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Short communication

How does Germany's green energy policy affect electricity market volatility? An application of conditional autoregressive range models

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HIGHLIGHTS

- We estimate a CARR model for German electricity price data.
- We augment the model by dummies capturing important regulations.
- We find a significant decline in the price range after the year 2009.
- This implies effective price stabilisation by German energy policy.

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ABSTRACT

Based on a dynamic model for the high/low range of electricity prices, this article analyses the effects of Germany's green energy policy on the volatility of the electricity market. Using European Energy Exchange data from 2000 to 2015, we find rather high volatility in the years 2000–2009 but also that the weekly price range has significantly declined in the period following the year 2009. This period is characterised by active regulation under the Energy Industry Law (EnWG), the EU Emissions Trading Directive (ETD) and the Renewable Energy Law (EEG). In contrast to the preceding period, price jumps are smaller and less frequent (especially for day-time hours), implying that current policy measures are effective in promoting renewable energies while simultaneously upholding electricity market stability. This is because the regulations strive towards a more and more flexible and market-oriented structure which allows better integration of renewable energies and supports an efficient alignment of renewable electricity supply with demand.

1. Introduction

Over the past decades, German policy makers have introduced a variety of regulations to promote renewable energies because they are regarded as a central pillar in the efforts to protect the climate, reduce import dependency, and safeguard jobs (see Frondel et al., 2010). In particular, the Energy Industry Law (Energiewirtschaftsgesetz, EnWG), the Renewable Energy Law (Erneuerbare-Energien-Gesetz, EEG), and the regional implementation of the EU Emissions Trading Directive (ETD) have not only led to a significantly increased share of renewables in the electricity market (see Büsgen and Dürrschmidt, 2009) but also to intensive research on current and future economic consequences (see Hillebrand et al., 2006; Lehr et al., 2008; Rogge et al., 2011) and potential improvements (see Langniß et al., 2009) of the regulations.

A very important strand of this literature deals with the influence of renewables on electricity prices. Based on a variety of models (e.g., multi-agent, fundamental, reduced-form, statistical, computational intelligence and hybrid models; see Weron, 2014), which can capture the special characteristics of electricity prices with varying degrees of success, these studies document a price reducing effect of low marginal costs of renewable electricity commonly referred to as merit order effect (see Würzburg et al., 2013). For example, Cludius et al. (2014) and Dillig et al. (2016) show that, at specific times of the year, wind and photovoltaic electricity generation shifts the supply curve of conventional electricity virtually out of the market leading to temporary very low market prices.[1] In addition, Sensfuß et al. (2008) present

[1] Dillig et al. (2016) also provide an interesting overview of studies documenting the merit order effect in countries other than Germany. They also highlight that the estimation methodology has crucial impact on the documented size of the effect.

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similar results for a wider range of renewables (also including biomass and hydro power).

While a status of increased feeding of renewables at low prices can be considered a regulatory success, Van Asselt and Biermann (2007) and Haas et al. (2013) argue that renewables may impact the costs at which fossil fuels are offered at times when renewable energy sources are scarce and the resulting higher prices in these cases may cause high overall market volatility. As a consequence, electricity traders and consumers may be exposed to significantly higher risks (see Aggarwal et al., 2009). To avoid increased market volatility, the EnWG and the EEG seek to promote renewables in a way that maintains electricity market stability (i.e., low price risks) (see Mitchell et al., 2006; Brandstätt et al., 2011). A typical mechanism for this purpose is the market premium scheme of the EEG which creates incentives to realign renewable electricity supply with demand and thus aims at preventing strong price fluctuations (see Gawel and Parkus, 2013). Unfortunately, the issue of how Germany's green energy policy has affected electricity market volatility (i.e., the question of whether such mechanisms are effective) has not been analysed so far.[2]

In this article, we seek to fill this research gap. That is, we analyse whether the volatility of electricity prices in Germany has significantly changed with the introduction of the EnWG, EEG and ETD by using a new kind of volatility model. Interestingly, in studies of electricity market dynamics, an explicit focus on volatility modelling with hypothesis testing regarding volatility properties is rather rare (see Karakatsani and Bunn, 2010). Most studies focus on price forecasting and derivative pricing but try to improve the forecasting accuracy of the underlying models by incorporating realistic volatility structures. For example, classic jump-diffusion models or Markov regime-switching models with constant volatility are typically modified by using time-dependent volatility terms (see Cartea and Figueroa, 2005; Chan et al., 2008; Janczura and Weron, 2010), support vector machines are augmented by heteroskedastic variance equations (see Zhao et al., 2008) or autoregressive models are coupled with generalised autoregressive conditional heteroskedasticity (GARCH) models (see Knittel and Roberts, 2005; Misiorek et al., 2006; Diongue et al., 2009; Tan et al., 2010; Giafreda and Grossi, 2012; Khosravi et al., 2013). We are the first to estimate a pure electricity volatility model (i.e., a model solely for volatility which can avoid biases originating from misspecified higher or lower moment equations) and define a set of dummy-variables to test for changes in volatility.

Specifically, we use price data from the European Energy Exchange (EEX) to estimate the conditional autoregressive range (CARR) model of Chou (2005). This choice of volatility model is motivated by two reasons. First, classic GARCH models most commonly used for describing the volatility dynamics of commodities (see Tully and Lucey, 2007; Baur and McDermott, 2010) cannot capture the extraordinary characteristics of electricity prices and volatilities which have their origins in (i) the non-storability of electricity requiring a constant balance between production and consumption and (ii) the dependence of electricity demand on the weather and the intensity of business and everyday activities. For example, they show significant jump patterns (see Seifert and Uhrig-Homburg, 2007) which call for the CARR model because it is designed to accommodate such extreme values. Second, range is not only an efficient estimator of local volatility (see Parkinson, 1980; Andersen and Bollerslev, 1998), range-based volatility models have also been shown to provide sharper volatility estimates compared with classic GARCH models (see Chou, 2005; Brandt and Jones, 2006; Miralles-Marcelo et al., 2013).[3]

To test for significant differences in market volatility, we follow the standard way of analysing the impact of periodic events (see Connolly, 1989; De Jong et al., 1992). That is, we estimate an econometric model (the CARR model for the weekly electricity price range) and augment the model by structural dummy variables representing different (regulatory) periods. The significance of the dummy coefficients then allows a judgement of significant change over time. In addition to using such exogenously determined dummy variables, we implement a procedure which calculates optimal breakpoints and then use the corresponding dummy variables in our CARR model.[4] Specifically, we apply the Narayan and Popp (2010) endongenous structural break unit root test which (i) has become a new standard in recent studies explaining the dynamics of energy variables (see Apergis and Payne, 2010; Salisu and Fasanya, 2013; Tang et al., 2016), (ii) can identify up to two breakpoints, (iii) has been shown to have better size and power than related tests and (iv) identifies structural breaks accurately in finite samples (see Narayan and Stephan, 2013). Finally, in order to ensure the robustness of our analysis, we perform several sensitivity checks that take into consideration additional model variables, alternative range measures, different error distributions, an alternative procedure to determine optimal breakpoints, and different data frequencies.

The remainder of our article is organised as follows. Section 3 provides a brief description of our dataset. Section 3 discusses our dummy-augmented CARR model. Section 4 contains our results, including the estimated CARR parameters for the weekly price range of the entire market, a sub-analysis for hourly electricity contracts, and some robustness checks. Finally, Section 5 summarises and concludes.

2. Data

In our analysis, we use market data supplied by the EEX which was founded in 2002 by a merger of the first German electricity exchanges in Frankfurt and Leipzig. Specifically, we obtain a rich sample of hourly electricity price data from June 2000 to August 2015.[5] This data is the basis for the daily EEX baseload contract and covers 5,556 days with 133,344 hourly day-ahead prices.

Due to transmission constraints, electricity markets are local markets with individual features depending on the climate, power plant park and other characteristics. As a result German data shows some special properties in comparison to data from other electricity markets. The German electricity market has a power plant park which is a well-balanced mix of nuclear power, lignite, coal, and gas-fired plants and a high part of regenerative power plants. Highest loads and prices occur in winter months due to low temperatures such that this kind of seasonality has to be considered in volatility modelling.[6] In addition, past studies observe

[2] This is partially related to the fact that some authors argue that lower prices also suggest lower volatility. However, we know from statistical theory that a lower average price level does not necessarily imply lower volatility (see Crawley, 2015).

[3] This is partially related to the fact that they use a wider information set. While a GARCH model uses only the closing prices of the range interval, say a week, the CARR model uses the entire price path in the interval in computing its range variable. Furthermore, CARR models are more robust to market microstructure noise (see Anderson et al., 2015).

[4] We thank an anonymous reviewer for pointing out this approach. It is similar to Salisu and Fasanya (2013) where the identified breaks are added to the mean equations of different crude oil GARCH models.

[5] Previous studies analysing the impact of renewables on the German electricity market cover significantly smaller samples of mostly just three years (see Dillig et al., 2016).

[6] There is also evidence of weekly seasonality with lowest prices at the weekends. Furthermore, holiday effects can be identified with lower price levels (see Seifert and Uhrig-Homburg, 2007). However, because our analysis is conducted using a weekly range, such effects are not crucial for our volatility process.