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The impact of investors' risk aversion on the performances of capacity remuneration mechanisms

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ABSTRACT

This paper analyses the impact of risk aversion on the performances of capacity remuneration mechanisms, with investors facing an uncertain peak load. Three market designs are studied for this purpose: a competitive energy-only market, a capacity market and a strategic reserve mechanism. A simulation model based on system dynamics is developed in order to represent investment decisions and analyse the behaviour of each market design. Risk aversion is modelled through the computation of Conditional Value at Risk. The results are discussed in terms of impact on the reliability (ability to limit shortages) and cost (total generation costs) of the studied market designs. When comparing the three market designs, the capacity market seems to be the least affected by the introduction of risk aversion, both in terms of cost and reliability. This result suggests that implementing a capacity market is preferable in order to deal with the adverse effects of risk aversion, given the simulations and parameters that were used.

1. Introduction

Well-designed energy-only markets should in theory send adequate price signals to stimulate needed investments in generation capacity (Stoft, 2002). In the theoretical energy-only market, generators recover a significant part of their fixed costs during scarcity periods (i.e., when the capacity in the system is not enough to satisfy the demand). The revenues earned during these periods are particularly vital for peaking units. At equilibrium, a well-functioning energy-only market with scarcity pricing (i.e., a market in which prices are allowed to reach the Value of Lost Load or VoLL[1] during scarcity periods) enables generators in each type of technology to earn just enough revenues to recover their total costs, therefore inducing a socially optimal mix of capacity in the long run.

However, for political or social considerations, prices in most electricity markets are capped[2] at a lower level than the VoLL, reducing at the same time the scarcity rents[3] of generators. In addition, the increasing penetration of renewables has a significant impact on conventional plants' profitability as it reduces both the frequency and the magnitude of price spikes (Sensfuß et al., 2008). Finally, some aspects related to investors' behaviour and their response to price signals may prevent energy-only markets from achieving their generation adequacy objective. Among these are: herd behaviour and risk aversion (associated with market incompleteness), which may lead to cyclical tendencies in investments and cause deviations from the optimal equilibrium (Arango and Larsen, 2011). All the factors mentioned above constitute barriers to the well-functioning of energy-only markets and can lead to sub-optimal level of investments, resulting in more shortages than what is desired.

In order to restore appropriate investment signals, complementary policy instruments (or market designs), called capacity remuneration mechanisms (CRMs) are being discussed and implemented (see Batlle and Rodilla (2010) or Cramton et al. (2013) for a discussion on design options and typology of CRMs). These instruments remunerate power plants for their capacity, in addition to the revenues received on energy markets. Two CRMs in particular have drawn a lot of attention in theory and in practice: the capacity market (in its various forms) and the strategic reserve mechanism. The first one has been implemented for

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[1] The Value of Lost Load (VoLL) is defined as the willingness to pay of the consumers in order to avoid being curtailed. Since there are several types of consumers, there should be different VoLLs corresponding to each consumer. However, we assume here that the VoLL has been properly defined and do not address the problem of the determination of the VoLL.

[2] Price caps are generally introduced in order to mitigate the effects of some market imperfections which prevents energy only markets from functioning properly as explained by Stoft (2002) (e.g., lack of sufficient short term price elasticity on the demand side, the inability of a system operator to perform selective curtailment, exercise of market power, etc.).

[3] Profits earned during scarcity periods.

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instance in France, Great-Britain and PJM[4] whereas the second one has been preferred by Belgium or Finland. Both mechanisms are quantity-based[5] but they differ in their design regarding the determination of the required amount of capacity, the targeted capacities and their interaction with the energy market. The differences between these two mechanisms are discussed more extensively in Section 2.5.

To decide which CRM to implement, policymakers should assess their economic performances first, in particular regarding their reliability and their cost (De Vries, 2004). The former refers to the ability of the mechanism to provide adequate investment to reach the target of security of supply and reduce shortages, while the latter refers to the total generation costs associated with it (investment costs, variable generation costs and fixed O & M costs). As power markets are prone to investments cycles, the aforementioned performances should be assessed in a dynamic perspective, relying on simulation models, as demonstrated by the extensive literature on the dynamics of generation investments in liberalised power markets (De Vries and Heijnen, 2008; Gary and Larsen, 2000; Hasani and Hosseini, 2011). Unfortunately, most of the time, these models oversimplify investors' behaviour. For instance, a risk-neutral hypothesis is generally considered for investors. This is the case in (Bhagwat et al., 2017; Cepeda and Finon, 2011; De Vries and Heijnen, 2008; Hary et al., 2016; Hasani and Hosseini, 2011; Petitet et al., 2016a), where the authors tackle the issue of security of supply by analysing the impact of some CRMs on investment incentives.

Yet, many sources of uncertainties (e.g., about demand, prices, policy, etc.) can directly alter the behaviour of market players in their investment decision-making (Dyner and Larsen, 2001; Gorenstin et al., 1993; Soroudi and Amraee, 2013). Moreover, these investments are capital intensive and irreversible. In this context, the risk-neutral assumption about investors' behaviour is arguable. Indeed, they are more likely to be risk averse (Hobbs et al., 2007; Meunier, 2013; Petitet, 2016; Petitet et al., 2017). Nonetheless, given the incompleteness of electricity markets as highlighted in Willems and Morbee (2010), investors cannot transfer all their risk or trade it on existing markets. This impacts their investment decisions and consequently their reaction to a specific policy instrument. Therefore, investors' risk preferences should be properly accounted for when assessing the performances of policy instruments.

Several studies have investigated the relationship between agents' risk aversion, market design and investment decisions in generation capacity. For example, Meunier (2013) shows, using a stylized equilibrium model, that risk averse agents can invest in more capacity than risk neutral ones in the long run. Such configurations occur when risk averse agents overinvest in peaking units as a means to hedge the risks faced by the baseload technologies. Willems and Morbee (2010) demonstrate that improving market completeness by introducing more derivatives increases investments because it provides better hedging opportunities.

Blyth et al. (2007) develop a real option approach to assess the impact of climate change policy uncertainty on investment incentives in different generation technologies. They illustrate that uncertainty on climate change policies can lead investors to wait for stronger price signals before investing (compared to a case of perfect certainty). Fan et al. (2012) find similar results by using a game theoretic model. They find that various sources of uncertainties (for instance about carbon permits allocation schemes or investment costs) and risk aversion have impacts on investment incentives as they reduce or delay investments. Aghaie (2017) also comes to the same conclusions by analysing the impact of risk aversion on investments in an energy-only market using a stochastic optimization model. He shows in addition that risk aversion leads to more shortages and an increased utilization of demand response resources in such a market. Although these studies are based on static equilibrium models, they are relevant to this discussion because they highlight the importance of considering investors' risk aversion while assessing policy instruments.

As explained above the cyclical nature of investments in power markets and investors' risk aversion are two fundamental aspects that should be considered by policymakers when comparing policy instruments such as CRMs. To the knowledge of the authors, only a limited number of studies take both these aspects into account (i.e., use a dynamic simulation model which considers investors' risk aversion). For instance, Hobbs et al. (2007) develop a representative agent model that accounts for agents' risk preferences in order to simulate investment decisions and to assess the performance of the PJM capacity market for different demand curves. They illustrate that using a sloped capacity demand curve instead of a vertical one can reduce the costs of providing a desired level of reliability. They explicitly represent risk aversion through a quadratic utility function but do not provide any analysis of the impact of agents' risk attitude on the performances of the studied market designs.

Another relevant work is the one by Eager et al. (2012). The authors build a dynamic model to simulate investments in thermal generation in a context of high wind penetration. The concept of Value at Risk (VaR) is used to represent risk aversion. By applying their model to the British power system they illustrate how a lack of sufficient revenues for peaking units can affect the security of supply. Nevertheless, their analysis focuses on an energy-only market and does not extend to CRMs. At last, in a recent work, Petitet et al. (2017) use a dynamic simulation model to study the influence of risk aversion on the performances an energy only market (with and without scarcity pricing) and a capacity market. Their results show that taking risk aversion into account significantly modifies the comparison between the studied market designs. However, their study does not consider the strategic reserve mechanism which is yet one of the most discussed CRM.

The aim of this paper is to analyse, in a dynamic perspective, the impact of risk aversion on the performance of CRMs, with investors facing an uncertain peak load. Three market designs are studied for this purpose: a competitive energy-only market (EOM hereafter), a capacity market (CM hereafter) and a strategic reserve mechanism (SRM hereafter). A simulation model based on system dynamics is developed in order to represent investment decisions and analyse the functioning of each market design. Risk aversion is modelled through the computation of Conditional Value at Risk (CVaR). The results are discussed in terms of changes in the reliability (i.e. ability to limit shortages) and the cost (i.e. total generation cost) of the studied market designs.

This work contributes to the literature on generation adequacy by bringing some insights about the potential effects of investors' risk aversion on the performances of a CM and a SRM. More precisely, we show that risk aversion leads to reliability losses and increased costs in all three market designs. However, the CM appears to be the least affected one. Moreover, the benefits resulting from the implementation of a CRM are higher in the presence of risk averse investors. In addition to these results, the paper presents some interesting modelling features which can help improve dynamic investment models and the representation of investors' behaviour in such models.

The paper is organised as follows: Section 2 explains the model and the functioning of the three market designs. Section 4 provides a presentation of the simulations and a discussion of the results. Finally, the conclusions and policy implications are presented in section 4.

2. Model

2.1. General structure of the model

This paper is based on the system dynamics (SD) approach which was first introduced by Forrester (1961). It has since been used in the energy sector for several purposes (Teufel et al., 2013), in particular for

[4] France has decided to implement a decentralised capacity market, also known as capacity obligations, whereas the UK and PJM run centralised capacity auctions.

[5] Meaning that the quantity (i.e., target capacity to be contracted) is explicitly determined by some central body.