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Market power and system cost: The long run impact of large amounts of wind electricity generation?

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HIGHLIGHTS

- Increasing wind generation is analyzed using an agent based model.
- In the energy only market increased capacity reduces market power.
- Increasing wind results in more market power in some periods.
- This leads to inefficient dispatch – which get worse with more wind.

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ABSTRACT

In the short run, it is well known that increasing wind penetration is likely to reduce spot market electricity prices due to the merit order effect. The long run effect is less clear because there will be a change in new capacity investment in response to the wind penetration. In this paper we examine the interaction between capacity investment, wind penetration and market power by first using a least-cost generation expansion model to simulate capacity investment with increasing amounts of wind generation, and then using a computer agent-based model to predict electricity prices in the presence of market power. We find the degree to which firms are able to exercise market power depends critically on the ratio of capacity to peak demand. For our preferred long run generation scenario we show market power increases for some periods as wind penetration increases however the merit order counteracts this with the results that prices overall remain flat. Returns to peakers increase significantly as wind penetration increases. The market power in turn leads to inefficient dispatch which is exacerbated with large amounts of wind generation.

1. Introduction

The rise of intermittent generation such as wind and solar in electricity networks has raised concerns about whether existing electricity market designs are sufficient to ensure reliability of supply. These concerns stem from three results well established in the literature. First, increasing the penetration of intermittent generation leads to greater price and dispatch volatility in the market (Ray et al., 2010; Woo et al., 2011). Second, increasing the penetration of intermittent generation requires an increase in peaking generation to ensure security of supply during periods where the intermittent resource is unavailable (De Jonghe et al., 2011). Thirdly there are concerns about how intermittent generation which is typically high capital cost with low running costs can deliver investment returns (Boot and Van Bree, 2010). This is exacerbated by the merit order effect which drives down the returns of intermittent generation (and increases the risk) compared to those of firm producers (Muñoz and Bunn, 2013). These results have driven recent discussion on whether electricity markets should be redesigned. See for example Hall (2014), and the recent German Government green paper on market design changes to accommodate increasing renewable generation (Federal Ministry for Economic Affairs and Industry, 2014).

The energy-only market design is particularly susceptible to concerns about security of supply. In theory, an energy-only market can accommodate significant amounts of renewables. With

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more renewables, the price would be zero or close to zero more of the time. However, the volatility of renewables implies that inevitably, there would be times when renewable generation is low, and the demand supply imbalance is tight. At such times, prices would spike. The number of periods where this occurs would need to increase with large amounts of intermittent generation so that all units could cover investment and fixed operating costs. The success of such markets thus relies first on the price spikes being sufficiently high and/or of duration to cover the capital costs of peaking units, and second, on consumers accepting these price spikes as the cost of security of supply. Some authors doubt that the public would accept a “structural appearance of scarcity” (Hall, 2014). Many of the major'energy only' design electricity markets around the world are experiencing a large amount of wind investment including Texas (ERCOT), Germany, Alberta (AESO), Australia and New Zealand. In this paper the case study of the NZ market is analysed, however the conclusions reached have relevance for a large number of electricity markets worldwide.

Absent from much of the discussion is the role market power plays in driving these price spikes and how increasing intermittent generation could affect that market power. The theoretical principles for energy-only markets were established under the paradigm of perfect competition. This theory tells us that the capital costs of peaking units can be covered by price spikes at the VOLL for a small number of hours a year, when some demand is left unmet (Stoft, 2002). In practice, all existing markets maintain reserve ratios such that demand is always met and thus these demand shaving peaks rarely or never eventuate. Instead, obtaining the price spikes necessary to cover the capital costs of peaking units requires firms to successfully bid at prices above SRMC – essentially exercising market power. Thus market power is crucial to maintaining security of supply in an energy-only market even absent any intermittent generation. The literature shows that energy only markets frequently see prices well above marginal cost, likely due to a degree of market power being exercised (Borenstein et al., 1999; Bushnell et al., 2008; Wolak, 2009; Joskow, 2008; Browne et al., 2012).

In an energy only market setting where firms are permitted to bid above SRMC, tight demand/supply[1] conditions are precisely those periods where firms have market power – implying there will be more opportunity for firms to exercise that market power as the penetration of renewables increases. This implies an increase in the quantity and duration of price spikes, which would help to cover the costs of the additional peaking units required, but could in turn undermine public support for the market. Counteracting this is the fact that there will be more investment in peaking units, and an increasing number of periods where the price is zero, both of which will reduce market power. The overall impact on average prices and returns to peaking units is undetermined in the literature.

The key question we seek to understand is how increasing wind penetration interacts with market power in the long run, after the capacity mix adjusts to the increased wind generation. Can the exercise of market power generate sufficient returns to peaking units to maintain security of supply? We show that this depends on the reserve margin in the market, which impacts the degree to which market power can be exercised, and thus whether the market can generate the returns needed to support the market capacity mix.

To address this question, we seek to construct a model to examine how the degree of market power can change as the amount of wind capacity in a market increases. This model would need to take into account three factors.

The first is the so-called ‘merit order effect’. This is an established observation that in the short run, increasing the penetration of intermittent generation will depress the average spot price. See for example, empirical studies by Ketterer (2014), Würzburg et al. (2013), Munksgaard and Morthorst (2008), and Woo et al. (2011). Gelabert et al. (2011) analyse the Spanish market and find strong evidence of the merit order effect. They also find some evidence that the merit order effect decreases with time as the capacity mix adjusts. Forrest and MacGill (2013) quantify the merit order effect for the Australian market. Another approach is to use power system models to simulate prices with and without significant wind penetration for markets. In the German market Sensfuß et al. (2008) and Sensfuß (2011) used a computer agent based model which demonstrates that in the short run prices decrease as wind penetration increases. de Miera et al. (2008) find a similar result for the Spanish market however they do point out that in the long term the capacity mix should adjust and prices should return to the level needed to provide the required investment returns

The second factor is the amount of market power that firms can exercise when the demand/supply imbalance is tight which implies the model must be able to represent strategic behaviour. Game theoretic Cournot models are often used to understand market power in electricity markets (for example Joskow and Tirole, 2007). A recent example is Traber and Kemfert (2011) who find that prices decrease and incentives to invest in gas fired plants decrease as wind penetration increases in the German market. With increasing amounts of wind Twomey and Neuhoff (2010) establish in a theoretical model that thermal plants are able to exercise more market power during periods when the wind is not blowing. Mountain (2013) provides empirical evidence for this from the South Australian National Electricity market.

Another approach is to use a computer agent based model. In such a setting Guerci and Sapio (2012) find for the Italian market that prices tend to be lower- although with very high wind penetration line congestion give firms an opportunity to exercise market power. Weidlich and Veit (2008) and Guerci et al. (2010) have written critical surveys of the many applications of agent-based modelling to electricity markets. The advantage of agent-based modelling is that it allows modelling market power on realistic networks.

The third factor the model must address is the response of the long-run capacity mix to increasing generation intermittency. This last factor is particularly difficult to capture. One approach is to try and find the profit maximizing mix of generation.

Two of the few papers to model this explicitly are Green and Vasilakos (2010) and Green and Vasilakos (2011) whom model strategic behaviour using supply function equilibria. They find that if the wind generators do not receive the market price the mark up for thermal plants is less as wind penetration increases. However such a supply function equilibria approaches require considerable simplifications to be tractable, and would not be appropriate to study most real world markets where a large number of heterogeneous firms compete on a complex network with line constraints and losses. Bushnell (2010) draws similar conclusions using a different approach.

In this paper, we use a model of the New Zealand electricity market as the basis to understanding the impact of wind penetration on energy-only markets more widely. The New Zealand electricity market is one of the purest examples of the form in the world, with no capacity incentive schemes, no explicit price cap, no renewable subsidies, and has the additional advantage of a large potential wind resource, which makes wind generation economic without subsidies. The New Zealand market has other advantages for modelling. First, the market is small enough that

[1] To be precise a tight demand/supply balance means that the ratio of effective capacity (with wind de-rated by its average capacity factor) to peak demand is lower than that seen in today's market of 1.35.