise market power when there is little wind leading to implausibly large market prices and rents to generators. When capacity is low relative to peak demand peak generators are unable to exercise market power and generate any return on their capacity costs. In practice, the ratio of capacity to peak demand will be endogenous. We examine an intermediate scenario and show that at moderate (30% of capacity) levels of wind penetration it is possible for both wind and peaking generation to generate adequate rates of return on capacity investment. However these returns are sustained by market power. A competitive market would see returns below that needed to recover investment costs. We also find the surprising result that market power rents increase as wind penetration increases despite an increase in the number of periods when prices are zero. However we also find that that the exercise of market power leads to a loss of efficiency by distorting dispatch from its marginal cost optimal which is least cost. The loss of efficiency is significant and increases as wind penetration increases. This also leads to increased greenhouse gas emissions compared to competitive dispatch. We show that nonetheless most plants including peak plants cover their fixed costs however this is due to the large amounts of market power firms are able to exercise. We also show that if the market is competitive no plants can cover their fixed costs.

Conclusions

The New Zealand Electricity Market behaves quite differently with large amounts of renewable electricity generated. With significiant intermittent wind generation are much more volatile with significant periods of time with a zero spot price which increases investment risk and reduces investment incentives. As wind penetration increases these problems are exacerbated.The suggested levels of security of supply used in the New Zealand Electricity Authorities generation expansion model yield competitive market prices which are too low to recover fixed costs on peaking plants and indeed most plants. This means that either we must accept a lower level of security of supply or other policy measures such as a capacity markets need to be implemented if markets are competitive. The agent based model simulations suggest that there is significant market power which even for very high wind pentrations means that most plants including peakers can recover fixed costs. Surprsingly the exercise of market power during periods of low wind pushes up market power rents as wind penetration increases. Market power distorts efficient dispatch and increases system costs. An Energy Only market with large amounts of generation forced to bid in at zero cost and with an implicit price cap cannot simultaneously: be competitive and have the level of security desired by the system operator.

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