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How to correct for long-term externalities of large-scale wind power development by a capacity mechanism?

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HIGHLIGHTS

- We model power market players' investment decisions incorporating wind power.
- We examine two market designs: an energy-only market and a capacity mechanism.
- We test two types of wind power development paths: subsidised and market-driven.
- Capacity mechanisms compensate for the externalities of wind power developments.

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ABSTRACT

This paper deals with the practical problems related to long-term security of supply in electricity markets in the presence of large-scale wind power development. The success of recent renewable promotion schemes adds a new dimension to ensuring long-term security of supply: it necessitates designing second-best policies to prevent large-scale wind power development from distorting long-run equilibrium prices and investments in conventional generation and in particular in peaking units. We rely upon a long-term simulation model which simulates electricity market players' investment decisions in a market regime and incorporates large-scale wind power development in the presence of either subsidized or market driven development scenarios. We test the use of capacity mechanisms to compensate for long-term effects of large-scale wind power development on prices and reliability of supply. The first finding is that capacity mechanisms can help to reduce the social cost of large scale wind power development in terms of decrease of loss of load probability. The second finding is that, in a market-based wind power deployment without subsidy, wind generators are penalised for insufficient contribution to the long term system's reliability.

1. Introduction

Competitive electricity market designs were introduced to enhance the role of market signals in guiding efficient short- and long-term operation and the investment choices, which are necessary to ensure security of supply. However, in the energy-only market design,[2] opportunities to hedge risks and generate revenues are not enough to recover the fixed costs of capital intensive investments in new generation capacity, particularly for peaking units. Not only expected income by potential new generator entrants during price spikes is uncertain because random on their frequency, duration and magnitude of price increase, but there is a "missing money" problem in many systems because the implementation of quite low price cap for acceptability reasons, but also because the system operators frequently take premature technical decisions in order to reduce the risk of physical disequilibrium and brown-out (Joskow, 2006). To resolve this so-called "missing money" problem, the energy-only market design has to be supplemented by a capacity mechanism,[3] through which existing and new capacities can gain additional value. By ensuring their availability, the capacity mechanism thereby addresses the potential shortages that would result from the apparent paradox that during any load curtailment, market prices are very high.

The massive expansion of renewable generation supported by generous output-based subsidies has brought two difficulties to energy systems. First wind power development creates a large-

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2 An energy-only market is a market in which there is no capacity adequacy instrument for stimulating investment in generation capacity and in particular in peaking units, that means the electricity price is the only driver for investment.

3 The range of capacity mechanisms covers: capacity payments, mandated capacity obligation on suppliers, forward capacity contracts auctioning, reliability options auctioning and strategic reserve contracts with the TSO. For an analytical comparison of the different capacity mechanisms, see Cramton and Stoft (2006), De Vries (2007), and Finon and Pignon (2008).

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scale need of flexibility and back-up services that the existing systems are not able to offer while the market rules are not yet adapted to give sufficient values to these services (ramping up, ramping down, etc.). Second large-scale wind power exacerbates the “missing money” problem which pre-exists in many systems because it reduces scarcity rents which are embodied in price spikes in comparison to a counter factual scenario without such a wind power development.

The amplification of the “missing money” problem due to wind generation results from three effects. The first effect concerns the shifting in the short-term of the supply curve to the right, resulting in a lower price during periods of large wind power generation. This is called the merit-order effect which tends to reduce the average revenue per MWh for all the technologies, and in particular for new peaking units because of the second reason (Sensfuß et al., 2008). The second effect is the correlation between peak load and wind power generation during peak periods in most of the years. Moreover the probability distribution of wind power is an asymmetrical distribution which makes the residual electricity demand duration curve (i.e. the electricity demand less wind power generation) much more pointed in peak load hours. This is a factor of reduction of scarcity rents during peak periods. The third effect relates to the increase in price volatility during all the year, because of the greater variability in residual electricity demand. It contributes to modify a bit more the profit anticipations of peaking units increasing the risk premium for investors in these units. Faced with this problem, the introduction of capacity mechanisms in an electricity market leads to greater social efficiency.

In order to investigate the effectiveness of a capacity mechanism to correct for the long-term effects of large-scale wind power development, we analyse how the transition to the new long-run equilibrium is affected by short-term price effects induced by this development. We also examine how, once in place, this mechanism potentially corrects for these effects. We do insist on the fact that we do not cope with the need of flexibility services implied by the large-scale development of wind power. We do not consider that incentives to invest in peaking units and demand response programs which result from the capacity mechanism are sufficient to answer to all the need of flexibility services, even if these new resources could increase the potential of flexibility of the electricity system. It is by improving spot and real time market design that flexibility will be correctly valued and developed in a power system.

For our purpose, we develop a dynamic model of an electricity market, with detailed representation of wind power specificities and their impact upon investment dynamics in different generation technologies. The approach relies on a system dynamics model such as used by several authors (in particular De Vries and Heijnen, 2008; Cepeda and Finon, 2011) to simulate the long-term evolution of electricity markets. This model is expanded to incorporate wind power generation in a realistic way. Contrary to the traditional approach which determines an optimal generation mix to satisfy fluctuating demand combined with wind generation (Lamont, 2008; Bushnell, 2010; Green and Vasilakos, 2010), the system dynamics approach reproduces the dynamic externalities affecting prices during the transition to reach a new long-term equilibrium.

In this paper, we study two scenarios of wind power development, one driven by output subsidies, and another by the market. In the former, we analyse the dynamic effects of regulatory-based wind power development on investments in conventional technologies, as well as on prices and reliability performance. In the second scenario, we study the same effects but with a market-driven development with wind power progressively increasing competitiveness. In both scenarios, we evaluate the capacity mechanism as a means of compensating for external effects on capacity investments, as well as their ability to achieve reliable supply relative to the counterfactual scenario without wind generation. This approach allows the comparison over time, of the overall costs including shortage costs, between an energy-only market design and a market design with a capacity mechanism. Simulations provide insights on priorities for ensuring future generation adequacy in electricity markets with massive expansion of wind power.

In the following section, we examine the growing problem of “missing money” caused by the development of large-scale wind power development. It also offers a brief overview of the existing literature on new long-term market equilibrium after large-scale wind power development. Section 3 presents the long-term dynamic model of an electricity market in the presence of subsidised, or market-driven, development of wind power and details data and assumptions used in the model. Section 4 presents the simulation results and lessons to be drawn on long-term effects of wind power generation, as well as the potential for correction by a capacity mechanism. We conclude in Section 5.

2. Effects of large scale wind power development upon the new market equilibrium

Large-scale wind power development changes short- and long-term market equilibriums and exacerbates the “missing-money” problem. Existing literature on the new long-term market equilibrium in the presence of wind power covers only static effects. It captures in a simplistic way, the random wind power generation patterns hence poses limits to studying the potential to correct for new market failures introduced by wind power, by means of a capacity mechanism.

2.1. The long-term effect of wind power development on generation adequacy

The organisation of the electricity industry post liberalisation reforms has led to a transformation of the long-term coordination in generation investment. Before reforms, coordination relied on utilities' to plan large enough generation margin so as to sustain a minimum level of outage risk. A trade-off between the investment costs for new generation capacity in peaking units and the reduction in outage cost for consumers would in theory determine the optimal risk of outage (Boiteux, 1949).

In the new market regime, however, the long-term coordination between market players is driven by market prices. Can market price signals lead to investment decisions in different generation technologies so as to achieve optimal supply reliability? Investment decisions depend on prospects of infra-marginal rents and, in particular, of scarcity rents that result from price spikes at peak demand, which exceed the marginal costs of the generation units. Price spikes result from the price inelastic nature of electricity's real time demand, creating opportunities for producers' strategic behaviour when the system is stressed (Stoft, 2002). However, in reality, scarcity rents that emerge in the electricity markets are too low. Regulators in some jurisdictions opt for fixed price caps to limit price spikes (e.g.1000 $/MWh in North America regional markets and 3000 €/MWh in some European markets) responding to criticism around the social acceptability of scarcity rents and the exercising of market power by generators. Besides, in certain tight situations, protocols of TSO interventions from various reserves are used quite rapidly outside the market, which reduces incomes of peaking units (Cramton and Stoft, 2006; Joskow, 2006).