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Analysis of design options for the electricity market: The German case

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HIGHLIGHTS

- EOM performs well in the short term, but fails without support in the long term.
- High capacity of sheddable loads helps to guarantee generation adequacy in the EOM.
- Capacity market leads to additional investments and a higher adequacy level.
- No market design option can be assessed as the most cost-efficient one.
- Agent-based simulation is an adequate methodology to evaluate market design options.

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ABSTRACT

The effectiveness of the energy-only market (EOM) in providing sufficient incentives for investments is intensively discussed in Europe. While supporters claim that an improved EOM can guarantee generation adequacy, energy suppliers in particular favor the introduction of a capacity market to finance power plant investments. However, there is a lack of quantitative assessment of market design options taking into account individual decisions of market players. Existing studies mainly include a system view based on a central planner optimization. This paper on the other hand is based on an agent-based simulation model for the German electricity market. This method can explicitly incorporate individual investment decisions and aggregate them to present a holistic view of the system.

Our results show that an EOM extended with a strategic reserve can incentivize investments, and guarantee supply security in a market with high share of renewable energies. However, the generation adequacy can be more easily achieved with a capacity market. Furthermore, the cost advantage of an EOM diminishes in the long-term, as scarcity prices in the EOM lead to similar system costs as with a capacity market.

1. Introduction

After intensive discussions in the past few years, some European countries like Belgium, France and the UK have implemented capacity mechanisms. Germany decided to adjust the design of its electricity market (energy-only market) by introducing a capacity reserve, which is similar to the strategic reserve mechanisms found in some other European countries (e.g. Belgium, Sweden). Major changes such as the implementation of a capacity market are rejected under the current proposal of the electricity market act (in German: "Strommarktgesetz", see Federal Ministry for Economic Affairs and Energy [BMWi] [1]). However, the appropriate market design remains a controversial issue.

The reason for that are ambiguities regarding whether the current energy-only market (EOM) can provide sufficient incentives for investments in flexible generation technologies to ensure the long-term security of supply or not. The wholesale electricity prices are currently very low (see Table A.1 in the appendix), which can be explained by different factors. Firstly, there are surplus capacities originating from times before the liberalization of the energy market. The surplus increased due to the large-scale introduction of renewable energies in addition to the coupling of European market areas. And secondly, the currently low CO_2 and coal prices lead to low electricity prices, thereby favoring coal-fired power plants. These developments cause gas-fired power plants to be less competitive.

As the electricity feed-in from intermittent renewable energy sources (RES) rises (e.g. Ederer [2]), the operating hours of conventional power plants subsides. Their revenue situation worsens considerably. However, flexible conventional back-up capacities might

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still be necessary, especially when peak load times overlap low feed-in from photovoltaic (PV) and wind power. This raises the question whether the marginal cost based EOM provides enough incentives for investments in new power plant capacity or whether a capacity market should be introduced as a new market segment for the product secured capacity.

Besides providing sufficient capacity in peak load times, the new market design also aims for other objectives. This includes both the elimination of local supply (grid) bottlenecks within Germany and the conversion of the electricity system towards a more flexible one with sufficient power generation and storage capacity. The latter is especially important with respect to the objective of the federal government to generate 80% of electricity from RES by 2050. Predominantly, flexible capacity such as gas turbines and energy storages, or demand side management (DSM) measures will be required in the future, in addition to the volatile generation of renewable energies. These different objectives also influence the configuration of the future market design and the parameterization of a capacity mechanism [3].

The need for bigger changes to the EOM design and the introduction of a capacity market are still not sufficiently analyzed, especially based on simulative approaches. Existing studies are based on optimization or Cournot equilibrium models (see r2b [4] and Léautier [5]), focusing on a system analysis from a central planner perspective. However, the electricity system changes to a more decentralized one with different market players that follow their own profit targets. This can differ from the objectives of a central planner or the regulator. Besides, market players have to make decisions with limited foresight of future developments. This study therefore focuses on individual decisions and investment behavior of market players. The agent-based analysis of the effectiveness and cost efficiency of different market design options is done by paying attention to the specific decisions of stakeholders and their limited foresight (especially of the major power plant operators and the regulator). Another advantage of agent-based simulation is that it allows the determination of market failures, especially possible capacity gaps (e.g. the power plant operators do not realize sufficient investments to cover peak demand). In contrast to optimizing energy or electricity system models, there is no restriction in the agent-based approach that the demand has to be met in each time step (energy balance constraint). Therefore, in this approach, the total capacity derived from the single investment decisions can be lower than the required capacity to meet the peak demand consistently. This characteristic of the agent-based simulation approach allows for the analysis of generation adequacy, as a possible lack of generation capacities due to less investment activity of market agents can be directly determined from the output of the model.

This paper introduces a powerful method to analyze the effectiveness and cost efficiency of market design regulations that are intensively discussed not only in Germany, but also in other European countries like France, Belgium and UK. The effectiveness of a market design is defined by its ability to trigger investments in power plants or other flexible capacity and to serve the demand for electricity through generation capacity in every point of time. Beside the effectiveness and cost efficiency (the overall system costs of electricity supply) in each market design are also analyzed in this paper.

The analysis of various market design options can support policy makers in their decisions on new regulations for the electricity market. It primarily provides insights about circumstances under which an EOM still can guarantee security of supply, especially generation adequacy, and at which time the introduction of a capacity market could be more advantageous. This study may also help energy supply companies to recognize the impact of different market regulations on their investments and to understand at which point of time new investments could become economically feasible.

To achieve these goals, the paper is structured as follows: Section 2 gives an overview of the most recent literature on the security of supply, in particular regarding the required power plant capacity to meet the demand. The focus here is also on market designs that are favored to guarantee generation adequacy. This is followed by a detailed overview of the proposed market design options for the German electricity market (Section 3).

Section 4 describes the applied agent-based modeling approach for the German electricity market. In the case of an EOM market design, it focuses on investment agents, who make their decisions based on their expected income on the futures and spot market. However, if the underlying market design contains a capacity market or strategic reserves, then the assessment of investments is carried out considering incomes from the capacity remuneration as well. Section 5 focuses on the results, especially on the question whether the EOM can provide sufficient investments and guarantee generation adequacy. Parameters that are essential to improve the effectiveness of the EOM are also highlighted. Furthermore, it is described how much capacity remuneration mechanisms can improve generation adequacy ant to which costs. Finally, the main conclusions drawn from the results are summarized in the last section. This section also critically reflects on the applied modeling approach and discusses possible improvements going forward.

2. Literature review about security of supply and market design analyses

2.1. Literature on security of supply analyses and the role of capacity mechanisms to ensure generation adequacy

There is a wide range of research covering the issue of market design analysis and security of supply. Some of the literature follows a rather theoretical approach (i.e. Stoft [6], Cramton and Stoft [7], and Batlle and Rodilla [8]). But few have conducted a model based analysis (e.g. Genoese et al. [9], Vazquez et al. [10], and Cepeda and Finon [11]) that quantifies the effect of capacity mechanisms on electricity system and prices.

Stoft [6] states that price spikes are necessary for ensuring generation adequacy. These price spikes are required to cover all fixed costs of the generation capacities. Theoretically, a capacity market is not needed, but real markets have two failures: the mostly inelastic demand due to missing real time metering, and the impossibility of excluding consumers not willing to pay for security of supply. Thus, capacity markets are necessary to encourage sufficient investment in new capacity. Cramton and Stoft [7] argue that a capacity market is needed in most restructured electricity markets, and present a design that avoids the many problems found in the early capacity markets. They propose a capacity market, which induces supply to invest in sufficient generation that is in the right location, satisfies a reliability standard at low costs, and is of the right type. They state that the market structure is imperfectly competitive, especially during times of peak load.

Genoese et al. [9] uses the agent-based model PowerACE to compare the impact of capacity payments (similar to that in the Spanish market) on electricity prices and new investments. The results show that a system with fixed capacity payments suffers from overcapacity and lower spot prices. The capacity payments overcompensate the lower electricity prices spot market.

With regards to security of supply, there are several studies that have been carried out recently. The Pentalateral Energy Forum (framework for regional cooperation in Central Western Europe) has published an analysis of the European electricity system until 2021 [12] in which they have stated that there still will be enough