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Uncertainty and the long-term adequacy of supply: Simulations of capacity mechanisms in electricity markets

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ABSTRACT

Deregulation in electricity markets has changed the conditions for maintaining long-term adequacy of supply. Particularly in the last decade, security of supply has become a major issue for policymakers due to a number of changes in technology, especially the introduction of renewables, where regulators have introduced capacity mechanisms. In this paper, we focus on the use of two different capacity mechanisms: procurement for long-term strategic reserves contracting, and centralized auctioning for capacity contracts. We investigate the effect of uncertainty on the effectiveness of these two mechanisms in maintaining a stable and sufficient supply of capacity. We use simulation to establish the behavior as the level of uncertainty is increased. Our results suggest that a market's level of uncertainty plays an important role in the effectiveness of these two interventions. The results raise questions about when it is appropriate to introduce either of them.

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1. Introduction

Over the last two decades, electricity markets in many countries have gone through several major restructurings, from an initial deregulation to changes in the structure, pricing mechanisms, and regulations when problems or policies required alignment of the markets [1]. The initial focus was on making sure that the deregulation was efficient and effective, which means delivering the promises in terms of new investments, reliability and, in many cases, lower prices. This led regulators and policy makers to focus on the short to medium-term promotion of competition [2,3] and the prevention of market power [4]. More recently, the discussion has moved on to the long-term security of supply, i.e. the market's ability to deliver enough new investments (and power) at a required time, in order to avoid shortages [5]. This concern has resulted from a number of issues in the last decade, such as the desire to withdraw nuclear capacity in Europe [6], and financial problems for companies in the electricity sector [7], among others.

While there are many elements in security of supply, we focus on capacity adequacy, i.e. making sure that there is enough available capacity to deliver electricity at a reasonable market-based price [8]. We start from what might be seen as the result of the investment behavior in deregulated electricity markets: the occurrence of capacity cycles. These capacity cycles are generally seen as a major threat to markets' sustainability and society's welfare [9]. Cycles in generation capacity have been discussed during the last two decades [2,10–13]. More recently, there has been empirical evidence that cyclical behavior does occur in deregulated markets [14]. When there is excess capacity, the capacity cycle creates a situation with relatively low prices, benefiting the consumers, while generation companies have low or no profit. This in turn will lead to limited investment in new generation capacity, as the economic return is not sufficient, which will eventually erode the excess capacity and create a shortage, thereby reversing the benefit between the consumer and the generation companies. This situation might compromise the adequacy of capacity as prices could soar and blackouts might occur more frequently. Such cyclical behavior takes a significant amount of time to correct because of the interplay of reluctant investors (due to the previous period of low return) and the long lags in adding new generation capacity, which typically takes from three years for CCGT, and up to a decade for big hydro and nuclear plants.

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There is a possibility that security of supply will be further compromised in the future; see, e.g. Refs. [16,56,57]. One reason for this is the numerous policy initiatives for introducing renewable energy. Some countries, like Germany, have now reached more than 49% of installed capacity and 33.9% of production from renewables [15,55]. While renewable energy has a number of advantages in terms of the environment, less dependence on fossil fuels etc., it has the potential to create an issue for security of supply. As renewables often get priority in scheduling (as well as a different pricing mechanism), the residual demand for the remaining generation capacity is reduced, such as with CCGT and coal, and therefore receive lower revenue. In Germany, for example, CCGT plants only produce once every four days. This has led to the closure of thermal plants; in the UK, for example, the regulator has expressed concern about the future reserve margin [16,53]. The reason for this is that, in periods when the renewable generation has a relatively small production, e.g. due to weather conditions, there is a need for the thermal generation plants to make up the missing production. However, because of the low economic return the required thermal capacity might have been decommissioned or mothballed. Even if prices increase, it is unlikely that utility companies are going to invest in new thermal capacity on the basis of market conditions, if they do not believe that they can meet their minimum threshold return on the investment.

We have observed similar behavior in other cases where there has been a large dependence on hydro, particularly in South America, where the Pacific weather system has created situations of excess water in some periods, followed by a shortage in others. This has led to a high volatility in prices and reluctance to invest in thermal capacity to offset the variability in water, due to the relatively long period of excess water during which the thermal capacity would not produce [17].

Regulators and policymakers have become increasingly aware that this issue may jeopardize security of supply [16]. The response has been to adjust regulation, particularly in the area of ensuring adequate thermal capacity to maintain a reserve margin that is large enough to offset variability in the production of renewables. Different policies have been proposed and implemented in deregulated electricity markets in order to maintain adequate capacity and prevent cycles such as capacity mechanisms [18], mothballing [5], and forward markets [19].

In this paper, we investigate two of the capacity mechanisms suggested in the literature. The first is procurement for long-term strategic reserves contracting, and the second is centralized auctioning for capacity contracts. The first one is an interventionist mechanism that introduces a regulator-owned firm into the electricity market. The second is a market-oriented mechanism that consists of the implementation of a centralized auctioning system, where the market participants bid for capacity contracts [18]. By using simulation, we test these two mechanisms under different levels of uncertainty to understand which of them is the most efficient in maintaining a desirable level of generation capacity and in avoiding capacity cycles.

The paper is organized as follows: the next section presents the capacity mechanisms we consider. The third section explains our economic models. The fourth section shows the simulation's results and finally, the fifth section presents the conclusion and discussion of our findings.

2. Capacity mechanisms

We focus on two capacity mechanisms in order to test their economic impacts on investment, in a stylized electricity market. We have selected one interventionist mechanism, procurement for long-term strategic reserves contracting, and one market-oriented mechanism, centralized auctioning for capacity. We investigate whether they both represent an economic improvement for a market base line, and if so, which of the two yields the better results under different levels of uncertainty. We select these two specific mechanisms because they both have a good theoretical foundation in the literature, and they represent two theoretically opposed ways of solving the issue of maintaining adequate capacity. The first one provides partial market control (influence) for the regulator, while the second is an integrated part of the market dynamics. One might argue that both, in their own ways, are interventions that partly set aside the idea of a market, i.e. interventions that to some degree suspend the market. While this is not necessarily a bad thing, given that regulators have overseen and intervened in the market since the beginning of deregulation, one has to consider that market principles must be preserved. It can be argued that such interventions can be necessary in order to maintain a well-functioning market.

Procurement for long-term strategic reserves contracting allows a governmental institution to use production capacity. Countries like Germany, Sweden, and New Zealand have implemented this mechanism. The results in these countries and the academic discussion of them have portrayed high efficiency in capacity adequacy as its main advantage, and a reduced compatibility with market principles as its main disadvantage, as it interferes directly in the market and is not linked to a market-based mechanism [20,21].

Centralized auctioning for capacity licenses is the second mechanism we investigate, where the government or regulator has control over the total market capacity and holds auctions for licenses to build new capacity when there is a perceived need. New England is one area where this mechanism has been implemented [22,58,59]. The literature points out capacity-adequacy targeting and market compatibility as its main advantages, and lack of control over physical plants as its main disadvantage [22,23].

3. Economic model

The analysis of the capacity mechanisms discussed above can be done at different levels of analysis: from a model calibrated to a particular context, such as a country, to a more stylized model, that provides more general insight. We chose the second option, a stylized model for a deregulated electricity market, as it helps to understand the main implications of the two market interventions. In reality, generators adjust capacity year-on-year by closing stations when there is excess capacity and such excess is expected to persist. This adjustment may not be sufficient to eliminate price cycles, but it can dampen them. In fact, previous works on capacity mechanisms have found that the possibility of mothballing capacity can significantly reduce price cycles [4]. Since we consider a stylized market with no interventions as a base case, we decided not to include this feature. Furthermore, mothballing has also been criticized in the literature for enabling generators to raise prices [5].

The model is based on Arango and Moxnes [24]; we extend the model by including the possibility of testing the two capacity mechanisms discussed above.

3.1. Base model

The base model of the electricity market follows the model developed by Arango and Moxnes [24], where investors make investment decisions for capacity in a market-based system. The model represents a stylized electricity market with long capacity lifetimes and investment delays (i.e. capacity construction time). This market setting also resembles other capital-intensive industries, even though the lifetime of investment is normally shorter

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