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RESEARCH *review*

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Has Southern California's Cap-and-Trade Program Delivered on its Promises?

Harnessing market forces to reduce pollution has gained prominence since the early 1990s. Cap-and-trade programs have been implemented in a variety of regulatory jurisdictions and are the preferred approach for climate change regulation. Questions remain though whether cap-and-trade programs really are more effective at reducing pollution than the traditional

"command-and-control" approach. And do these programs achieve mandated emissions reductions in a way that disproportionately harms traditionally disadvantaged communities? New research on Southern California's cap-and-trade program for nitrogen oxide (NOx) emissions answers these questions based on a new and innovative approach.

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Researchers Meredith Fowlie (University of California, Berkeley), Stephen Holland (University of North Carolina, Greensboro) and Erin Mansur (Yale University) take a rigorous and sophisticated approach in creating a "what if" scenario within Southern California's Regional Clean Air Initiatives Market (RECLAIM) program. In their paper, "What do Emissions Markets Deliver and to Whom? Evidence from Southern California's NOx Trading Program" (CSEM Working Paper 186), they exploit unique design features of the RECLAIM program to construct credible and transparent estimates of what the emission levels would have been had command-and-control (CAC) regulations applied rather than cap and trade. Although there have been previous efforts to measure the effectiveness of the RECLAIM program, the results have been contradictory and controversial.

The RECLAIM program was the first mandatory trading program to supplant a pre-existing CAC regime that was, in theory, capable of achieving the same environmental objectives. It was also the first program to include a broad and diverse population of sources, making it particularly relevant to future trading programs targeted at achieving ambitious goals for air quality and climate change. Finally, RECLAIM was also the first emissions trading program to be challenged on the grounds of environmental justice and noncompliance.

Fowlie, Holland and Mansur take a sophisticated approach to identify the causal effects of RECLAIM on facility-level emissions vis-a-vis the CAC regulations RECLAIM replaced. They carefully construct an estimate of what emissions would have been in the absence of RECLAIM using econometrically adjusted emissions

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How NOT to Use the Smart Grid

A major cause for many of the problems that have afflicted wholesale electricity markets is the absence of demand-side participation. These problems constitute the motivation behind the Federal Energy Regulatory Commission's (FERC) recent efforts to increase demand-side participation through promoting "demand response" programs. Expansion of demand response programs, however, could become the single largest barrier to truly price-responsive demand.

James Bushnell (Iowa State University), Benjamin Hobbs (Johns Hopkins University), and Frank Wolak (Stanford University) argue that FERC's focus on demand response programs is counter-productive to adoption of a truly symmetric treatment of supply and demand, which is an essential component of an efficient wholesale market. In their recent paper, "When It Comes to Demand Response, is FERC its Own Worst Enemy?" (CSEM Working Paper 191), the authors describe demand response and dynamic pricing programs and explain how demand response programs can crowd out dynamic pricing initiatives.

It has often been asserted by the FERC and others that there must be "symmetric treatment of supply and demand" in the electricity industry. What does it mean for supply and demand to be treated symmetrically and why is that important? Symmetric treatment means that supply and demand can respond via price signals to the underlying behavior of the firms and consumers in the electricity market. Enabling this fluidity of response is what allows the market to function efficiently and to allocate the product, electricity, efficiently.

Demand-side participation in the market is largely absent because consumers only see an administratively-set price for electricity that does not vary with market conditions. This can and does lead to periods of crisis when the price of wholesale electricity skyrockets, either as a reaction to a shortage of supply or a steep increase in demand, but demand doesn't respond because it doesn't get the market price signal. Generally during those crises, public officials launch public campaigns pleading with consumers to voluntarily cut back their electricity consumption. This is not how an efficient market functions.

The two flavors of demand-side participation discussed and promoted are demand response programs and dynamic pricing. Traditional demand response programs typically pay customers to reduce their consumption relative to an administratively-set baseline level of consumption. This reduction in consumption is treated as a service provided by the consumer and historically has been called upon for reliability purposes. In many cases, demand response resources can only be called upon to provide a reduction in consumption in response to a declaration of a system emergency.

The term dynamic pricing refers to prices that vary with real-time supply and demand conditions. Most industries operate with retail prices that reflect actual supply and demand conditions for the good, but that is not the case for electricity. In past decades, arguments could be made that technological constraints, such as a lack of available interval meters or cost constraints, prohibited the adoption of dynamic pricing. Today, however, not only are meters available, they are being installed in homes throughout the country. In California, all three investor-owned utilities plan to complete interval meter installation for all their customers by 2011 and, through the federal stimulus funding for a "smart grid," the rest of the nation will also receive meters at an accelerated rate.

Within the electricity industry, various models of dynamic pricing have been applied, including real-time pricing (RTP) and less dynamic and more restrictive forms such as critical peak pricing (CPP). Even if an hourly RTP were implemented as a default price by a utility this in no way obligates consumers to pay the hourly wholesale price for their electricity. Utilities can and do offer a variety of pricing options where some portion of a consumer's expected usage is essentially bought ahead of time at a pre-determined price in the same manner that cell phone plans are bought for a specified number of minutes. The consumer anticipates how many minutes they may use in a month and buys the plan that includes that number of minutes in the flat monthly fee. If you consume more, then you pay a per-minute cost for each additional minute. RTP for electricity can work this way as well and the RTP rates for additional electricity consumption would vary depending if your usage were during peak or off-peak times of the day or night. So just as with your cell phone plan, a consumer could have control over the bill depending on how much electricity consumption they wanted to buy ahead and when they chose to concentrate their electricity usage.

Most of what are traditionally described as demand response (DR) programs pay consumers to reduce their consumption relative to some administratively set level. Any initiative that pays consumers not to consume something faces a serious challenge of measuring what the consumer would have consumed without the payment. It is impossible to observe this hypothetical consumption level, because we cannot measure something that did not happen. Determining what the consumer's consumption

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Gasoline Content Regulation: A Case Where Flexibility Isn't A Good Idea

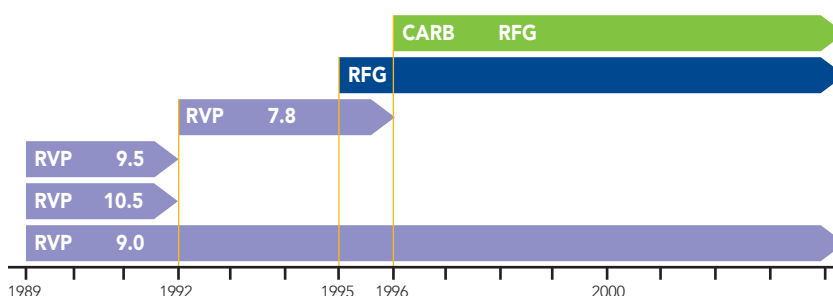
Discussion of any new regulation brings with it the question of how flexible or prescriptive it should be. A more flexible regulation allows the regulated firm to choose how to meet a standard while a more prescriptive approach specifies precisely what the firm must do to comply. In one particular set of gasoline regulations targeted at reducing ozone pollution, regulators have imposed both types of regulation: a performance standard which allows the firms to choose how to meet an overall emissions standard, and a chemical content specification, which dictates the chemical composition of the gasoline. After years of experience with these regulations, the question is how have they performed in reducing ozone pollution?

The primary goal of gasoline content regulation is to reduce ground-level ozone by targeting emissions of its chemical compounds. Ozone is created in the atmosphere through chemical reactions involving these compounds, sunlight and warm temperatures. The two classes of chemical compounds that react in the atmosphere to produce ozone are volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). VOCs include a large number of chemical compounds with varying degrees of reactivity; some compounds are nearly 80 times more reactive than others.

Maximilian Auffhammer (University of California, Berkeley) and Ryan Kellogg (University of Michigan) examine the effectiveness of regulations on the chemical composition of gasoline that are primarily intended to reduce VOC emissions from mobile sources. Their paper, "Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality" (CSEM Working Paper 185), is the first study to comprehensively analyze whether these regulations actually led to lower levels of ground-level ozone.

Gasoline content standards are not uniform across the country: the Environmental Protection Agency (EPA) regulates some states and counties more tightly than others, and some areas have implemented their own standards that are more stringent than those set by the EPA. The first gasoline regulations, adopted in 1989, targeted ground-level ozone pollution through a performance standard – the Reid vapor

FIGURE 1: REGULATORY TIMELINE



Notes: RVP: Reid vapor pressure regulation (the number refers to the vapor pressure limit). RFG: Federal reformulated gasoline. CARB RFG: California Air Resources Board reformulated gasoline

pressure (RVP) standard. RVP gauges the intensity with which the VOCs are released from gasoline through evaporation and is measured in pounds per square inch (psi). RVP regulation was introduced in two phases. Phase I covered 1989 through 1991 and the RVP limits differed by state and by month.

Phase II began in 1992 and required all states to meet the most stringent Phase I requirement. Moreover, RVP II mandated an even more strict requirement for non-attainment areas in southern states. RVP II remains active today, though in some areas they have been superseded by federal reformulated gas (RFG) or California Air Resources Board (CARB) standards. RFG regulations were introduced in 1995 and federally mandated in areas designated to be in severe non attainment of the EPA's ozone standard. RFG was also implemented in two phases. Phase I began in 1995 and phase II in 2000. RFG regulations are tighter than those of RVP and involve both content and performance standards. In addition to setting limits on the intensity with which VOCs are released, RFG also set a specific limit on the amount of benzene and mandated a minimum oxygen requirement for the gasoline.

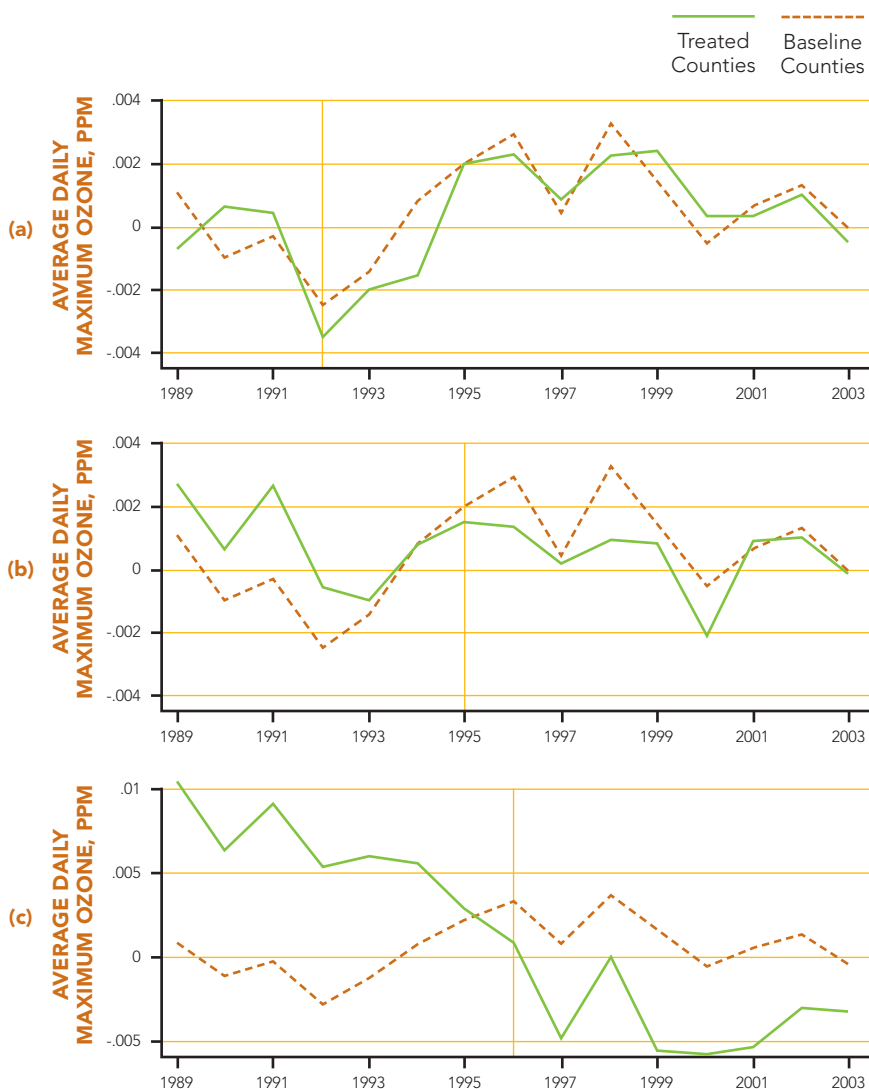
California and Arizona have implemented their own gasoline programs that are even more stringent than federal RFG. Like federal RFG, CARB gasoline caps the benzene content, but it also imposes more stringent VOC emissions standards, and limits the concentrations of olefins and aromatic hydrocarbons, both of which are highly reactive in forming ozone. Figure 1 illustrates the timeline of the introduction of each of these gasoline regulatory standards. This patchwork of regulations – including both more flexible and more prescriptive approaches – combined with an abundance of emissions data from across the country allows for a careful comparison of the effectiveness of the regulatory approaches.

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GASOLINE CONTENT REGULATION

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FIGURE 2: MEAN SUMMER OZONE CONCENTRATIONS



Notes: Values plotted are averaged residuals of a regression of daily maximum ozone on weather variables Wit and Dit described in section 4.1 and monitor fixed effects. Vertical bars indicate the first implementation of the indicated regulation. Data include only those monitors recording data in every summer.

Figure 2 depicts the time path of summer ozone concentrations in counties under different forms of regulation. Panel (a) compares the ozone emissions in counties treated with a stringent RVP Phase II standard to counties with a much more relaxed RVP standard. The introduction of the RVP phase II standard in 1992 does not appear to have substantially affected summertime ozone concentrations. Panel (b) suggests that the introduction of federal RFG in 1995 may have caused modest reductions in ozone pollution. However, panel (c) shows a substantial decrease in ozone concentrations in California counties around the time CARB gasoline was introduced in 1996. It is difficult to discern from this graph alone whether this decrease can be attributed to CARB gasoline or to other factors acting over a multi-year span.

Through rigorous econometric analyses, however, Auffhammer and Kellogg were able to isolate the impact of the regulations and found that the introduction of federal

RFG in 1995 led to modest decreases in ground-level ozone in New Jersey and New York, but not elsewhere. In California, the adoption of CARB standards caused a large and statistically significant decrease in ozone concentrations in the densely populated and heavily polluted southern part of the state. They found no evidence that federal RVP standards were effective in reducing ozone pollution, even in California.

The likely explanation for the failure of RVP regulations to reduce ozone concentrations centers on the flexibility that RVP regulations grant to refiners in meeting RVP's VOC reduction standards. VOCs include a large number of chemical compounds, and while RVP standards cap the overall rate of VOC emissions from gasoline, they allow refiners to choose which VOC to remove. Refiners meet RVP requirements primarily by removing VOC butane from their gasoline because it is the most cost-effective means for them to achieve the RVP standards. However, butane is not highly reactive in forming ozone so even though the RVP standard is met, this emissions reduction does not translate into a reduction in ground-level ozone. It is the more prescriptive CARB regulation that identifies the particular VOCs to limit and has been more effective at significantly improving air quality.

In the case of gasoline regulations aimed at reducing ozone emissions, the more flexible regulatory standard allowed refiners to implement the most cost-effective technique from their standpoint, but the goal of the regulation was not achieved. It has been the more prescriptive regulatory standard that was effective at actually reducing ozone concentrations, albeit at a higher compliance cost to the refiners. These outcomes highlight the need for environmental regulations to anticipate and mitigate the behavioral responses of the regulated entities when faced with a more flexible regulatory approach.

CAP-AND-TRADE PROGRAM

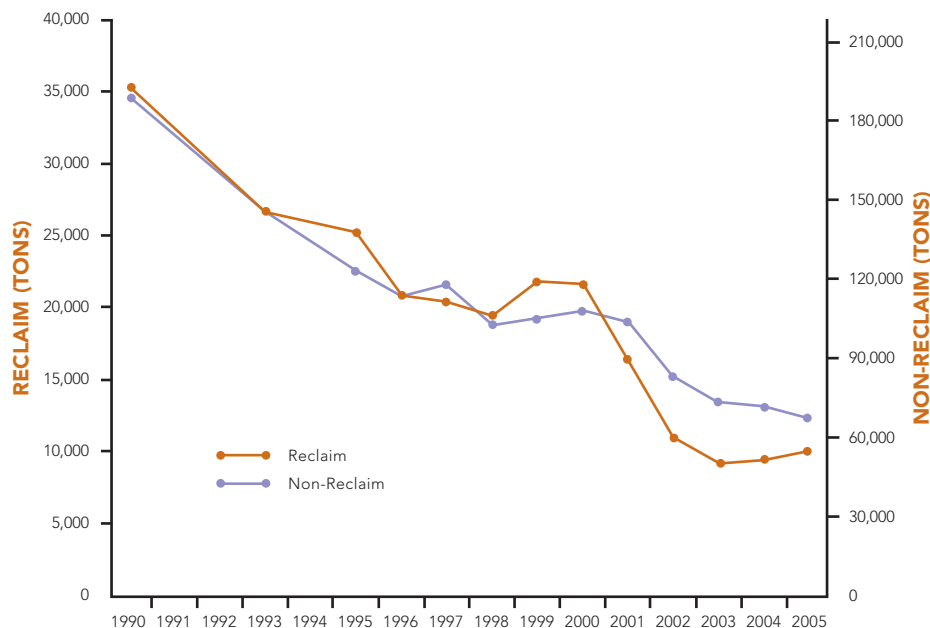
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observed at similar California facilities not regulated under RECLAIM. While RECLAIM applies only to major sources of emissions located within the South Coast Air Quality Management District (SCAQMD), there are thousands of California facilities located outside the Los Angeles air basin and hundreds of smaller emitters within the basin that are subject to more traditional CAC rules. From these non-RECLAIM facilities, the authors carefully construct a comparison group for each RECLAIM facility. These comparison groups yield a credible estimate of what the level of pollution would have been had the RECLAIM facilities continued to be subject to CAC rules.

Figure 1 shows the declining trends in total NO_x emissions at California's facilities between 1990 and 2005. The figure illustrates that, in the aggregate, NO_x emissions from both RECLAIM and non-RECLAIM facilities were declining at similar rates prior to the introduction of RECLAIM in 1994. In the early years of the RECLAIM program, when more permits were issued than were needed, emissions of RECLAIM facilities appear to increase slightly relative to facilities outside the program. After the cross-over point in 2000, however, the average rate of emissions decrease among RECLAIM facilities exceeds that of non-RECLAIM facilities. After carefully constructing their comparison groups, the authors estimate that emissions at RECLAIM facilities fell approximately 25 percent on average relative to emissions in the control group. These results suggest that the RECLAIM program did deliver on its promise to reduce emissions more than would have occurred under a command-and-control approach.

Environmental justice advocates have historically opposed market-based approaches to environmental protection. The most common criticism is that emissions trading programs fail to account for the distribution of pollution damages. If polluting facilities can

**FIGURE 1:
TOTAL NO_x EMISSIONS IN RECLAIM AND IN THE REST OF CALIFORNIA**



purchase permits instead of reducing emissions, it is possible for pollution concentrations to be greater in areas where poor or minority populations live. Another possible scenario, however, is that relatively dirty facilities with low-cost pollution reduction options may be disproportionately located in traditionally disadvantaged neighborhoods, so a well functioning permit market could ensure that a larger share of the mandated emissions reductions are achieved in those areas.

Using demographic data from the 2000 Census, the researchers use two complementary approaches to analyze the race and income characteristics of the neighborhoods where the emissions reductions took place. Looking at households living within a half mile, one mile, and two miles of a facility, Fowlie, Holland and Mansur find that both the actual and relative emissions (the difference between the actual emissions and the emissions for the comparison group) fall for almost all demographic groups. Overall, the emissions reductions do not have a clear pattern based on income or race; neither the wealthiest nor the poorest neighborhoods experience disproportionate decreases in NO_x emissions under RECLAIM. Using regression-based techniques, the authors find similar results: emissions reductions from RECLAIM are not correlated with income or race demographics. These results indicate the effectiveness of the RECLAIM cap-and-trade program and suggest that these benefits were evenly distributed across demographic groups.

Cap-and-trade has been used to regulate other pollutants and is currently the preferred approach for carbon dioxide regulation in California and beyond. Other pollutants in other markets may respond differently, so generalizing these results to other scenarios should be done with care. However, this evidence demonstrates that a cap-and-trade program can deliver more significant emissions reductions (as compared to more prescriptive, non-market approaches) without disproportionately affecting susceptible populations.

THE SMART GRID

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would have been without the payment must rely on an economic or statistical model of the consumer's behavior.

This problem is often described as the "baseline" problem, which can be broken down into two classic difficulties: adverse selection and moral hazard.

The adverse selection problem arises because all customers who reduce their usage relative to their baseline are rewarded with a payment, even if they would have reduced their usage without the payment. For example, if a household had a child graduating and moving out, the household's electricity consumption would likely decrease regardless of a demand response program. The household would receive a payment for an action that had nothing to do with the demand response program. The

moral hazard problem arises whenever customers are rewarded for having higher baselines. Firms and customers have a strong incentive to inflate their baseline because they are paid based upon the comparison of their actual consumption to this baseline. So as a reaction to a program designed to reduce demand, demand can in fact increase! Many of today's demand response programs are vulnerable to both adverse selection and moral hazard. Both problems can inflate the costs of the program, which are ultimately born by the customers.

Bushnell, Hobbs and Wolak conclude that the real barrier to active demand-side participation is legal jurisdiction. FERC only has authority to require demand response programs through its regulation of the wholesale markets. It is the state public utility commissions who have the authority to order dynamic pricing through their regulation of the distribution utilities. FERC is ready to do what it can to push demand-side participation but it is really the state commissions that have to step up to the plate and implement dynamic pricing. Unfortunately, FERC's efforts may lead to a proliferation of demand response programs, which can discourage the adoption of dynamic pricing. When offered the choice of either program, consumers are likely to prefer demand response programs that are more attractive financially to them as individual households, even if the programs inflate the overall cost of electricity.

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