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The case of negative day-ahead electricity prices ☆

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ABSTRACT

In recent years, Germany has significantly increased its share of electricity produced from renewable sources, which is mainly due to the Renewable Energy Act (EEG). The EEG substantially impacts the dynamics of intra-day electricity prices by increasing the likelihood of negative prices. In this paper, we present a non-Gaussian process to model German intra-day electricity prices and propose an estimation procedure for this model. Most importantly, our model is able to generate extreme positive and negative spikes. A simulation study demonstrates the ability of our model to capture the characteristics of the data.

1. Introduction

Following the liberalization of markets, electricity is now traded in a similar fashion to other commodities. During the last two decades, spot and forward markets have been established in many countries. Consequently, the behavior of electricity prices has been discussed and analyzed by practitioners and academics for the purposes of structuring, pricing and trading, implementing hedging strategies, and estimating the risks of energy portfolios.

Due to the special features of electricity, most notably its non-storability, the modeling of electricity prices is far from trivial. For many applications such as risk management it is however, essential to be able to properly describe the complex price behavior.

Therefore, a detailed analysis of historical data is necessary to accurately build up a model that permits us to capture the characteristics of the dynamics of electricity prices. Several models have been proposed for electricity price dynamics. In general, we can roughly divide these electricity models into two groups: spot price models and forward price models. In this paper, we introduce a model within the first category.

Stochastic processes driving the spot price dynamics proposed in the extant literature are designed to model seasonality, mean reversion, high volatility, and occasional positive spikes. Positive spikes are referred to upward jumps followed shortly by a downward jump and are the result of occasional outages, capacity limits of generation and transmission facilities or sudden, unexpected and substantial changes in demand or supply. In the following, we introduce a model that is able to generate also negative spikes. These can (but do not have to) generate negative prices.[1]

Thus, we consider another important feature of the price process which is peculiar to electricity markets: prices can be negative. In particular, we base our analysis on German intra-day prices from the European Energy Exchange (EPEX).[2] Covering the French and German

☆ The views expressed in this paper are solely those of its authors. It does not necessarily express the views of the company that the first author is working for.

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[1] For example, a drop from 100€/MWh down to 10€/MWh within 1 h and a subsequent upward jump can be considered a negative spike of −90€/MWh. However, when analyzing electricity markets, negative spikes can also be observed at or to a negative price level, e.g. a drop from 25€/MWh down to −100€/MWh within 1 h and a subsequent upward jump.

[2] EPEX is a joint venture owned by Powernext (50%) and EEX (50%). In May 2008, EEX and Powernext announced the cooperation of their electricity markets, resulting in the creation of two new companies:

- EPEX Spot SE: based in Paris, the joint venture EPEX Spot facilitates power spot market trading 365 days a year on the French, German/Austrian and Swiss hubs;
- EEX Power Derivatives: based in Leipzig, the company facilitates German and French power derivatives trading for futures and options.

markets, the EPEX could be considered the most important trading venue in Europe.

Analyzing the EPEX market, we can observe positive and negative price spikes.[3] For example, we observe a negative spike with size −99.93 €/MWh on November 24, 2009 from 3 am (−50.01 €/MWh) to 4 am (−149.94 €/MWh) and −34.05 €/MWh on January 6, 2008 from 6 am (36.07 €/MWh) to 7 am (2.02 €/MWh), and a positive one on November 25, 2008 with size +359.48 €/MWh from 5 pm (+134.78 €/MWh) to 6 pm (+494.26 €/MWh).[4] Fig. 1 shows the price series for these three dates.

Although occurring infrequently, these spikes appear often enough that disregarding them might be grossly negligent. Most likely, they are a result of the growth of electricity production from renewable sources enforced by the German Renewable Energy Act (Erneuerbare-Energien-Gesetz—EEG).[5] Negative spikes can also occur in periods of very low demand or interconnection failure.

Negative electricity prices pose a substantial challenge in energy risk management activities and for optimization and realistic valuation of generating facilities. We propose a non-Gaussian process to model German intra-day prices that permits us to capture the standard characteristics of electricity, namely seasonality, mean reversion, fat tails, positive spikes and, additionally, negative spikes. Furthermore, we propose a simple and practical estimation procedure for our model.

By doing so, we contribute to the literature in various ways. First, to the best of our knowledge, we are the first to conduct a detailed study on the problem of negative spikes in electricity markets. Second, we are also the first to propose an arithmetic Lévy-based fractional autoregressive (FAR) model to describe electricity price dynamics with negative prices and negative spikes. Although Knittel and Roberts (2005) observe negative prices when studying the distributional and temporal properties of hourly electricity prices from California, they do not investigate them from a modeling standpoint. Third, our paper contributes to the empirical literature as we are the first to study the EEG's effects on hourly German day-ahead spot prices.

The rest of the paper is structured as follows. In Section 2, we describe the EEG and discuss its effects on day-ahead spot prices in the German market. Section 3 provides a literature review of electricity spot price models. In Section 4, we introduce a model for the dynamics of electricity spot prices allowing for positive and negative price spikes. In Section 5, we describe the data used and develop the estimation procedure for our model. In Section 6, we demonstrate the ability of our model to capture the features of the data. Section 7 concludes.

2. The German electricity market and the effects of the EEG

In Germany, coal, nuclear, and gas power are the most important resources to produce electricity. However, renewable sources for electricity production have become more and more important. Wind represents the major renewable source of electricity in Germany. According to information provided by the German government, electricity consumption generated by wind turbines was 37.8 TWh in 2009, which equals 6.5% of Germany's total electricity consumption in that year. From 1995 to 2009 the renewable capacity has grown by an average rate of 10.95% per year.[6]

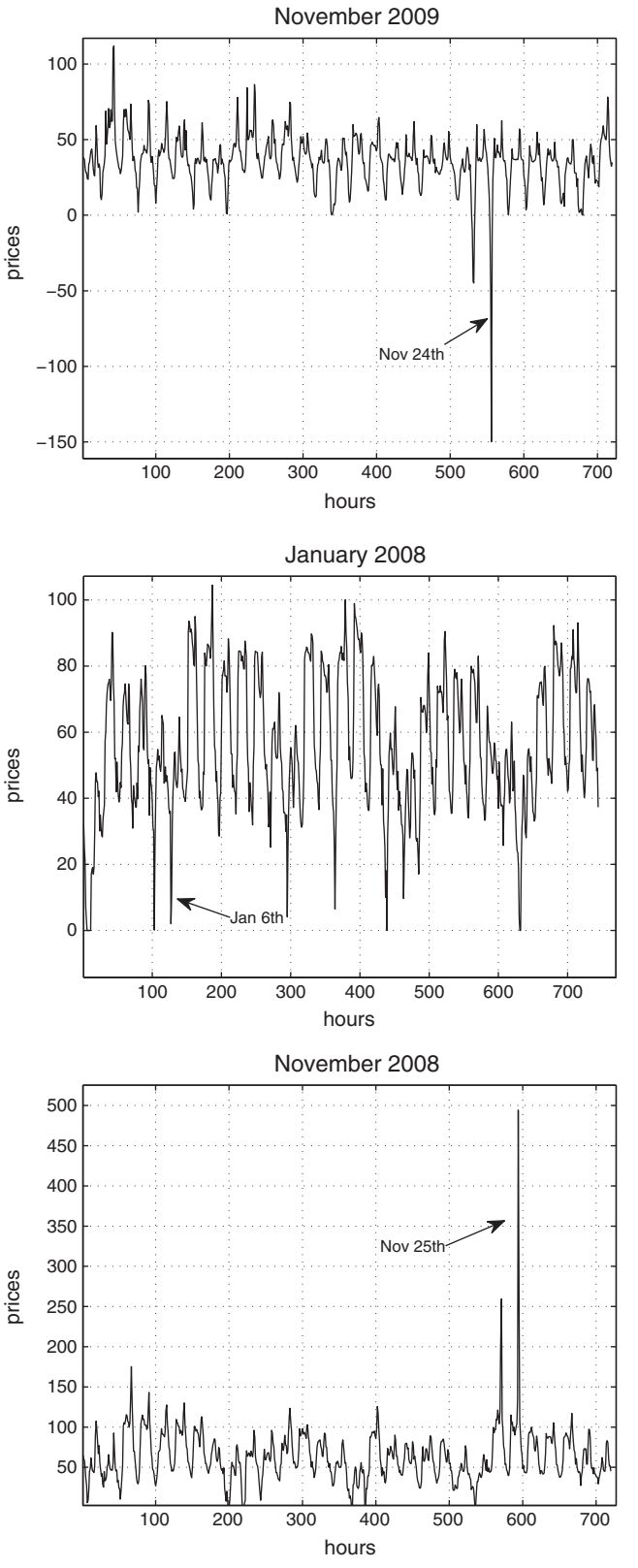

Fig. 1. Negative and positive spikes. Time series of hourly EPEX day-ahead electricity prices (in €) for the German market in November 2009 (top graph), January 2008 (middle graph), and November 2008 (bottom graph).

The development of wind-based generation technologies has been mainly driven by a guaranteed feed-in tariff due to the Electricity Feed-In Act (Stromeinspeisungsgesetz—StrEG), which has been in place since 1990. The aim of feed-in tariffs (FITs) has been to support

[3] Negative spot prices are a new phenomenon in European power markets. Nordpool electricity prices have exhibited this feature since the end of 2009. In the US, this phenomenon has also been observed; furthermore, negative spikes can be also observed, as analyzed in Knittel and Roberts (2005).

[4] The identification of a spike (whether positive or negative) can be done using some statistical procedure (see Section 5.2).

[5] See Section 2 for a description of the EEG and its consequences for electricity prices.

[6] This information can be found on the webpages of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): www.bmu.de/english.