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Assessing the impact of wind generation on wholesale prices and generator dispatch in the Australian National Electricity Market

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HIGHLIGHTS

- Proposes methodologies to estimate short run impact of wind on electricity markets.
- Quantifies the merit order effect of wind generation on wholesale spot price.
- Wind is found to be significantly effecting gas fired generation.
- Evidence is found for wind having a notable impact on baseload coal generation.
- Discusses the implications for development of wind generation in Australia.

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ABSTRACT

Growing climate change and energy security concerns are driving major wind energy deployment in electricity industries around the world. Despite its many advantages, growing penetrations of this highly variable and somewhat unpredictable energy source pose new challenges for electricity industry operation. One issue receiving growing attention is the so-called 'merit order effect' of wind generation in wholesale electricity markets. Wind has very low operating costs and therefore tends to displace higher cost conventional generation from market dispatch, reducing both wholesale prices and conventional plant outputs. This paper extends the current literature on this effect through an empirical study employing a range of econometric techniques to quantify the impacts of growing wind penetrations in the Australian National Electricity Market (NEM). The results suggest that wind is having a marked impact on spot market prices and, while wind is primarily offsetting higher operating cost gas generation, it is now also significantly reducing dispatch of emissions intensive brown coal generation. Great care needs to be taken in extrapolating these results to longer-term implications, however, the study does propose a methodology for assessing this effect, highlights the impacts that wind is already having on NEM outcomes and suggests promising directions for future research.

1. Introduction

Over the last decade, wind energy has emerged as one of the most successful and promising low-carbon electricity generation technologies worldwide. It is amongst the fastest growing sources of generation (REN21, 2011), has achieved significant penetrations in a number of countries (LBNL, 2011) and is widely agreed to be one of the key technologies for achieving a more sustainable future electricity sector (IEA, 2011). In general, the expansion of wind is being driven by its growing cost competitiveness, yet also by a varied mix of policies in support of energy security, environmental and wider social outcomes. However, the growing deployment of this highly variable and somewhat unpredictable generation source poses new challenges for electricity industry operation. Any significant deployment of new generation within an electricity industry is likely to impact on the physical dispatch of existing plant, overall industry economics and commercial outcomes for participants. Wind energy is no exception and due to its unique operational and economic characteristics and the fact that it is the first intermittent generation to reach significant penetrations in large electricity grids, there is still much to learn about its technical, economic and commercial implications, and what type of electricity industry arrangements (and wider policy support frameworks) might best facilitate its deployment.

As well as the recent attention on the operational impacts of high wind penetrations (IEA Task 25, 2011), including balancing costs, reserve requirements, transmission and system capacity, there is a

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growing body of literature exploring the potential impact of wind generation on commercial outcomes within wholesale spot markets. Two key issues that have emerged in this regard are the impact of wind output on spot price and the dispatch of other generation types.

The impact on price, or the 'merit order effect', results from low marginal cost wind output systematically displacing higher marginal cost generation through the least cost market dispatch process. It has been identified and its impact quantified in a range of markets around the world through descriptive (Cutler et al., 2011), simulation (Lamont, 2008; Sensfus et al., 2007) and empirical (Woo et al., 2011; Nicholson et al., 2010) studies.

The displacement of generation of various types by wind generation arises from this same merit order effect. The literature generally concludes that when wind is generating, dispatch of the higher operating cost, typically peaking, plant is the first to be impacted and that only under certain circumstances will baseload plant also be displaced (Green and Vasilakos, 2010b; Delarue et al., 2009; Goransson and Johnsson, 2009; Ummels, 2006).

To date, the focus has been on simulation studies with limited empirical work on the impact of wind generation being conducted. Although less common, empirical studies have particular importance because of the complexities in wholesale electricity markets that are difficult to capture in market simulations. While subject to their own set of assumptions and limitations, direct analysis of market data can provide valuable insights and is a vital supplement to other simulation work. In this paper we present an econometric analysis of the impact of wind generation on wholesale spot prices and outputs of other generation types within the South Eastern region of the Australian National Electricity Market (NEM). This region has a significant wind penetration by international standards (Cutler et al., 2011) and the wholesale market has high transparency with regard to historical prices and generating plant dispatch (MacGill, 2010).

We first develop an autoregressive linear model for the truncated half hourly spot price that can be used to estimate the merit order effect of the change in wholesale spot price per MWh of wind output. Second, we develop several simple linear models to assist in understanding the dynamic relationships that exist between wind output and baseload and peaking generation. The intent being to estimate how much of each generation type (primarily coal and gas plant in this case) can be considered to be displaced by wind output in the short run and the associated impact on greenhouse gas emissions from the electricity industry. The abatement issue is of particular relevance to South Eastern Australia where coal fired generation is from high emissions intensity brown coal (lignite) plants.

Section 2 of this paper outlines the theoretical underpinings of our analysis and some key hypothesised outcomes for the impact of wind in wholesale electricity markets. It also describes some of the key simulation and empirical studies conducted to date. Section 3 provides background on the Australian NEM design, structure and policy context, and experience with wind industry integration. Section 4 outlines our model and the model development procedure for the price and dispatch analyses. Section 5 describes the data used in the analysis. Sections 6 and 7 outline the results of the price and dispatch analyses respectively and Section 8 provides some key conclusions for the study, and possible avenues for future work.

2. Quantifying the impact of wind energy on wholesale electricity markets

2.1. Economics of electricity supply and wind energy

A number of studies have presented the potential impact of wind generation in terms of it impact on the supply curve, or merit order, of generation within electricity spot markets (EWEA, 2009; Sensfus et al., 2007). Our framework presented here, provides a simplified representation of such markets for ease of interpretation, simplifying out potentially relevant factors such as transmission constraints, strategic bidding by generators, and potential demand-side participation, with the purpose of developing a set of hypotheses for the impact of wind on wholesale spot markets.

Fig. 1 presents stylised supply and demand curves for an electricity spot market. The demand curve, which represents the demand of electricity retailers and often large direct consumers, is typically assumed to be very steep or even vertical (inelastic), due to the fact that the demand for electricity by end consumers is often near independent of the spot price in the short term. The supply curve represents the aggregated offers of each generator to provide particular quantities of power (MW) if the market price is at or above a specified amount. In theory, assuming that no market power is present, the supply curve is equivalent to the aggregate marginal cost curve of all generators. However, this is almost never the case, especially at high levels of demand when there is tight supply and generators with non-dispatched capacity have freedom to charge higher prices due to lack of competition (Twomey, 2010). This results in the dramatic slope of the supply curve at high levels of demand. Depending on the particular market, the combination

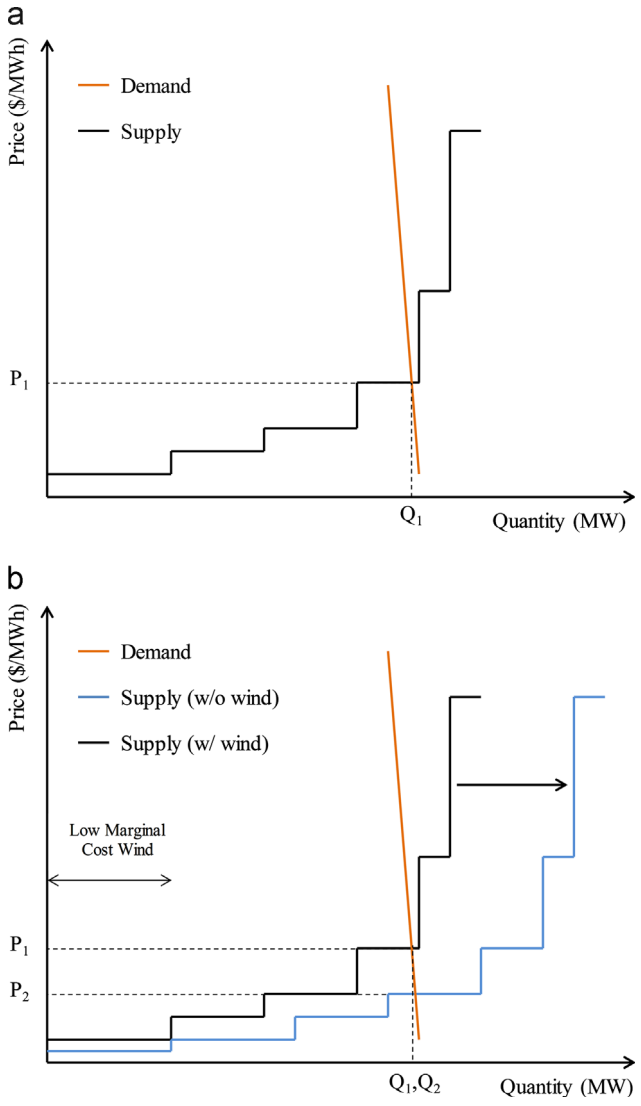

Fig. 1. Stylised supply and demand curves for spot market with inelastic demand curve. (a) without wind output and (b) with wind output.