SPRING 2006

CSEM
Center for the Study of Energy Markets

RESEARCH review

UNIVERSITY OF CALIFORNIA ENERGY INSTITUTE • EDITOR: KAREN NOTSUND

Regulating NOx: How Well is the Cap and Trade Approach Working?

For decades, economists have argued that a "cap and trade" approach to regulating air pollution from stationary sources will yield a more efficient outcome, as compared to more traditional approaches involving emissions or technology standards. Under a cap and trade program, a fixed number of pollution permits are allocated to polluting sources. The permits are tradable, so if one source reduces its pollution it can sell its permits to another source where reduction may be much more costly. Over the past few decades, the cap and trade approach has gained momentum and is now the centerpiece of air pollution regulation for stationary sources in the United States.

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Meredith Fowlie, a doctoral candidate in the UC Berkeley Agricultural and Resource Economics Department, explores the impact the cap and trade approach has had on investment in pollution abatement and on the reduction in pollution in her paper "Emissions Trading, Electricity Industry Restructuring, and Investment in Pollution Abatement" (CSEM WP-149). In particular, Fowlie looks at the Nitrogen Oxide (NOx) State Implementation Plan (SIP) Call program, which encompasses 19 eastern states. The NOx SIP Call was introduced by the U.S. Environmental Protection Agency in 1998 to facilitate cost effective reductions of NOx from large stationary sources, primarily electricity generation plants, and was designed to help these states come into attainment with the federal ozone standards. The NOx SIP Call mandated a dramatic reduction in average NOx emissions. Firms had to make costly decisions to meet the emissions cap through one or more of the following actions: purchase pollution permits, invest in pollution abatement technology or reduce production at dirtier plants during ozone season.

In her paper, Fowlie analyzes whether the type of electricity market in which a firm is operating has significantly affected the compliance decision. Of the 19 eastern states in the NOx SIP Call, all have considered restructuring legislation but only 12 passed legislation approving restructuring; the remaining 7 officially resolved to not move forward with restructuring. Fowlie uses data on 632 coal-fired generating units that are regulated under the NOx SIP Call program. Using software developed by the Electric Power Research Institute, she is able to generate boiler-specific variable and fixed cost estimates for each viable compliance option. She also develops an empirical model of a plant manager's choice between investing in pollution abatement technologies or purchasing pollution permits to comply with the NOx cap.

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If RTP Is So Great, Why Don't We See More Of It?

Economic theory tells us that real-time pricing (RTP) delivers the most efficient retail pricing for electricity. Despite clear efficiency gains in theory, RTP has encountered resistance from many quarters and has not been adopted as wholeheartedly as economists would wish. Stephen Holland of the University of North Carolina-Greensboro and Erin Mansur of Yale University attempt to understand why adoption of RTP has been so slow.

In their paper, "The Distributional and Environmental Effects of Time-Varying Prices in Competitive Electricity Markets" (CSEM WP-143), Holland and Mansur analyze the short-run effects of RTP in the Mid-Atlantic market known as PJM. They construct a simulation model of competitive wholesale and retail markets and then analyze the impacts on load distribution, prices, profits and emissions. Their data cover the period April 1998 to March 2000. During that period, 60% of the electricity generated in PJM was from fossil-fuel plants, of which 46% was from coal plants, 35% from natural gas and 19% from oil. The simulation model uses the data from PJM to estimate the effect of more customers adopting RTP in competitive markets.

Holland and Mansur find that as more customers adopt RTP, the price distribution shifts such that the "peak" (i.e., high demand period) prices decrease and the off-peak (i.e., low demand period) prices increase. This decrease in the peak price is noteworthy since much concern has been expressed about exposing unsuspecting customers to extreme price variation. They find that with only a third of customers on RTP, the highest simulated price drops from the price cap of approximately $1,000 per MWh to only $164 per MWh. Thus, having some customers on RTP insulates the market from extreme price swings.

RTP adoption's impact on load distribution is reflected in firms' output decisions: coal-fired, baseload generation increases, while oil- and gas-fired, peak-load generation decreases. These changes in the price and load distribution also affect operating profits. Despite the fact that generation from coal-fired units is increasing, the effect of a falling average price is stronger, and coal-fired operating profits drop by 5% from their baseline. Operating profits decline more sharply for the other fossil generators – up to 60% for oil-fired generators and 35% for gas-fired generators – since generation as well as prices decrease with RTP adoption. These decreases in short-run operating profits may explain some of the resistance to RTP adoption.

All modeled consumers, i.e., those already on RTP, those on flat rates and those who switch, benefit from RTP adoption. The gains to consumers are large enough to offset the lost generator profits so the overall impact of RTP adoption is an increase in efficiency. However, the customer gains are relatively small per customer. In addition, if a customer chose to free ride on the RTP adoption of other customers, the customer could get up to 90% of the benefits of RTP without incurring any additional metering costs. The modest short-run gains, their dispersion across many customers, and free riding may explain the ambivalence of many customers toward RTP adoption.

Holland and Mansur also estimate the environmental impacts of RTP, finding an increase in SO_2 and NOx emissions and a decrease in CO_2 emissions. [See Table 1, Panel A.] Since coal-fired generation accounts for a very large proportion of SO_2 and NOx emissions and coal-fired generation increases with RTP adoption, net SO_2 and NOx emissions increase. Coal-fired generators account for a smaller proportion of total CO_2 emissions, and thus the decreased emission from oil- and gas-fired generators offset the increased emissions from coal-fired generators for a net reduction.

Table 1, Panels B – D shows the individual impacts on SO_2, NOx and CO_2 emissions as RTP adoption increases to 100% of customers. Coal-fired plants are primarily used for baseload generation in the PJM market, and hence their emissions of all three pollutants increase. That the percentage increase in emissions for each pollutant is greater than the increase in supply indicates that RTP adoption leads to a shift toward relatively dirtier coal-fired generation. Panels C and D show that the supply of oil- and gas-fired generation decreases by 9% and 3%, respectively, if all customers are on RTP, but the decreases in all three pollutants are even greater. This indicates that adoption of RTP leads to a shift away from the dirtier oil- and gas-fired units.

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REGULATING NOX: HOW WELL IS THE CAP AND TRADE APPROACH WORKING?

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Her data show that a significantly larger proportion of the coal capacity in regulated markets has been retrofitted with selective catalytic reduction technology (SCR), and conversely, a greater proportion of those plants in restructured markets has not been retrofitted or has been retrofitted with less expensive technology. The model's estimation results suggest that economic regulation in the electricity market significantly affected how plant managers chose to comply with the NOx SIP Call, and that managers in restructured markets are more biased against more capital-intensive compliance options, as compared to their more regulated counterparts. [See Figures 1a and 1b.] Because capital-intensive compliance options are associated with significantly greater emissions reductions, this implies that plants in restructured markets chose "dirtier" compliance options.

Ozone non-attainment problems are significantly more severe in states that have restructured markets, largely because of differences in levels of industrial activity, population densities, and weather conditions. Consequently the health benefits from reducing NOx pollution are significantly greater in these states. However, as Fowlie discovers, electricity generators in these states are less likely to invest in the most aggressive pollution abatement technologies.

In cases where the damages from pollution vary significantly across an identified region, such as the NOx SIP Call area, Fowlie argues that an "exposure-based" rather than an "emission-based" cap and trade program is more effective in reducing the harm from pollution. An "exposure-based" approach recognizes that the damage caused from an additional pound of pollution varies significantly across the region so more pollution permits are required per unit of pollution emitted in heavily polluted areas than in less polluted areas within the region. An "emission-based" permit allows a pollutant to emit a certain quantity of pollutants regardless of where those pollutants are emitted.

COMPLIANCE CHOICES OF UNITS IN REGULATED MARKETS

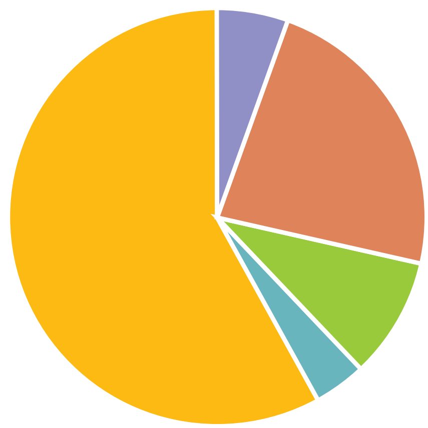

FIGURE 1A

COMPLIANCE CHOICES OF UNITS IN RESTRUCTURED MARKETS

FIGURE 1B

Combustion Modifications | No Retrofit | Low NOx Burners | SCR | SNCR

The NOx SIP Call program is an emissions-based cap and trade program.

Fowlie simulates exposure-based trading to determine how different the locational pattern of pollution would have been under exposure-based versus emission-based trading. She identifies "low damage" states as those that are primarily in compliance with the federal ozone standard and "high damage" as those states that are not. She assumes that one permit is required to offset one pound of NOx in low damage areas, and either 1.5 permits (scenario one) or 5 permits (scenario two) in high damage areas. These ratios are based on previous research done to examine damages from NOx pollution in the Eastern U.S. The simulation results predict an average reduction of 131 tons per day (6 percent) in emissions in the high damage areas in scenario one and an average reduction of 446 tons per day (22 percent) in scenario two. These results suggest more pollution would have been removed from areas of high damage and less from the areas of low damage if an exposure-based permit system were in place.

The effect of electricity market economic regulation on pollution control technology adoption affects permit markets in two ways. First, because plants with the lowest pollution control costs are not always the ones installing pollution controls, the permit market may fail to minimize the total economic cost of meeting the emissions cap. Second, because air quality problems are more severe in states that have restructured their electricity markets, this effect exacerbates the inefficiencies associated with emission-based trading. Not only are the companies with the lowest pollution control costs not necessarily the ones installing pollution controls, but those companies that are installing controls tend to be in areas where the impact of another pound of pollution is less than in other areas. The policy implications of this research are that permit markets for environmentally regulated regions where pollution damage varies should be designed to reflect the locational impacts of pollution, especially in cases where the economic regulation reduces the probability that pollution controls will be installed where they deliver the greatest social benefits.

Forward Contracts and Market Power

Experiences with electricity liberalization have varied greatly around the world. Differences in market design, regulatory oversight, and market structure no doubt play important roles in determining the relative performance of markets. However, much recent research points to the degree of vertical commitments between generation and retail as a key determinant of an electricity market's competitive performance. Most of the "successes" of electricity restructuring have featured markets with either a large amount of long-term supply contracts between generators and retailers or a continued integration between generation and retail, with the retailer's ability to raise prices restricted by regulators or transition agreements. By contrast, the California market was notorious for its lack of long-term arrangements between retailers and suppliers.

Contracts can play an important role in increasing competition by providing an additional avenue for firms to try to increase their market share. By committing publicly to a long-term power contract, or taking on a commitment to serve retail customers at a fixed rate for some time period, a firm signals to its competitors that it will compete more aggressively in the spot market. This is because this firm, having sold much of its output under fixed, pre-set prices, has much less incentive to raise spot prices at the expense of reducing sales. Knowing this, other firms would optimally respond by producing relatively less than they would if their competitor had not made such a commitment. This is the strategic advantage for a firm to sign contracts: it causes its competitors to cede market share to the firm signing the contract. However, every firm would prefer to sign contracts, leading every firm to increase production relative to the levels that would arise absent any contracts, and therefore, to a more competitive wholesale electricity market.

James Bushnell in his paper, "Oligopoly Equilibria in Electricity Contract Markets" (CSEM WP 148), demonstrates that the contracting effect strengthens as the number of firms in the market increases. Thus, while the impact of forward markets may be considered relatively modest when there are only two firms in a market, the effect is much stronger when there are even four firms. In fact, under some conditions the existence of a single forward market for a given spot period has an effect equivalent to squaring the number of firms competing in that market. Thus, four firms competing in both a single forward and spot market creates outcomes equivalent to 16 firms competing to sell in a spot market alone.

Among other insights, these results demonstrate the interaction of firm size and the opportunity to contract in making a market more competitive. The model is applied to sets of parameters derived from various U.S. electricity markets. Bushnell demonstrates that the addition of a single forward market to these markets is equivalent to a major increase in either the responsiveness of demand or supply, which can mitigate market power and make the market more competitive.

The pro-competitive effects are not universal, however. Several papers have demonstrated that contracts can have less appealing impacts in markets for differentiated products, or markets where contracting decisions are frequently repeated. These conditions do not seem to apply to electricity markets, however. Electricity is fundamentally a commodity market and long-term contracts or retail arrangements such as those for basic generation services (BGS) in eastern electricity markets are for the most part both publicly known and of sufficient duration that repetition is not a serious concern.

Traditionally, competition policy has operated with a focus on the size, or market share, of suppliers. At times other considerations, such as the use of vertical affiliates to block access to markets, play an important role. For the most part, however, competition policy has not considered the impact of long-term fixed-price contracts or other similar arrangements on the competitiveness of a market. These results indicate that the availability and type of long-term contracts in a market can have as much of an impact on competitiveness as demand elasticity and the concentration of supply. Therefore, forward markets need to be part of the equation when regulators formulate competition policies.

IF RTP IS SO GREAT, WHY DON'T WE SEE MORE OF IT?

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Holland and Mansur also explore whether allowing the flat retail rate to vary by month or by time of use (TOU) delivers gains comparable to RTP. Their simulations show that varying flat rates monthly has similar effects as RTP on load, prices, consumer surplus, profits, efficiency, and emissions. In fact, they find that approximately a third of the efficiency gains from RTP can be captured by simply varying the flat retail rates monthly and at no additional cost for metering. Capturing some of the benefits of RTP adoption through monthly variation in flat rates maintains the insurance features of flat rates in that customers are protected against "accidental" consumption during extremely high-priced periods but at a lower efficiency cost.

Although economists have been urging policymakers to adopt RTP for retail electricity markets for quite some time, RTP's adoption has been painfully slow. Holland and Mansur suggest, based on their simulation results for the PJM market, that perhaps the lack of enthusiasm for RTP stems from a short-run decrease in profits for generators and relatively small gains for individual consumers such that there is no strong constituency pushing for RTP. Even though the overall impact on the electricity market appears to be positive, without one sector or another clearly championing this change, it remains a rare feature of electricity markets.

TABLE 1: ENVIRONMENTAL EFFECTS OF RTP ADOPTION

PANEL A: ALL FOSSIL HOURLY EMISSIONS

Customers on RTP	Supply (MWh)	SO_2 (lbs.)	NOx (lbs.)	CO_2 (000 lbs.)
0%	18,144	294,109	174,512	74,995
Change in Supply and Emissions as Percentage of Customers on RTP Increases				
33%	0.00%	0.00%	0.00%	0.00%
67%	+0.07%	+0.39%	+0.14%	-0.08%
100%	+0.13%	+0.75%	+0.26%	-0.16%

PANEL B: COAL-FIRED HOURLY EMISSIONS

Customers on RTP	Supply (MWh)	SO_2 (lbs.)	NOx (lbs.)	CO_2 (000 lbs.)
0%	15,926	293,256	162,915	64,670
Change in Supply and Emissions as Percentage of Customers on RTP Increases				
100%	+0.93%	+1.28%	+1.33%	+1.29%

PANEL C: OIL-FIRED HOURLY EMISSIONS

Customers on RTP	Supply (MWh)	SO_2 (lbs.)	NOx (lbs.)	CO_2 (000 lbs.)
0%	345	768	4,857	2,971
Change in Supply and Emissions as Percentage of Customers on RTP Increases				
100%	-9.19%	-13.08%	-17.89%	-17.94%

PANEL D: GAS-FIRED HOURLY EMISSIONS

Customers on RTP	Supply (MWh)	SO_2 (lbs.)	NOx (lbs.)	CO_2 (000 lbs.)
0%	1,873	84	6,739	7,354
Change in Supply and Emissions as Percentage of Customers on RTP Increases				
100%	-3.4%	-5.34%	-6.87%	-5.58%

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