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FLEXIBILITY-ENABLING CONTRACTS IN ELECTRICITY MARKETS

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Overview

Power system flexibility, that is, the ability to modify consumption or generation in response to variability, expected or otherwise, is becoming increasingly valuable for power systems. Particularly for those that aim at integrating larger shares of intermittent renewable sources of generation in their energy mix. By increasing its flexibility, power systems become more resilient to the inherent uncertainty of renewable energy, thus becoming capable of operating at different generation levels and smoothly shifting among them. (IEA, 2014).

Although flexibility has been typically associated to rapidly dispatchable power plants, alternative resources, such as grid infrastructure, storage capacity, and demand-side integration are also relevant to enable flexibility.

Grid expansion, through the interconnection of supply to demand locations, has been the approach taken by countries like Denmark to integrate wind energy into their system. Green and Vasilakos (2012), for example, claim that Denmark is "effectively using its neighbours for short-term fluctuations in its output of wind energy, and is being used for a longer-term response to fluctuations in their availability of hydro power".

Energy storage of electricity, which is vastly dominated by pumped hydro, is one of the most effective forms of flexibility, as it provides an immediate response to variability. Electric Vehicles might also become a relevant source of storage in the future, provided that these make a breakthrough in the transportation sector. However, compared to other options, and with current technologies, storage is likely to be more costly than its alternatives.

Active demand response and demand-side management, on the other hand, are becoming more of a reality, as a result of developments in smart metering, automation and control. Energy companies operating in different markets throughout the world are already offering their commercial, industrial and residential customers with demand management services and the possibility to remunerate their response.

In summary, the electricity industry is undergoing a process of technological change and the emergence of Smart Grid solutions is becoming a catalyst in the development of new business models which encompass flexibility, adding new activities to the existing supply chain. New market participants, such as software developers and aggregators, are starting to play a role in the evolving electricity industry. Similarly, existing players are changing their traditional roles and are becoming involved in new activities and challenges. Retailers, for example, are not anymore exclusively involved in managing the delivery of power to end users, but are also becoming concerned with enabling flexibility. Another case in point is represented by Distribution System Operators, which will be required to manage a network characterized by larger shares of generation and flexibility-enabling resources, finding novel ways to deal with congestion and minimizing investment costs, while ensuring quality of service.

This paper builds on all of these developments and answers the fundamental economic question of *what are the incentives to enable flexibility in electricity markets.*

Our contribution is: i) to explicitly model contractual relationships arising in different forms of flexibility trading, accounting for risk attitudes and informational asymmetries, ii) to model flexibility as a related but distinct commodity than electric energy or capacity, and iii) to take a microeconomic approach by modelling individual decisions by agents involved in the exchange of flexibility.

Methods

Our theoretical modelling approach is based on the tradition of the theory of incentives (Laffont and Tirole, 1993), (Laffont and Martimort, 2002), also known as contract theory, as introduced by Bolton and Dewatripont (2005).

In our basic model, we consider a buyer (the principal) who procures flexibility from a seller (the agent), which has private information and has the incentive to exploit its informational advantage in the process of supplying flexibility. The solution to the principal's problem is to offer a menu of feasible contracts to which the agent self-selects, such that its individual rationality and incentive compatibility constraints are met.

A salient feature of our model is that we provide a general representation of flexibility as *energy available subject to quantity and time constraints*. This definition provides fundamental economic insights into flexibility as a horizontally-differentiated product, whose provision depends on the cost structure of its suppliers. In other words, there are time-flexible suppliers, quantity-flexible suppliers and others lying in the middle of the two extremes.

We consider two extensions to the basic model. First, to account for the case when competition is feasible among sellers, we extend the basic model to a single-buyer, multiple-seller setting, which is equivalent to an auction. Second, to account for the role of trading in a Smart Grid environment, in which information is revealed by the agents, we modify our model to account for the fact that the principal might be more informed than the agent.

Results

The intuitive appeal and applicability of our results to the case of flexibility trading is immediate and we classify them in the following way: a) Our basic model describes the optimal contracts arising in *bilateral* relationships, where competition is infeasible. Such is the case of retailers or aggregators offering contracts to incentivize the provision of flexibility by agents who find it costly to compete, b) Our extended model, which is more general, describes the case where a single buyer of flexibility, such as Distribution System Operator or Aggregators optimize a portfolio of flexibility-enabling assets and induces competition among sellers. This describes an optimal *multilateral* relationship.

Conclusions

In the absence of transaction costs, where a flexibility-enabling technology is already in place, bilateral contracts lead to an efficient outcome and an equal distribution of the gains from trade. These gains become unequally distributed, depending on the technology investment cost-sharing agreement between the parties. In any case, the efficiency of the outcome remains unaffected.

In our multi-lateral contract setting, the relative performance evaluation of flexibility suppliers and competition amongst them reduces the informational disadvantage of the buyer and may lead to an efficient outcome if a sufficient number of non-colluding bidders participate.

Our results also show that, the principal can design a strategy-proof contract, such that sellers are incentivised to reveal their marginal cost. We show that an optimal portfolio for the buyer would consist of merit-orderly ranked resources based on the specification of flexibility, such as size and time of response.

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