**Uncertainty in Electricity Markets: The German Case**

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## Overview

The reduction of greenhouse gas emissions demands an increasing share of renewable energy resources (RES) in the European electricity system. To achieve this goal, an adaptation of the conventional generation portfolio, as well as investments into the transmission infrastructure are generally agreed on as necessary measures. However, there remains an inherent uncertainty about the speed and circumstances of this transition process.

This uncertainty relates to market parameters, e.g., the future electricity demand, the price path of CO2 certificates, fuel prices, and investment costs in generation capacity and transmission lines, but also to uncertainty about the underlying pricing schemes, e.g., the bidding zone configuration and the regulation of congestion management. Investment decisions in both generation and transmission capacity are affected by this uncertainty. To develop a better understanding of investments in the electricity sector for different possible scenarios, it is therefore necessary to analyse electricity markets under uncertainty.

Germany is a suitable example to apply an analysis on investment decisions, as the renewable transition has reached a point where it requires a system transformation from the “old & static” system with mostly conventional generation capacity to a “new & flexible” system, which allows the integration of large shares of fluctuating renewable generation. This includes the phase out of non-flexible conventional generation capacity and network investments to reduce internal bottlenecks between northern and southern Germany. These bottlenecks also induce uncertainty about the future bidding-zone configuration within Germany, as it is possible that EU regulation will enforce a split of the German bidding zone to deal with internal congestion issues [1] [2]. In addition to that, there is also uncertainty about the renewable transition in neighbouring markets, which will influence actors on the German market as well.

In this research, an analysis is conducted, that focuses on regulated investment decisions in transmission capacity and investments into generation capacity by independent firms in a stochastic model environment. The theoretical background of this model analysis is given in [3]. This model covers the German market for electricity including several neighbouring countries and is backed up by an aggregated transmission network model for Germany. Decisions under uncertainty regarding the national bidding zone configuration incorporate a possible change from one bidding zone to a system with additional regional price signals, in this case a price zone split between northern and southern Germany. In addition, a nodal pricing scheme is analysed as a further scenario. In order to also incorporate uncertainty about the neighboring countries’ pathways to decarbonisation, scenarios reflecting the future market parameters in Europe are considered.

## Methods

We conduct an analysis focusing on regulated transmission investment in Germany and investment in generation capacity by independent firms in a stochastic model environment incorporating both uncertainty on market parameters and the bidding zone configuration. There is only few work focusing on uncertainty regarding bidding zone reconfiguration. Usually, uncertainty about market parameters is solely considered [4]. Alternatively, possible bidding zone configurations are compared to each other [5], however without incorporating uncertainty about a possible reconfiguration.

A stochastic trilevel optimization problem is used to model the named investment decisions in generation and transmission capacity.

1. The German regulator decides on transmission capacity investments at the **first level**. Uncertainty regarding the possible bidding zone split is accounted for by maximizing expected welfare. On this level, the regulator anticipates the two following levels.
2. Private firms act on the spot market for electricity at the **second level**. They decide on optimal generation and investments into new generation capacities. The market is characterized with perfect foresight and perfect competition. No temporal interdependencies are assumed.
3. Necessary congestion management in terms of case cost-based redispatch is determined for Germany at the **third level**.

This trilevel model can be reformulated into a two-staged model by combining the first and the third level into a single one [6]. The two resulting optimization problems are implemented either as mixed-integer quadratic problems or linear ones and are written in General Algebraic Modeling System (GAMS).

## Results

The results for the German electricity market incorporate the uncertainty about a possible bidding zone split between northern and southern Germany as well as a split towards nodal pricing under two scenarios focusing on the development of market parameters. Different probabilities for the bidding zone reconfiguration were chosen. The main focus is put on the modelled investments in generation and transmission capacity. For both, optimal decisions change, if the uncertainty about a possible bidding zone split and therefore possible regional prices is considered. For investments into new generation capacities, an anticipation of possible regional prices leads to a more efficient choice regarding the location as well as the choice the technology. Northern Germany is characterized by a relatively low demand, but a high potential for RES, especially wind. In contrast to this, Southern Germany has a higher relative demand. Therefore, the uncertainty about possibly two different price signals can help enhancing the efficiency of investment decisions. The anticipation of a possible bidding zone split towards nodal pricing would further enhance efficiency. Investments into transmission capacity depend on the location of investments into generation capacity and the resulting bottlenecks. A possible bidding zone split can take into account the alternating choice of investments into new generation capacity and therefore lead to more efficient network expansion.

## Conclusions

The mere possibility of a bidding zone reconfiguration within Germany can influence the investment decisions into generation and transmission capacity. Possible bidding zone splits approaching a nodal pricing scheme can positively influence the decision making regarding efficiency. In contrast, a possible merge of bidding zones might consequently lead to less efficient decision making by private firms, as price signals loose their local character. Parts of the welfare gains for a possible bidding zone split between northern and southern Germany are already realized, when an expectation is formed. However, the forming of expectations cannot be used as a policy tool. In the end, it needs to be stated, that expectations about future market design cannot substantially differ from reality. Still, policy makers should be aware of the effects of uncertainty regarding the market design on the market participants.

## References

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| [1]  | J. Egerer, J. Weibezahn and T. Hermann, “Two price zones for the German electricity market - Market implications and distributional effects,” *Energy Economics,* vol. 59, pp. 365-381, 2016.  |
| [2]  | K. Trepper, M. Bucksteeg and C. Weber, “Market Splitting in Germany - New evidence from a three-stage numerical model of Europe,” *Energy Policy,* pp. 199-215, 12 2015.  |
| [3]  | M. Ambrosius, J. Egerer, A. V. Grimm and A. van der Weijde, “The role of expectations for market design - on structural regulatory uncertainty in electricity markets,” 2019.  |
| [4]  | N. Gal, I. Milstein, A. Tishler and C. Woo, “Fuel cost uncertainty, capacity investment and price in a competitive electricity market,” *Energy Economics,* vol. 83, pp. 658-668, 2015.  |
| [5]  | T. Felling and C. Weber, “Consistent and robust delimitation of price zones under uncertainty with an application to Central Western Europe,” *Energy Economics,* vol. 75, pp. 583-601, 2018.  |
| [6]  | V. Grimm, A. Martin, M. Schmidt, M. Weibelzahl and G. Zöttl, “Transmission and generation investment in electricity markets: The effects of market splitting and network fee regimes,” *European Journal of Operational Research,* vol. 254, no. 2, pp. 493-509, 2016.  |