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Using restructured electricity supply industries to understand oligopoly industry outcomes☆

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ABSTRACT

This paper argues that many determinants of generic oligopoly market outcomes can be studied in bid-based wholesale electricity markets under much weaker assumptions than in other oligopoly industries because of their rich data, regulatory history, and clearly specified market rules. These methods are compared to those used in existing studies of oligopolistic industries where the best data available are market-clearing prices and quantities and demand and cost shifters. The extent to which the methods used in bid-based wholesale electricity markets generalize conventional methods is explained in detail and major applications of these techniques are summarized. Lessons from the study of wholesale electricity markets for the monitoring and design of other oligopolistic markets are also discussed.

1. Introduction

Starting with Chile in the 1980s, a growing number of countries around the world have restructured their electricity supply industries to introduce competition into the wholesale and retail segments. Electricity producers, traders, and retailers are granted open access to the bulk transmission network and local distribution network at regulated prices. All wholesale electricity is traded through a centralized short-term market that sets an hourly or half-hourly price for energy, but market participants are free to enter into forward contracts that clear against this short-term market. Competition among electricity retailers to supply final consumers exists to varying degrees.

Capturing a significant fraction of the potential benefits of industry restructuring has been much more challenging than many observers at first thought. The characteristics of the product and the technology used to produce it make bid-based wholesale electricity markets extremely susceptible to the exercise of unilateral market power. Electricity is very costly to store, its production is subject to severe capacity constraints, and it must be delivered through a transmission network with finite capacity, all of which limit the magnitude of the supply response to a firm's unilateral attempts to raise prices. Finally, because of how electricity has historically been priced to final consumers, the real-time wholesale demand for electricity is close to perfectly price inelastic. For firms that own a substantial fraction of the generation capacity in the industry, the combination of this inelastic aggregate demand with a limited supply response from competitors causes these suppliers to face steep residual demand curves, particularly during the high demand periods of the day. In an oligopolistic industry, the more inelastic the residual demand curve a firm faces, the greater is its unilateral ability to withhold output to raise market prices through higher offer prices or less output made available at the same offer price.

The susceptibility of bid-based wholesale electricity markets to the exercise of unilateral market power makes them an ideal environment in which to study the determinants of oligopolistic firm behavior and industry outcomes. In these markets, highly concentrated industry structures and unexpected high levels of demand are unnecessary for the occurrence of market outcomes that reflect the exercise of substantial unilateral market power. An additional advantage of studying bid-based wholesale electricity markets is the fact that they produce vast amounts of data each day about the strategies firms employ to exercise unilateral market power. Each market participant is required to submit its willingness-to-supply and purchase electricity for each hour or half-hour of the day for all possible market prices. In addition, the regulated or government-owned monopoly history of the industry implies that there is publicly available data on the technological characteristics of the production process—heat rates, operating and maintenance costs and emissions rates of the generation facilities and the physical

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characteristics of the transmission network. This is considerably more information about firm strategies and production costs than is available to researchers studying other oligopolistic industries, such as automobiles (Bresnahan, 1981, 1987; Goldberg, 1995; Berry et al., 1995), personal computers (Bresnahan et al., 1997), and breakfast cereals (Nevo, 2001). In these industries, the researcher typically has, at best, data on the market-clearing prices and quantities of each product sold and variables thought to influence production costs and the level of demand for each product.

A final advantage of studying wholesale electricity markets relative to other oligopolistic industries is that the market rules are clearly specified and publicly available. Specifically, the researcher knows precisely how the wholesale prices suppliers receive and demanders pay are determined from the actions taken by these two sets of market participants. This is dramatically different from other oligopolistic industries, where a standard criticism of the empirical model implemented is that the choice of the economic model of firm behavior and the price-setting process is ad hoc because it assumes away important details of the competitive interactions between firms and between firms and consumers. For example, in most industries wholesale prices are set through bilateral negotiations between the seller and each buyer. The usual Cournot quantity-setting or Bertrand price-setting modeling assumptions used to simplify more complex price-setting processes can significantly impact the researcher's conclusions about the ability and incentive of firms to exercise unilateral market power and the competitiveness of observed market outcomes.

In contrast, wholesale electricity markets have detailed rules that must be approved by the regulatory body specifying precisely how market-clearing prices are determined. These rules define the feasible set of market participant actions, what information the market participants know when they take these actions, and how they are compensated for their actions. Consequently, the researcher does not need to make any ad hoc assumptions about how a market participant's actions impact the price it pays or receives; the market rules on file with the relevant regulatory authority specify precisely how each market participant's actions impact its revenues and costs. In this sense, wholesale electricity markets are like experimental economics markets except that experienced and highly compensated market participants play a well-defined game for large sums of money.

Studying wholesale electricity markets allows the empirical researcher to address many of the concerns raised by Fisher (1989, 1991) regarding the usefulness of applying game-theoretical methods to oligopoly contexts. The data on bids and market outcomes, cost data from the former regulated regime, and detailed market rules severely limit the set of possible economic models that can provide institutionally and statistically valid descriptions of observed data. A common problem in modeling market outcomes in oligopolistic industries where only market-clearing price and quantity data are available is the uncertainty about how the actions of market participants impact their profits and those of their competitors. The market rules for bid-based wholesale electricity markets completely eliminate this source of modeling uncertainty. Instead, the major challenge in studying bid-based wholesale electricity markets is formulating a computationally tractable model of market outcomes that is not dramatically inconsistent with the actual market rules.

The goal of this paper is to demonstrate how the features of wholesale electricity markets described above can be used to recover a rich set of economic primitives, direct measures of market performance, and measures quantifying the ability and incentive of a supplier to exercise unilateral market power, while employing fewer untestable assumptions relative to the approaches used to study these issues in other oligopolistic industries. The methods described below cannot be implemented in other oligopoly environments because the necessary data is unavailable and/or there is uncertainty about the form of market institutions. Instead, functional form assumptions for market demand and firm-level cost functions, as well as untestable assumptions about the form of competition (typically, Cournot quantity-setting or Bertrand price-setting behavior), must be made to gain traction on these questions in oligopolistic industries where only market-clearing price and quantity data are available. Consequently, wholesale electricity markets can provide insight about the determinants of market performance and the design of economic institutions that limit the ability and incentive of firms to exercise unilateral market power without many of the untestable assumptions employed in similar studies of other oligopolistic industries.

The four major issues addressed in this paper are: (1) testing the assumption of expected profit-maximizing behavior, (2) quantifying the ability and incentive of a supplier to exercise unilateral market power, (3) measuring overall market performance, and (4) assessing the competitive impacts of mergers. The data available and clearly specified rules for bid-based wholesale electricity markets allow a test of the hypothesis of expected profit-maximizing behavior without any assumptions on the functional form for the demand for electricity, minimal assumptions on the form of the variable cost function for producing electricity, and without assuming a specific oligopoly equilibrium model – the key assumptions required to test this hypothesis with data on market-clearing prices and quantities. Section 3 describes the details of this test and discusses the results of applying it in several electricity markets.

The data availability and precisely specified market rules allow the construction of direct measures of the firm-level ability and incentive to exercise unilateral market power. These measures of the ability and incentive to exercise unilateral market power can be constructed from the data on market participant bids and offers and market-clearing prices and quantities. Section 4 describes the construction of these measures and summarizes applications to wholesale electricity markets in California, Spain, and New Zealand.

The exercise of unilateral market power reduces the economic efficiency of wholesale market outcomes. Information on the technological characteristics of the generation facilities, input fuel prices, and bid and market outcome data can be used to construct a measure of market performance. This measure compares actual market prices to the market prices that would exist if no firms were able to exercise unilateral market power. This procedure accounts for daily input fuel price changes, generation unit outages, and emissions permit price changes in computing the counterfactual no-market-power outcomes. Section 5 describes the details of this procedure and summarizes applications to Spain, California, New England, and the PJM Interconnection region in the United States.

Quantitative merger analysis has recently begun to rely on models of industry equilibrium estimated or calibrated from data on market-clearing prices and quantities (see Werden and Froeb, 1994, 2002; Nevo, 2000). These models rely on functional form assumptions for firm-level demand and cost functions, as well as a model of strategic interaction determining market outcomes. Because of the availability of bid data and information on generation unit-level production costs, these assumptions can be dispensed with when analyzing proposed mergers in bid-based wholesale electricity markets. Section 6 proposes a method for estimating the competitive effects of mergers and provides a hypothetical application of this procedure.

2. Empirical models of oligopoly market outcomes

This section describes the identifying assumptions typically used to estimate models of oligopoly market outcomes that are