Electricity Markets in Transition

A forty-year simulation of entry and exit in the PJM electricity market

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Short Abstract

Electricity markets worldwide are undergoing a many-decade transition in the way electricity is generated and consumed. The success of this transition depends critically on climate policy and market design. We model PJM—perhaps the largest and most advanced electricity market in the world—to evaluate the impact of alternative policies on electricity market outcomes over the next 40 years, including costs, profits, social welfare, risks, and reliability. Each year, investors decide which resources enter and exit given forward-looking consistent expectations about energy rents, prices and costs.

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Extended Abstract

Electricity markets worldwide are undergoing a transition in the way electricity is generated and consumed. This transition is expected to last multiple decades. The pace and success of this transition depends critically on climate policy and market design. To evaluate the impact of policy on the energy transition, we develop a model of PJM—a wholesale electricity market in the United States, including 13 states and the District of Columbia. PJM is arguably the largest and among the most advanced electricity markets in the world.[2] As in most markets worldwide, investors in the PJM market face a chaotic climate policy, which increases risk and uncertainty in making resource entry and exit decisions. Our model allows us to evaluate the impact of alternative policies on electricity market outcomes throughout the transition, including costs, profits, risks, and reliability.

We take an investor's perspective. Each year, investors decide which resources enter and exit. We consider the market both with and without a capacity market. The investors know the current state of the market and make forecasts of prices critical to the investment decision. Entry and exit decisions are made on an annual basis. Given forward-looking expectations about energy rents, prices and costs, profitable resources enter the market and unprofitable resources exit. The equilibrium condition is that expectations are reasonably accurate. Entry and exit decisions are made three years in advance consistent with the current capacity market. Investor decisions are modeled over 40 years from 2020 to 2060. In fact, the analysis extends one hundred years (2120) to avoid end-game effects—an entry in 2060 will enjoy its full cash flows throughout the life of the resource.

We make many simplifying assumptions. First, transmission is assumed to be sufficiently robust so that transmission constraints never bind. Second, bids in both the capacity and energy markets are assumed to be competitive with the exception that in the energy market the last MWs of certain price-setting resources, such as gas and coal units, are bid at prices greater than marginal cost, consistent with observed behavior. This assumption better replicates the "hockey stick" bidding observed in practice. Third, an explicit carbon price path is assumed. This is a transparent way to model either an explicit carbon price or an implicit carbon price that results from climate policy, whether a carbon tax, cap-and-trade, or other regulation. Fourth, we assume that by 2060 the transition is complete. The resource composition remains stable in years beyond 2060.

Energy rents—the profits earned in the energy and reserves markets over the year—are determined by explicitly modeling the day-ahead and real-time energy and reserves markets. The model of the PJM markets is meant to be as accurate as possible. Every unit is modeled at the five-minute level. Units, including battery storage, are optimally scheduled based on expectations and dispatched in real time. Two versions of the energy and reserves markets are considered: (1) the current markets in which scarcity pricing is limited to a high shortage price when reserve constraints are violated and (2) the proposed markets with an operating reserve demand curve (ORDC) as specified in the Price Formation proceeding before the U.S. Federal Energy Regulatory Commission (FERC). Both the day-ahead and real-time markets are modeled. This is necessary since shortage or near-shortage conditions typically are observed only in real time. The day-ahead market is a financial market that optimizes unit commitments for each of the 24 hours in the next day based upon the day-ahead forecast. During the day, the forecast is revised resulting in changes in unit commitments. In real time, the optimal dispatch is determined based on the available

[2] In 2019, PJM's peak load was 151,558 MW; by contrast Germany's peak load was about 80,000 MW.

resources and demand realizations. Both day-ahead and in real time, the market co-optimizes energy and reserves to maximize as-bid social welfare.

Our model enables us to evaluate alternative market design choices and see the impact of market design on the evolution of the market over several decades. The impact of alternative climate policies on investment decisions also is evaluated. The model calculates consumer cost, generator profit, reserve margins, as well as variations in these metrics, which are relevant for assessing risk and reliability.

Our modeling work is not yet complete. We plan to finish the model and analysis in mid-June. A complete paper with the results of our study will be available in July.