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Germany's nuclear power plant closures and the integration of electricity markets in Europe

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HIGHLIGHTS

- Associations between spot prices and wind power are time-varying.
- Greater spot price and volatility associations across markets are observed.
- In the long run, the German market is less integrated with neighbouring markets.
- Policies on a local electricity mix can affect spot prices in connected markets.

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ABSTRACT

This paper examines the potential implications of national policies that lead to a sudden increase of wind power in the electricity mix for interconnected European electricity markets. More specifically, it examines market integration before and after the closures of eight nuclear power plants that occurred within a period of a few months in Germany during 2011. The short- and- long run interrelationships of daily electricity spot prices, from November 2009 to October 2012, in: APX-ENDEX, BELPEX, EPEX-DE, EPEX-FR, NORDPOOL, OMEL and SWISSIX; and wind power in the German system are analysed. Two MGARCH (Multivariate Generalized Autoregressive Conditional Heteroscedasticity) models with dynamic correlations are used to assess spot market behaviour in the short run, and a fractional cointegration analysis is conducted to investigate changes in the long-run behaviour of electricity spot prices. Results show: positive time-varying correlations between spot prices in markets with substantial shared interconnector capacity; a negative association between wind power penetration in Germany and electricity spot prices in the German and neighbouring markets; and, for most markets, a decreasing speed in mean reversion.

1. Introduction

Common goals in European energy policy are security of supply, affordability and climate change. An integrated electricity market is seen as a means to address these objectives. Nonetheless, national policies that affect wholesale prices in one electricity market can impact the process of integration. The present study investigates short- and- long run associations of electricity day-ahead prices and wind power penetration in the German market, which is the largest and most liquid in Europe, with other European markets, by comparing the periods of one year before and after the closures of eight nuclear plants that followed the 13th *Gesetz zur Änderung des Atomgesetz* (Nuclear Phase-Out Act).

A consensus on European energy policy could promote cleaner energy mixes, optimise complementarities, lead to dynamic pricing and align grid investment strategies (Boeckers et al., 2013; Hooper and Medvedev, 2009). Yet, in 2011, a unilateral course was taken in Germany that potentially altered wholesale electricity prices beyond its borders. As hinted by Germany's Environment Minister a year after, unintended consequences were possible: 'It was not possible to discuss the consequences of such a decision with Germany's neighbours. Now is the time for that. (Peter Altmaier, European Energy Review, 2012). Indeed, Germany is Europe's largest economy and is committed to reduce emissions between 80% to 95% below the level in 1990 by 2050, of which 21% has since been achieved (Committee on Climate Change, 2013). Its energy transition, *Energiewende*, has led to considerable growth in intermittent renewable energy sources (RES-E), and wind power capacity increased from 183 MWh in 1992 to 31.308 MWh in 2012, so that Germany had a third of the installed EU wind power capacity in 2012 (European Wind Energy Association, 2013).

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Consequently, with the closure of eight nuclear plants in a short period, the German electricity mix changed significantly; the share of other technologies increased, most noticeably wind power, as will be highlighted in the next section.

The possibility of unintended consequences from isolated national energy policies that alter the electricity mix in interconnected electricity markets motivates this study. In the next section, the contextual background is described in greater detail. Section three reviews the literature on the implications of growing RES-E for electricity price behaviour, price volatility transmission and market integration. Section four sets the hypotheses to be tested. Section five describes the methodology and data. The results are reported in section six. Section seven discusses the main findings, and section eight concludes the paper.

2. Germany's electricity mix and trade flows following the nuclear phase out

The decommissioning of eight nuclear power plants in Germany as a response to the events in Fukushima led to a 23% reduction in gross electricity generation capacity from nuclear (Öko Institut, 2013). Given an increase in the share of intermittent RES-E in the German electric system, secure capacity, which is the generation that is available 99% of the time, decreased. Fig. 1 illustrates the secured and available electricity generation capacities in Germany in January 2011 in GW, before the closures. At that time, of the total installed RES-E capacity (51.5G W), only 9% (4.8 GW) was classified as secure. In the case of conventional plants, availability is subject to outages, revision and failures. Consequently, from the total installed available capacity of 160.2 GW only 58% (93.1 GW) was secure. Given a peak-load demand in Germany of 80.6 GW in 2011, the reserve margin before the closures of the eight nuclear power stations was equal to 12.5 GW. This value exceeded the adequate reserve margin of 7G W, which is suggested by ENTSO-E. However, after the closures of eight nuclear plants in 2011, the reserve margin decreased to 6.2 GW, which is below the security threshold (BDEW, 2011).

Until August 2011, Germany had been a net exporter of electricity with stable commercial flows. Exports were generally to the Benelux countries, which have a high proportion of variable peak electricity sources, such as coal- and gas-fired plants. Germany imported electricity from France, mostly produced by nuclear plants, and the Czech Republic, which in 2010 had high proportions of fossil fuel-based (54.8% or 47.1 TWh) and nuclear (32.6% or 28 TWh) generation (European Commission, 2012). Electricity flows with Denmark, Sweden and Poland depended on the availability of wind power (BDEW, 2011).

After August 2011, with lower reserve margins, trade patterns changed. In the six weeks that followed the announcement and the reduction of total net capacity by 6.305 MW, Germany became a net-importer of electricity (BDEW, 2011). However, the decommissioning of the nuclear power capacities in Germany coincided with the seasonal shift in its electricity trade with neighbouring markets: electricity was traditionally exported in the winter and imported during the summer, when there is greater availability of hydro and lower demand for nuclear in neighbouring markets (Öko Institut, 2013). Nevertheless, when considering a longer period (one year before and one year after 6th of August 2011), Germany remained a net exporter. Overall imports rose by 894 GWh, while the increase in net exports was 5103 GWh (ENTSO-E, 2014). Trade flows actually increased, and the expectation of greater imports was not confirmed. The reduction in electricity generation from nuclear was offset in the annual balance by two thirds, through increased generation from RES-E (+20.2 TWh) (Öko Institut, 2013). In addition, when comparing statistics of newly commissioned wind turbines in the years 2009/2010 to 2011/2012, a 30% increase in capacity is observed (BWE, 2014). In short, favourable weather conditions and strong investments in wind farms further increased the share of electricity generated by RES-E in Germany.

3. RES-E and electricity market integration in Europe

Several studies have addressed growing RES-E integration (e.g. Gross et al., 2006; Henriot and Glachant, 2013; Holttinen et al., 2009; Smith et al., 2007), but they mainly highlighted the need for secure reserve capacity due to the intermittent nature of wind power. Some authors (e.g., Bode and Groscurth, 2006; Gil et al., 2012; Jacobsen and Zvingilaite, 2010; Neubarth et al., 2006; Nicolosi, 2010; Ray et al., 2010; Saenz de Miera et al., 2008; Sensfuß et al., 2008), however, observed that increasing wind power penetration is negatively correlated with electricity spot prices. In high-wind scenarios, given the merit order of dispatch, more expensive generators have very low load factors (Claudius et al., 2014; Forrest and MacGill, 2013, Sensfuß et al., 2008; Woo et al., 2011, Würzburg et al., 2013), and therefore electricity wholesale

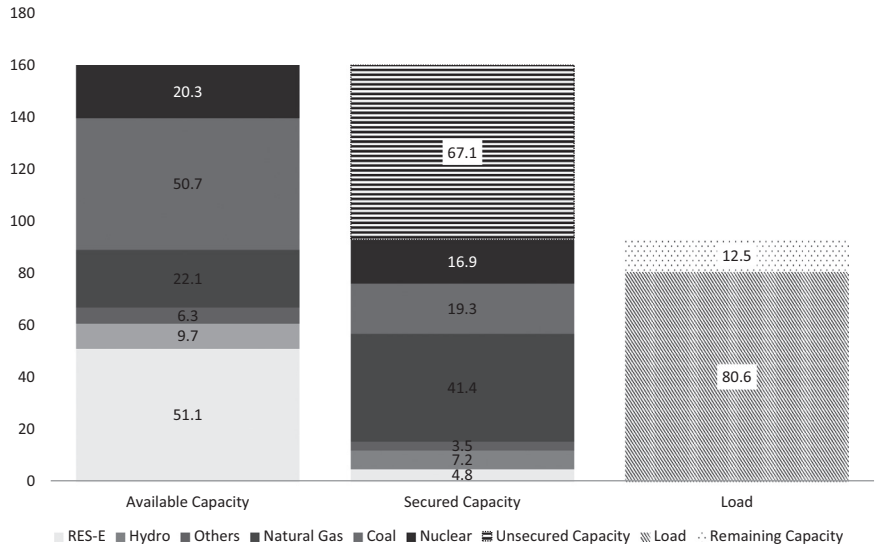

Fig. 1. Electricity generation capacity and peak load in Germany-January 2011. Source BDEW (2011).