

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

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## **Overview**

In the interest of improving the performance of wholesale electricity markets, virtual financial products have been introduced. Virtual transactions 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. If prices are inflated because of the virtual transactions, consumer welfare may not be improved even though price convergence has occurred. Although some work has been done on the impact of virtual transactions on the welfare of electricity market participants, that work provides an incomplete assessment because it ignores some important aspects of the electricity market system. In particular, the prior work of 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 and 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 an explicit network to analyze the welfare changes of electricity market participants in a congestion constrained multi-settlement electricity market. Integrating the network in the model enables a comparison of welfare changes between the simpler congestion-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 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 3, we calculate optimal bidding strategies and welfare impacts under a variety of network configurations. In Section 4, we address the conclusions, implications, and future work.

## **Methods**

Stochastic programming, Bilevel programming, Empirical Industrial Organization

## **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, having congestion in the network creates differences in optimal bidding strategy of the financial trader and its welfare impact 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 findings in the 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 demonstrate that 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.