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Master Thesis

Using Ensemble Learning for Price Prediction in German Short-term Electricity Markets

The increasing share of renewable energies has caused an exacerbated need of short-term trading opportunities for electricity. Forecast uncertainty and highly volatile feed-in profiles of renewable energies favor the trade of shorter contracts closer to the time of physical delivery [1,2,3]. Against this backdrop, the German electricity market design comprises successive markets which differ in terms of their respective market design. The day-ahead auction which is probably the most important wholesale electricity market is held at noon one day ahead physical delivery and allows for trading hourly contracts. Its uniform market clearing price acts as an important reference price. As information with respect to the electricity generation by renewable energies is updated several times until delivery, there is a need to balance the corresponding short-term forecast errors. As a consequence, the continuous intraday market which allows to balance forecast errors continuously until 30 minutes[1] before delivery was established in Germany. The continuous intraday trading period begins at 3pm one day ahead delivery. Within continuous intraday trade, bids and asks are continuously matched whenever possible and a pay-as-bid principle is applied.

When analyzing the development of prices along the continuous intraday trading period, it is striking that electricity prices for the same product vary significantly dependent on the time difference between the trading and delivery period. Especially close to market closure, a very high volatility of prices can be observed. These relations suggest that the predictive and explanatory power of different influencing factors may vary across the trading period. These influencing factors, for example, comprise previous price observations, the current market liquidity, forecast errors with respect to load as well as renewable electricity generation, and day-ahead prices. Intuitively, one may expect that the impact of these rather fundamental impacting factors decreases closer to physical delivery as herding behavior and irrational decision-making tend to prevail. Furthermore, the relative importance of different influencing factors may also vary along the day due to typical working hours. Imagine, for example, that especially smaller trading companies may apply trading bots during the night, whereas human traders process the transactions based on market information from 9 am to 5 pm.

As a consequence, the performance of different data science approaches and models with the purpose of predicting continuous intraday auction prices may differ significantly dependent on specific framework

[1] Inside one specific balancing zone, it is possible to trade continuous intraday contracts until 5 minutes before delivey.

conditions. These framework conditions may especially refer to different hours of the day, seasonality, and different trading periods. Consequently, the model choice may be ambiguous.

One suitable approach to circumvent hindrances related to strongly changing accuracy of different predictive models is the usage of ensemble learning [4]. Ensemble learning means the derivation of a combined prediction based on several, potentially fundamentally different, underlying models and their respective predictions. In the end, the basic idea boils down to assigning weights with respect to the individual models. According to the previous considerations, optimal weights may differ dependent on the specific framework conditions and have hence to be learned using suitable data science techniques.

To support the decision making process of relevant stakeholders, such as energy trading companies, the results of the data science approach shall be contextualized against the backdrop of the underlying business goals. One major purpose is to develop and test different trading strategies based on the prediction algorithm and historical market data. Furthermore, this thesis shall address how to implement the models which have been developed within the thesis in a real-world business application.

This thesis will be supervised in collaboration with ProCom GmbH. We will provide extensive historical order book data from German intraday electricity markets covering a sufficient period of time to guarantee meaningful results.The data science and machine learning tools shall be developed by the use of the *Python* programming language.

Literature References:

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[4] Zhang, C. and Ma, Y. (2012). Ensemble Machine Learning. Methods and Applications. Springer

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