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Investments and Market Outcomes under Regulatory Uncertainty: A Case Study of German Electricity Bidding Zones

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Motivation
The German bidding zone prevents that structural north-south bottlenecks in the transmission system become visible on the electricity market, i.e., there is no regional price discrimination. In the short-term, this results in inefficient market results at national and European level, which translates in technical infeasible market results due to network constraints, high levels of congestion management and increased system costs. In the mid-term, the lack of regional pricing results in inefficient regional investment incentives for transmission projects, generation capacity, electricity storages and large consumers. The academic literature has shown since many years that a market setting with two or more bidding zones can reduce congestion management costs and increase system welfare (Egerer et al., 2016; Grimm et al., 2016; Trepper et al., 2015). However, implementing bidding zone configurations as suggested in the bidding zone review (ENTSO-E, 2025) is politically challenging in Germany and the ongoing discussion results in regulatory uncertainty for stakeholders. This study extends the literature on regulatory uncertainty on the possible implementation of different bidding zone configurations in Germany which would affect investment decisions and market rents of various actors, as well as redispatch costs and the overall efficiency of the system. In particular, the impact of investments and operation of flexibility at regional level is evaluated.

Methods
In order to assess the impact of regulatory uncertainty on future bidding zone configurations (one, two or five bidding zones) in Germany within the European integrated electricity market for the year 2030 a comparative analysis is carried out using a multi-level electricity market model (Egerer et al., 2025; Grimm et al., 2016). The scenarios are compared, assuming uncertainty regarding the introduction of either one or two or one or five bidding zones, each with an increasing probability of one of the bidding zone configurations occurring. The research question is analyzed using a stochastic two-level electricity market model that captures (dis)investment decisions, market operation and congestion management under uncertainty regarding future bidding zone configurations (cf. Ambrosius et al., 2020). At the first level, companies decide on (dis)investments in generation, storage and electrolyzers within the framework of the equilibrium price on the spot market and the aim of maximizing welfare. This is done by taking into account investment and operating costs, trading capacities and the uncertainty regarding the future bidding zone configuration in Germany. Subsequently, after the realization of one bidding zone configuration, companies participate on the spot market for one reference year with hourly time resolution with their realized (dis)investment decisions from the first level. The two steps of investment and operation can be combined in one level in the mathematical model optimizing system welfare under uncertainty of future bidding zone configurations. At the second level, the costs of congestion management are minimized on the basis of cost-based redispatch by a transmission system operator (TSO). In redispatch, the physical load flow requirements must be met based on market results using a lossless direct current (DC) load flow approximation of an aggregated German electricity grid.

Results
The preliminary results show that the degree of uncertainty regarding the future configuration of bidding zones has a significant impact on the level of investment in various technologies. Even a low probability of more than one bidding zone occurring is sufficient to position the investment locations and their capacities in a certain way. This means that the technologies in which investments have been made contribute to an increase in system welfare if, contrary to the low probability, more than one bidding zone is actually implemented. As another aspect the influence on redispatch costs have been considered. It has been shown that

those redispatch costs rise in the case of only one bidding zone continuing after the investments have been made under the uncertainty. Additionally, it has been shown that the total redispatch costs increase with the increasing probability and actual implementation of more than one bidding zone. This effect can be explained by the increasing capacity of electrolyzers and the associated greater demand for electricity. But it should be emphasized, that the total redispatch costs are lower in the cases with more than one bidding zone compared to the case with one bidding zone. In addition to those examples the dependency on the degree of uncertainty was analyzed for various positive and negative effects on the rents of different technologies.

CV

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