Market Design Considerations for Scarcity Pricing: A Stochastic Equilibrium Framework

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Motivation. Scarcity pricing is currently being discussed in Europe as an alternative or complement of capacity mechanisms for supporting the provision of reserve services from flexible resources. This is reflected in various policy documents published by the European Commission and European Parliament, including the Clean Energy Package and the European Balancing Guideline. However, the implementation of scarcity pricing in the form of Operating Reserve Demand Curves (ORDC) in European electricity markets requires a careful consideration of the difference in fundamental principles between U.S. and E.U. market designs, and specifically (i) the role of balancing as a service, (ii) the role of virtual trading, and (iii) the co-optimization of energy and reserves. These differences in E.U. and U.S. market design principles affect the ability of scarcity prices based on ORDC to back-propagate to day-ahead and other forward markets, and thereby provide a robust investment signal for flexible resources. The present paper presents a stochastic equilibrium framework for describing a spectrum of market design options between the current E.U. market design and an ideal U.S.-style two-settlement system. These models are used for conducting a numerical analysis of the Belgian electricity market. This analysis provides the basis for a concrete proposal of market design changes in the Belgian electricity market that aim at ensuring that scarcity pricing can back-propagate to forward markets and appropriately signal investment in flexible capacity.

Performed Research. We develop a stochastic equilibrium framework for analyzing two types of arbitrage that allow scarcity pricing to remunerate flexible resources for reserve services: the arbitrage between energy and reserve capacity, and the arbitrage between real-time prices and day-ahead prices. This stochastic equilibrium framework relies on coherent risk measures, and is sufficiently flexible to capture a wide range of differences in market design principles that exist between U.S. and E.U. markets. The motivating question for our analysis is the following: "can we introduce scarcity pricing, which is inspired by a U.S. design, to E.U. markets, or do we require additional changes in the E.U. design in order for scarcity pricing to be effective"? We use our stochastic equilibrium framework in order to make this motivating question more specific: In order for scarcity pricing to be effective: (i) Do we need to trade reserve capacity in European real-time markets? (ii) Do we need to introduce virtual trading in Europe? (iii) Do we need to co-optimize energy and reserve in European day-ahead markets?

We apply our stochastic equilibrium framework in order to represent these increasingly disruptive reforms of the European market. We apply our model to a case study of the Belgian market for the time interval from September 2015 until March 2016. Due to the large size of the model, we present our analysis in a risk-neutral setting, which can be solved equivalently as a stochastic program. We focus our analysis on the back-propagation of scarcity prices to the day-ahead market, and the resulting effect of scarcity pricing on flexible generators (specifically 8 CCGT units in Belgium) and flexible consumers.

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Conclusions. Our analysis produces the following observations: (i) The introduction of a real-time market for reserve capacity, which is the least disruptive measure towards implementing scarcity pricing in Europe, restores the financial viability for CCGT units in Belgium, and creates opportunities for loads to offset the increase in energy prices that results from the introduction of scarcity pricing. (ii) Virtual trading and the co-optimization of energy and reserve in day-ahead market clearing have a lesser effect on reserve and energy prices once a real-time market for reserve capacity has been put in place. These measures are also fairly disruptive interventions to E.U. market design. On the basis of these observations, our analysis produces a concrete policy recommendation: (iii) The introduction of a real-time market for reserve capacity in Belgium is a pragmatic no-regret measure towards setting up a European real-time market that can value reserve services accurately, and has been recommended for implementation to the Belgian regulator.

Potential Benefits, Applications, and Policy Implications. The modeling framework that has been developed in the present paper is a novel application of stochastic equilibrium beyond long-term models of investment to short-term models of electricity market clearing. The framework has been shown to be highly agile, and useful in providing guidance regarding the design of short-term (day-ahead and real-time) electricity markets. Our modeling framework allows us to highlight the challenge of properly remunerating flexibility as a result of the fact that real-time markets for reserve capacity are absent in Europe. Steps towards the implementation of scarcity pricing in Belgium that have resulted from the analysis include: (i) the issuing of a report on behalf of the Belgian transmission system operator that back-calculates ORDC adders for 2017, as they would have occurred based on telemetry measurements of the Belgian Available Reserve Capacity; (ii) the publication of scarcity pricing adders by the Belgian transmission system operator, effective October 2019; and (iii) the launch of a public consultation by the Belgian transmission system operator regarding the market design proposal of the present paper.