Quantifying the Influence of Volatile Renewable Electricity Generation on EEX Spotmarket Prices using Artificial Neural Networks

Bachelorarbeit

zur Erlangung des akademischen Grades „Bachelor of Science (B.Sc)“ im Studiengang Wirtschaftswissenschaft der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

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Ort, Datum: Hannover, den 11.08.2015

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1 Introduction

Most achievements of modern society are dependent on stable availability of a source of energy. During the 20th century, conversion of fossil fuels into usable energy was the main energy-source for most developed countries. The most commonly used fossil fuels were coal, oil and natural gas. During this time, the world has seen an unprecedented economic growth. Towards the end of the 20th century several problems of different nature started to arise: First, the massive conversion of fossil fuels into usable energy releases carbon-dioxide, which plays a critical role in climate change. Second, the dependency on fossil fuels lead to multiple international crises, because many countries are dependent on importing almost their entire consumption of fuels. Third, the use of fossil fuels for energy generation is limited to the availability of those resources. Due to the amounts of resources necessary to fuel the modern world, relying on the use of fossil fuels is unsustainable and it is estimated, that by the end of the 21st century most fossil fuels will be depleted. This event is commonly referred to as Peak Oil.

In order to solve these problems it is necessary to shift the sources of energy towards ecological sustainability. Germany has been one of the first countries to put this need for a shift on the political agenda, with the earliest legislation dating back to 1991. The legislation regarding renewable energy generation has changed several times since then, with the most famous being the Erneuerbare Energien Gesetz (EEG). The purpose of this legislation is to facilitate the transition towards renewable electricity generation, by subsidizing and prioritizing the feed-in of renewable electricity into the power grid. Subsidies in this context mean a fixed feed-in tariff for renewable electricity. During the early 21st century, subsidies have lead to a significant growth of the market share of renewable electricity in Germany. The problem with renewable energies like wind-power and photovolataic-power lies in the volatile generation, depending on external factors like sunshine and wind. Volatile electricity generation threatens energy security, because there might be times, when energy supplied by renewable sources is very low and therefore not able to meet demand. To cope with this uncertainty, it is necessary to adjust the remaining electricity generation accordingly, so that demand can be met. The volatility of renewable electricity generation in combination with fixed feed-in tariffs has lead to a rise in extreme price movements on common exchanges for electricity, namely European Energy Exchange (EEX) and European Power Exchange (EPEX). It has become a common phenomenon, that during certain hours of the day, especially at night because of low demand, extreme negative price strikes occur, with prices going several hundred euros below zero.

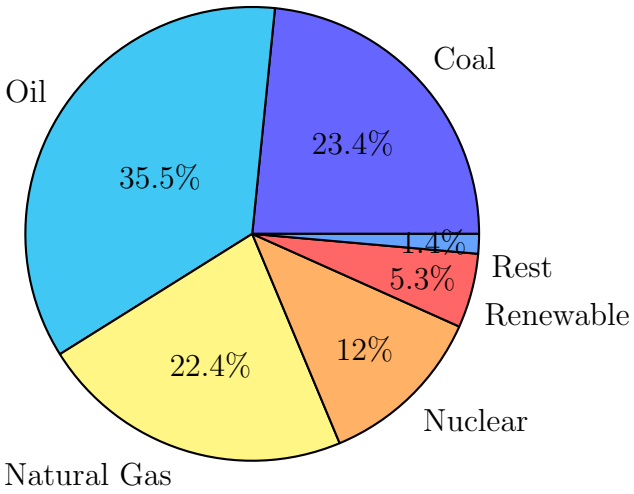
To investigate the link between renewable electricity generation and EPEX continuous prices, a neural network model is deployed. The model is generated using the neurosimulator Fast Approximation with Universal Neural Networks (FAUN), provided by the Institute of Information Systems Research at Leibniz University of Hanover. A neural network model is used, because the impact of renewable electricity generation on EPEX prices is most likely

non-linear. Electricity has special features, that differentiate it from other commodities. Most important of these features are the inelasticity of demand and the inability to efficiently store electricity. The inelasticity of demand leads to a market clearing for electricity at any given point in time. In the electricity market the supply always has to equal demand, because of stability needs of the power grid. Additionally demand exhibits a seasonal pattern on an intra-day and longer perspective. Especially the intra-day seasonality of demand strongly affects prices. At night, when demand is comparatively low, the price for electricity is significantly lower than for peak demand hours during the day. Neural networks are able to model arbitrarily complex non-linear relations and can therefore be used to assess this problem.

2 German Energy Market

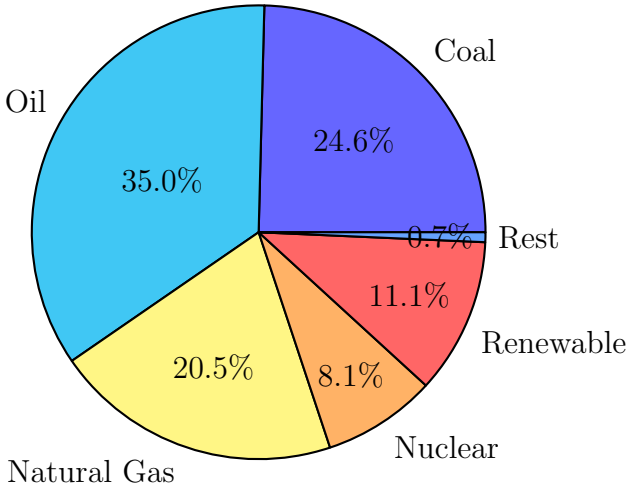
2.1 Primary Energy Consumption

In order to assess the demand for energy in an economy, and to describe the corresponding sources, it is necessary to have a quantity representing the total power consumption. Primary Energy refers to energy found in natural resources before undergoing any kind of transformation or conversion. Due to losses occurring in the transformation process, primary energy is greater than actual demand, but it accurately measures all resources necessary to generate enough power to satisfy demand. This has the inherent advantage, that it provides an accurate picture of resource consumption and structure of resources used.
Figures 1 and 2 show the structure of primary energy sources in Germany for the years 2005 and 2014.



Source: [Arbeitsgemeinschaft Energiebilanzen e.V., 2015]

Figure 1: Structure of Primary Energy Sources Germany 2005



Source: [Arbeitsgemeinschaft Energiebilanzen e.V., 2015]

Figure 2: Structure of Primary Energy Sources Germany 2014

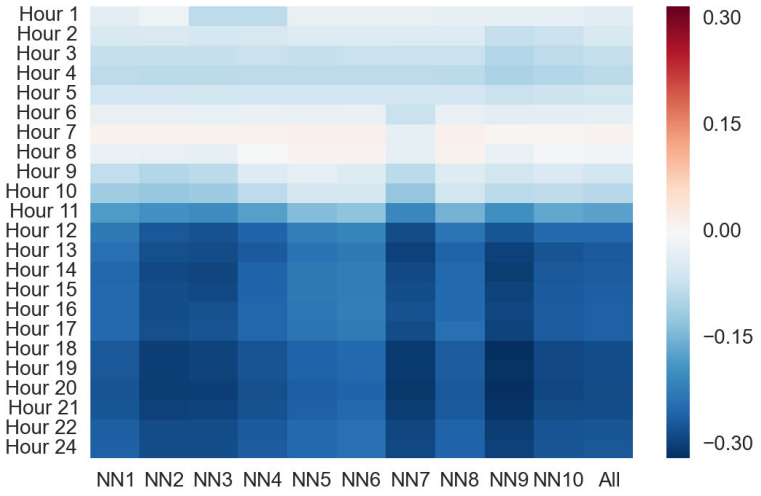


Figure 14: Heat Map, Sensitivity of Last Price to 10% increase in Renewables

monotonously negative, suggesting that there is a general negative relationship between the in-feed from renewables and Last prices. As in the previous figure, the magnitude of the reaction of Last prices is dependent on the examined hour. During morning hours, the magnitude of the reaction is significantly lower than during other hours. On average an increase of in-feed from renewables by 1 GWh lowers the Last price by 0.15€.

8 Conclusion

In this paper the relationship between the amount of electricity generated by renewable sources and EPEX continuous Last prices was analyzed. Due to strong seasonal effects on electricity demand, the modeling of electricity prices is a very complex topic. In order to quantify the relation an ANN model was deployed to model electricity prices. The model was able to capture the general behavior of electricity prices quite well, but had problems modeling extreme positive and negative price spikes, which occur in electricity markets. After modeling electricity prices, a sensitivity analysis was performed to quantify the influence of renewable electricity in-feed on prices. The sensitivity analysis showed a monotonously negative relationship between the in-feed from renewable electricity and EPEX Last prices. The magnitude of this negative relationship differs depending on the examined hour and therefore quoting an average relationship might be too simplistic.

Due to the negative relation of renewable electricity generation on Last prices, it can be expected, that the general level of electricity prices is going to fall in the future, as an even larger share of electricity production will come from renewable sources.

If the findings of this paper are compared to the findings of [Ziel et al., 2015] it is evident, that the relation between in-feed from renewable electricity and EEX day-ahead futures prices is much stronger, than the relation between renewables in-feed and EPEX Last prices.

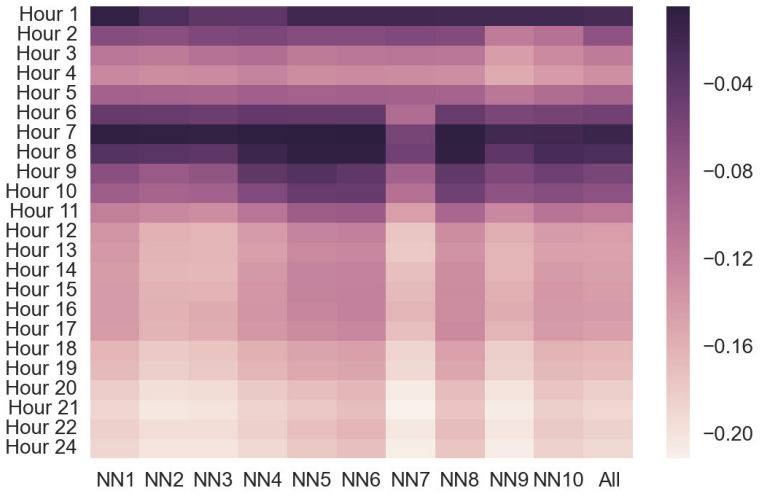


Figure 15: Heatmap: Sensitivity of Last Price to a flat 1GWh increase in Renewables

The reason for this might be, that market participants are able to anticipate the approximate amount of in-feed from renewables for the following date and therefore the negative relation between the amount of renewable electricity and Last prices is already priced by day-ahead futures.

A possible subject for future work would be repeating the performed analysis for non-business days. It can be expected, that the influence of renewables on electricity prices will be larger on non-business days, than on business days.

Due to the general pricing capabilities of the ANN electricity pricing model, it could become the basis of a decision support system for determining electricity prices. For this purpose, the ANN model could be enhanced, by including information on other fundamental drivers of electricity prices. However, it would also be necessary to change the model structure from an ex-post model to a forecasting model, which would certainly decrease its performance.