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How to benefit from a common European electricity market design☆

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A B S T R A C T

The realization of an Internal Electricity Market in Europe is currently, on the one hand, progressing, in particular thanks to the wide-spread implementation of market coupling solutions for cross-border congestion management. On the other hand, diverging national market designs pose a threat to the continuation of this process. Given the challenges to electricity market design in a multi-regional context, we analyze how different design aspects, namely cross-border congestion management and capacity mechanisms, affect welfare and generation adequacy in Europe. In doing so, we rely on an agent-based simulation model for electricity wholesale markets which we apply within several numerical, computational case studies for the region of Central Western Europe (2012–2030). Our results confirm the benefits of market coupling in terms of welfare as well as generation adequacy. Furthermore, we find indications that coordinating market designs across regions supports these targets. Therefore, we recommend that European energy policy forms a stable, transparent regulatory framework with cross-border market coupling as an integral component. In this context, energy policy targets should be clearly defined and operationalized, which also needs to consider potential conflicts between them. Finally, electricity market designs need to be coordinated among states to benefit most from a common European market.

1. Introduction

Creating an Internal Electricity Market (IEM) in Europe on the wholesale level is a long-term goal of the European Commission. A harmonized and competitive European electricity market is expected to provide improvements in terms of efficiency, end-user prices, standards of service, security of supply and sustainability (European Parliament and the Council of the European Union, 2009). Transforming formerly regulated, nationalized electricity systems is a complex task and requires the design of various measures and their practical implementation. The plurality of energy policy targets – usually concerning *security of supply*, *economic efficiency* and *environmental impact* – and the predominance of national competencies challenge this process in particular. Overall, cross-border congestion management plays a pivotal role as does the cooperation of relevant bodies, i.e., market operators, grid operators, regulators and politicians (Knops et al., 2001).

Currently, the realization of the IEM is at a critical crossroads (Glachant and Ruester, 2014). On the one hand, there is significant progress, first and foremost, with regard to congestion management between European electricity markets, but also, for instance, on the level of harmonizing different operational processes across member states. On the other hand, there is substantial headwind because of the way how electricity generation from renewable energy sources (RES) and capacity mechanisms in several countries (e.g., France, Germany, Great Britain) are promoted. It is not necessarily the measures themselves that entail a potential risk of slowing down European market integration, but rather the prevalence of uncoordinated national steps. Against this background, it is necessary to evaluate the current and future impact of coupling markets in Europe considering the actual specifics and imperfections of electricity markets. In order to support the creation of an IEM, electricity market design in Europe needs to take into account different levels of interactions between regions, markets and targets.

There is a large body of literature related to coupled electricity markets in general as well as with a specific focus on Europe. First, there is extensive empirical research on the state of the European market integration with a large consensus that there is measurable progress, though it is still a long way from being completed (e.g., Zachmann, 2008; Bunn and Gianfreda, 2010; Menezes and Houllier, 2015). Empirical approaches are suitable for analyzing historical developments, but less for evaluating future market design changes. Second, theoretical as well as numerical work has shown the relative benefits of different approaches to congestion management (e.g.,

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Hobbs et al., 2005; Ehrenmann and Neuhoff, 2009; Neuhoff et al., 2013). While these studies lay the foundations for designing cross-border congestion management, they are often restricted to relatively short evaluation periods ignoring the dynamics of electricity markets over time. Our approach is to be attributed to a third stream which comprises studies explicitly addressing electricity market design issues and target criteria concerning the development of coupled electricity systems. For instance, Boffa et al. (2010) estimate how Italian electricity end-users might benefit from an improved interconnection between the Northern and Southern price zone. The authors find that increasing interconnection capacity, even in small-scale increments, can lead to substantial end-user savings. Cepeda and Finon (2011) analyze the impact of different market designs (e.g., energy-only market, central capacity market) on generation adequacy for a stylized system of coupled electricity markets. Their findings emphasize, amongst others, the merits of harmonizing market designs in coupled systems. Similarly, Ochoa and van Ackere (2015) study interdependencies between France and Great Britain as well as Colombia and Ecuador under varying market design options. They find that the potential welfare benefits of market coupling heavily depend on the complementarities between the coupled markets. For the Finnish electricity market, Ochoa and Gore (2015) analyze potential benefits and risks of an integration with the Russian market. The identified effects on welfare and reliability are strongly determined by the respective market characteristics and policy measures.

Despite existing research, several aspects in the field of cross-border electricity market design are still only scarcely studied. In particular, we identify the need to consider economic efficiency and security of supply under certain market designs in a more integrated and consistent fashion. Market design choices on the wholesale level include selecting cross-border congestion management schemes as well as remuneration instruments (e.g., capacity mechanisms). In this regard, it is essential to highlight potential conflicts between the different targets and market participants in order to point out particular design challenges. Moreover, specific agent decisions over time and market imperfections are important drivers of the development of electricity systems, which equally require a greater attention. The objective of market design is exactly to set a regulatory framework in a way that the market participants' behavior supports achieving energy policy targets. Therefore, the influence of design changes on agent actions (e.g., investments) in imperfect markets like liberalized electricity markets should be considered in an explicit way for certain analyses. Furthermore, conducting numerical studies for detailed real-world cases can help to transfer theoretical findings to the European electricity system. This paper aims to reduce these research gaps and ultimately intends to contribute to the shaping of the European market integration process. While certain aspects in this context, such as the general effect of market coupling on security of supply and economic welfare, have already been studied in isolation, we also see a need for a more comprehensive evaluation considering potential interactions between them. As a result, we hope to derive more balanced recommendations for a future European electricity market design.

Concerning our general research approach, we rely on numerical, computational simulations. Electricity markets can be considered as complex, adaptive systems with heterogeneous participants, various imperfections and out-of-equilibrium dynamics (Tesfatsion, 2006; Miller and Page, 2007). In particular, market areas in Europe are not isolated but interconnected via a physical and economic coupling (Knops et al., 2001). Furthermore, it is vital to analyze the evolution of electricity systems over time in order to consider changes to the market structure (Arango and Larsen, 2011). For instance, imperfect foresight makes the forecast of fundamental price drivers a complex task within the investment valuation process. The approach of agent-based computational economics (ACE) is based on a detailed and explicit representation of agents in an economic system, of their interactions and of an emergent evolution on the macro level (Tesfatsion, 2006). In this paper, we make use of this methodological concept by developing an electricity market simulation model and by applying it to several case studies for Central Western Europe (CWE). Thereby, we study the impact of different market design constellations on security of supply and economic welfare by varying the interconnection network configuration as well as by simulating an asymmetric market design across the considered market areas.

This paper is structured the following way. Section 2 provides relevant background on the design of electricity markets in Europe and on how economic efficiency and generation adequacy can be operationalized. In Section 3, we formally present our methodological approach in the form of an agent-based simulation model for wholesale electricity markets. Our simulation design and relevant input data are illustrated in Section 4. In Section 5, we give an overview of our model results with regard to the potential development of the CWE Market Coupling under various scenarios. Finally, Section 6 concludes with implications for the European electricity market.

2. Background

2.1. Electricity market design in Europe

The architecture and operation of liberalized electricity markets is generally determined by an explicit regulatory framework. Ideally, this electricity market design sets basic incentives for market participants in a way that energy policy objectives are achieved indirectly through the behavior of all parties involved.

In Europe, the long-term goal of creating the IEM requires a European-wide market design of some kind. After the liberalization of the energy sector in the 1990s, electricity markets in Europe have been structured according to different design principles (Stoft, 2002; Wilson, 2002). Notably, a differentiation can be made with respect to the nature of the producers' remuneration in electricity markets. Given that consumers demand a certain amount of electrical energy at a particular point in time, generators typically receive payments depending on the delivered electricity volume, which should cover the respective generation costs. In perfect energy-only markets, investments in new generation capacity are signaled through rising electricity prices in times of scarcity. If these prices materialize in the market, they allow the recovery of fixed operational costs and capital costs. However, given various imperfections in electricity markets (Stoft, 2002; Joskow and Tirole, 2007), the design of electricity markets is an intricate task and the practical functioning of energy-only markets is hard to verify. This is also why so-called capacity mechanisms are often discussed as an additional instrument to ensure security of supply by avoiding plant closures and incentivizing the construction of new plants, respectively (Joskow, 2008). The rise in electricity generated from RES increases concerns that imperfect energy-only markets are not fully suited to provide adequate incentives for market participants (Cramton and Ockenfels, 2011). Traditionally, electricity markets in Europe follow an energy-only design; however, the last years have seen a rising discussion and implementation of different kinds of capacity mechanisms, for instance, in France (MEDDE, 2015), Germany (BMWi, 2016) and Great Britain (DECC, 2015).

Furthermore, electricity markets in Europe follow a zonal design and, hence, neglect intra-zonal congestion. Traditionally, zones are defined according to national borders. As a result, market prices are equal for all market participants in the respective zone and, as such, do not exhibit any locational component but only reflect the marginal generation costs and marginal utility, respectively.[1] At the same time, national electricity markets in Europe are not isolated but intercon-

[1] In case schedules for injection and consumption based on energy market results lead to congested lines, grid operators need to perform curative measures, for instance, through a redispatch of units (Holmberg and Lazarczyk, 2012). These costs are distributed ex post among electricity consumers as part of the grid charges.