WELFARE IMPACTS OF OPTIMAL VIRTUAL BIDDING IN A MULTI-SETTLEMENT ELECTRICITY MARKET WITH TRANSMISSION LINE CONGESTION

Hyungkwan Kim, Purdue University, Phone +1 765 479 5290, E-mail: kim1841@purdue.edu
Paul V. Preckel, Purdue University, Phone +1 765 494 4240, E-mail: preckel@purdue.edu
Douglas Gotham, State Utility Forecasting Group, Phone +1 765 494 0851, E-mail: gotham@purdue.edu
Andrew L. Liu, Purdue University, Phone +1 765 494 4763, E-mail: andrewliu@purdue.edu

Overview

In the interest of improving the performance of wholesale electricity markets, virtual financial products have been introduced. Virtual bids are purely financial instruments that may be used to speculate on the differences between prices in the forward and spot markets in a two-settlement electricity market. While there is evidence that price convergence across these markets can be induced by virtual bidding, other research has shown that the impacts on the welfare of market participants are less clear. The problem is that, while virtual bidding may narrow the price gap, if it does so by inflating the prices, then electricity consumers may not be better off. Although some work has been done on the impacts of virtual transactions on welfare for the electricity market participants, that work provides an incomplete assessment, ignoring some important aspects of the electricity market system. In particular, the prior work due to Giraldo (2017) essentially ignores the electricity network as well as the physical laws governing electricity flows. The objective of this research is to understand the effect of virtual transactions on electricity market efficiency using a model that explicitly includes the network as well as relationships that reflect the physical properties of electricity flows through a network (i.e. loop flow). The core research question is; what impact does network congestion have on the welfare shifts caused by the participation of financial virtual traders? This study employs models with multiple buses to analyze the welfare changes of electricity market participants in a network constrained multi-settlement electricity market. Integrating the network in the model enables a comparison of welfare changes between the simpler network-free models and a network based model with the possibilities of line congestion and proper treatment of loop flow.

This paper is structured as follows. In Section 2, we briefly present background on the electricity market. In Section 3, we address the method employed in the analysis and present algebraic welfare analysis, producing a closed form solution for a network-free model. In Section 4, we present methods and formulations for welfare analysis in models with an explicit network structure, the possibility of line congestion, and proper treatment of loop flow. In Section 5, we calculate optimal bidding strategies and welfare impacts under a variety of network configurations. In Section 6, we address the conclusions, implications, and future work.

Methods

Stochastic programming, Bilevel programming

Results

First, models that explicitly incorporate the network in a two-settlement electricity market are used to measure the expected welfare impact of optimal virtual bidding on market participants' welfare.

Second, the results suggest that virtual bidding may decrease consumer welfare while increasing producer welfare. The presence of congested lines in the network can aggravate the welfare impacts.

Third, the possibility of having line congestion due to demand uncertainty can change the optimal bidding strategy of the financial trader and the welfare impacts on market participants.

Fourth, the welfare impacts on market participants are not homogenous throughout the network. That is, some generators may benefit while others lose, and the same is true for load serving entities. It is rather heterogenous depending on where they are located in the network. The one constant is that virtual traders essentially always benefit.

Conclusions

In most cases, price convergence occurs with optimal virtual bidding, which is consistent with existing literature. The prices throughout the network in both forward and spot markets are changed, and there are welfare transfers among producers, consumers, and virtual traders relative to the market equilibrium without virtual bidding. However, the results address that the optimal virtual bidding tends to decrease consumer welfare and congested lines in the network can magnify the welfare changes. These implications should be considered in the design of regulations governing virtual transactions in the wholesale electricity market.

References

Giraldo, Juan S., Paul V. Preckel, Andrew L. Liu, and Douglas Gotham. 2016. “Welfare Impact of Virtual Trading on Wholesale Electricity Markets.” Manuscript Submitted for Publication.