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Capacity Remuneration Mechanisms in the Integrated European Electricity Market: Effects on Welfare and Distribution through 2023

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A R T I C L E I N F O

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A B S T R A C T

A reduced attractiveness of investments in reliable fossil power plants in liberalized markets on the background of a transition towards renewable energies has brought a discussion on capacity policies to Europe. I develop a partial equilibrium model to compare effects of three polar capacity remuneration mechanisms (CRMs) based on the assumption that a CRM is indicated. A strategic reserve (SR) policy with administratively set capacity targets, a capacity market (CM) based on public procurement, and a decentralized reserve market with the obligation of generators to finance reserves in relation to their peak supply (RM). Substantial differences of policies arise across countries and regarding consumers and producers due to power plant structures. By 2023, we find the decentralized RM to induce least pronounced distributional effects and only modest welfare reductions, while SR and CM induce higher losses. In the longer term until 2033, welfare results differ less pronounced, although the RM is most friendly to consumers. A robust policy conclusion has to pay attention to further aspects concerning the environment and technological developments.

1. Introduction

A stream of literature investigates efficient pricing in electricity systems, market failure and policy proposals for the achievement of reliable and adequate generation capacity. In order to provide a starting point for the introduction of policy oriented work, I first summarize basic insights from the literature on efficient pricing and give an overview of possible market failures.

Dating back to the era of electricity supply by regulated monopolies, one strand of economic research has been concerned with how to price and incentivize efficient capacity levels. The peak load pricing literature started in the field of electricity with the analysis of cases in a deterministic setting. Boiteux (1960) finds that while off peak consumers should pay only the marginal costs, marginal costs as well as capacity costs have to be borne by peak load consumers. Crew and Kleindorfer who introduce a multiplicity of technologies and uncertainty on the demand side further elaborated these insights. Their numerical results illustrate that as the diversity of technology increases, a higher level of security of supply becomes desirable. They state that the "analysis indicates that a practical evaluation of optimal safety margins is [...] involving a simultaneous assessment of pricing and capacity [...]" (Crew and Kleindorfer (1976)). Chao (1983) extended these findings by also including uncertainty on the supply side. He finds that plant outage probabilities, cost differentials between technologies as well as the length of peak load events are essential for optimal time differentiated pricing. The basic insight of this literature is that efficient prices include a mixture of marginal costs and fixed costs, where periods with more than average consumption, and corresponding high probabilities for a loss of load, contribute over proportionally to fixed costs. Moreover, the optimal mixture of price components depends on time profiles of the uncertainties regarding demand and the availability of technologies.

Real world liberalized electricity markets hardly implement the theoretical ideal of peak load pricing. On one hand, occasional high electricity price peaks are frequently limited by explicit price caps, out of market actions (redispatch) or the inadequate remuneration of ancillary services (Hogan (2013), Newbery (2016)), thereby creating a problem of missing money for investors. On the other hand, it is argued that power plant projects are time consuming so that scarcity prices that correctly signal the demand for capacity may prevail until the new capacities are built, leading to potentially large transfers from consumers to producers (Oren (2003), de Vries and Hakvoort (2004)). Moreover, potentially adequate revenues may not be perceived to be so by generators or their financiers if

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risks are not efficiently manageable, which indicates a problem of missing markets Newbery (2016).

Similarly, de Vries and Hakvoort (2004) summarize a variety of reasons in addi-tion to price caps, which may cause the market to fail to induce efficient investment levels. In particular, they point to the potential problem of imperfect information of investors in regard to stochastic demand and supply developments, as also described by Hobbs et al. (2002). In addition, a potential problem may arise due to regulatory uncertainty for instance with respect to emission policy, nuclear energy policy, and renewable energy policy as has recently been pointed at by Newbery (2016). Such uncertainties have especially pronounced consequences when investors choose a risk averse strategy, which is explained in more detail in Vazquez et al. (2002). These arguments are frequently dubbed market failures and give rise to the literature that provide quantitative and theoretical analysis of alternatives for capacity remuneration mechanisms (CRMs), although the case for the necessity of a CRM remains unclear.

Several of the aforementioned papers also compare effects of the introduction of possible policies for the remedy of assumed market failures. These studies predominantly use stochastic programming techniques under the assumption of inelastic demand (de Vries and Heijnen (2008), Hobbs et al. (2002), Vazquez et al. (2002)). For instance, based on a numerical electricity market model with growth, de Vries and Hakvoort (2004) emphasize the advantages of a system of capacity obligations due to its effective reduction of risk and lower price volatility compared to a policy of operating reserves, a pure energy only market or an energy only market with mar-ket power. More recently, Meyer and Gore (2015) added a numerical analysis to the discussion and demonstrated the importance of interconnections between electricity markets for the effectiveness of the policy design. They find that the unilateral introduction of CRM policies has negative cross-border effects aggravating the miss-ing money problem in an adjacent market without CRM. However, Meyer and Gore (2015) point out that the results critically depend on the assumptions concerning competition in the markets.

A most comprehensive study on policy proposals for electricity system reliability and adequacy is presented in Joskow and Tirole (2007) who cover many of the afore-mentioned aspects and assume the presence of price caps and demand rationing in an analytical framework. Elaborating on a variety of challenges for market solutions in the electricity system, Joskow and Tirole (2007) develop simple economic rules for second best solutions. They show how price caps reduce reliability and how reliability standards can be introduced to compensate for these deficiencies. However, Joskow stresses the view that price caps are unlikely to be the sole source of the so-called missing money problem (Joskow (2006), (2008)), and proposes a set of measures that can be used to remedy at least part of the suspected problems of liberalized markets. These measures include raising the price caps, require prices to rise to the price caps if the system operator has to take out of market actions (e.g. redispatch), increase real-time demand response, include more operating re-serves products in the market, and review and adjust reliability rules and protocols. Similarly, Lehmann et al. (2015) advocate on the basis of theoretical reasoning and empirical evidence that it is indicated to first strengthen existing structures before resorting to a complete reorganization of markets, particularly since it is difficult to revise such policy.

In summary, the results from the literature are ambiguous, and stress that the case for the introduction of CRMs and merits of their exact form depends on a variety of system characteristics. In addition, potential distributional effects of CRMs appear considerable as is emphasized by Oren (2003), and de Vries and Hakvoort (2004) and are to the best knowledge of the author not sufficiently studied earlier. I therefore investigate three polar CRMs to develop their distributional properties and relative welfare effects. However, I do not attempt to solve the question whether a CRM is indicated or not. Rather, the present work contributes to the understanding of the political economy of CRMs by highlighting their potentially substantial transfers. For that aim, I further develop a model on the basis of EMELIE-ESY (Schröder et al. (2013)).[1]

The set of analyzed policies include a strategic reserve (SR), a centralized capacity market (CM), and a reserve obligation implemented by a certificate scheme (RM). As the simplest form of capacity mechanism, a CM arises from an administratively set binding capacity target and rewards all firm capacity needed to reach the target with a payment. Instead of targeting firm capacity, we also consider mechanisms that more directly incentivize reserve capacity exemplified by the RM and SR policies. Under both regulations, a part of the power plant park operates only under predefined extreme conditions. In case of a SR, a regulator acquires as much capacities not sustained by the energy market, as the fulfillment of a target requires. By contrast, the RM leaves the exact amount of reserves to the market, but prescribes a capacity margin, which obliges suppliers to hold reserve capacities in excess of their expected supply peak. Similar to the operating reserve model proposed by Hogan (2013), the RM establishes a market for reserve capacities, and induces scarcity prices.

2. Model

In the following, the models for the simulation of a capacity market (CM), a strategic reserve policy (SR), and a reserve obligation with certificates (RM) are introduced. The representation of these policies is based on a model of an energy only market, which is described in the next subsection.

2.1. Basic energy only market model

We first model a basic energy only market with power generation and plant investment of firms acting on a domestic market. The time horizon consists of single periods y, each consisting of a number of time steps t. Marginal costs are constant in output q in each period and include payments for emission allowances. They write:

$$C_q^{y,n} = \frac{p^{y,n} + \varphi^y e^n}{\eta^n} + oc^n, \tag{1}$$

where φ^y denotes the periodic emissions price, and $p^{y,n}$, e^n, η^n and oc^n denote the periodic fuel price, the specific fuel emission, the degree of efficiency, and the unit operation and maintenance costs of technology n respectively. Fixed costs accrue proportional to investments k with F^n denoting unit fixed costs.

Firms are assumed to behave competitively and to have perfect foresight. In particular, firms perfectly assign frequencies $f(\omega)$ to residual demand events denoted ω. Inverse demand is denoted $P^{y,t,\omega}(X^{y,t,\omega})$, where X denotes total consumption.

Now the profit maximization problem with regard to production q, and investment k of a representative firm i can be written as

[1] An advantage of the applied MCP format is the flexibility to represent a large range of economic problems including decisions under market power. Moreover, its mathematical description offers basic insights and intuition of the economic trade-offs related to the solution of the problems.

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