Review of the Economics Literature on US Electricity Restructuring

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Executive Summary

In the late 1990s, the US electricity industry began the process of partial deregulation and regulatory reform often referred to as *restructuring*. While this time period is often thought of as the origin of restructuring, it was, in fact, an acceleration of trends and changes that had been developing for some time. For some regions, restructuring brought dramatic changes where traditionally regulated and vertically integrated utilities were broken up and replaced with independent power producers (IPPs), wholesale markets, and competitive retail services. Other regions either only partially deregulated some sectors, like generation, or eschewed these changes altogether and retained the same structure that they had in 1996 before restructuring began.

Nearly 20 years of restructuring electricity markets has led to a mix of results. Retail competition remains relatively static while Regional Transmission Organization (RTO) markets expand and evolve. A natural question for both policy makers and researchers to ask is: "Did it work?" While simple, this question requires nuanced answers as areas may differ in what is meant by "restructuring" and because impacts vary by location, segment of the industry, and customer class. Careful, informative, and policy-relevant research has studied the many aspects of restructuring such as the effects of generation deregulation on competition, the efficiency of system operations, and the impacts on consumer prices.

This report discusses several key empirical and analytical findings in the economics literature on the subject of electricity restructuring. This review is not an exhaustive coverage of the extensive literature concerned with the electricity industry. Rather, we focus on several comprehensive and prominent economics studies that we organize into five categories: competitiveness; efficiency; generation investment; retail competition and price impacts; and environmental performance. Our main findings are below:

Competitiveness in Wholesale Markets

- Wholesale electricity markets are more vulnerable to the exercise of market power than those for almost any other commodity; several markets around the world (most notably California) have experienced periods where market power was a severe, though transitory, problem.
- Despite the notable isolated failures of competition, US electricity markets are now found to be reasonably competitive overall based on empirical measures testing for market power in the short run.

- A primary driver of this competitive performance has been the extent and magnitude of forward commitments, through contracts and vertical integration, between generation firms and retail providers.
- More research is needed on the competitiveness of forward markets, the market elements that promote liquid and competitive forward markets, and the effectiveness and impact of the various market power mitigation measures commonly deployed in RTO energy and capacity markets.

Efficiency

- Studies have demonstrated that expansion of RTO footprints has increased trade and improved coordination among power plants.
- Variable operating costs at regulated investor-owned plants in restructuring states declined in the 1990s, but not at municipal owned plants unaffected by the prospect of restructuring.
- Deregulation of nuclear power plants lead to substantial increases in their availability and output.
- Deregulation of coal-fired power plants lead to substantial decreases in their fuel prices.
- The effects of restructuring are likely to differ by region thereby implying that estimated effects of restructuring in one market need not apply to regions that did not restructure.
- In order to compare the benefits and costs of introducing an RTO, more research is needed especially on their direct and indirect costs.

Generation Investment

- The industry experienced a massive expansion in generation capacity that coincided with the onset of restructuring between 1998 and 2002.
- This investment boom led to periodic gluts of capacity and contributed to the severe financial distress of many non-utility generation firms during the 2000s.
- The economics literature has yet to identify the causal effects of restructuring on either the levels or types of investment.
- Academic studies and RTO reports have calculated that revenues from short-term energy and ancillary service markets have, most of the time, been insufficient to recover the full average cost of power plant construction and operations.
- Findings on the shortfalls of short-term markets may provide evidence on the need for supplemental resource adequacy policies, but also reflect the disequilibrium of an industry that has undergone shocks to regulatory treatment, fuel prices, and renewable policies over the last decade.

Retail Competition and Price Impacts

- Retail electricity prices are more tightly linked to natural gas wholesale prices in states that have restructured generation than in states that do not.
- Evidence of the impact of restructuring on retail price *levels* is inconclusive.
- Residential customers exhibit large choice frictions, and retail switching by residential customers has been relatively infrequent.

- Most residential customers purchase energy from Providers of Last Resort (POLR).
- More data and research are needed on the size and nature of retail margins, the impact of retail market structures on wholesale markets, the influence of vertical integration on retail competition, and on the methods of procurement (competitive and regulated) for POLR customers.

Environmental Performance

- Restructuring-driven increases in plant-level fuel efficiency and nuclear availability have provided sizable reductions in pollution.
- Increased inter-regional trade caused by RTO expansions has potentially increased total production from coal units, possibly negating pollution reductions achieved by plant-level efficiency gains.
- Regulated utilities and IPPs respond to pollution cap-and-trade programs very differently; regulated firms invest in capital-intensive abatement technologies while IPPs pursue lower cost abatement options – suggesting that cap-and-trade is more efficient in restructured markets.
- While cap-and-trade programs are most effective when combined with competitive electricity markets, well-connected wholesale markets have the potential to exacerbate the potential of pollution leakage in settings where pollution regulations only apply to a subset of the generators in the market.
- More research is needed to determine whether restructured markets are better able to integrate high volumes of intermittent, renewable electricity generation.

It may seem counter-intuitive that research has found improvements in both system-wide and plant-level operating efficiency, and reasonable competition (outside of California around 2000), but also that retail prices have seen little benefit from electricity restructuring. Part of the answer stems from the fact that retail prices cover many different expenses beyond the cost of generating electricity, and most of these additional costs are determined by traditional economic regulation. Any changes at the wholesale level are significantly diluted by the time they filter through to retail prices. Another explanation relates to the fact that much of the efficiency gains appear to be at baseload generation facilities. Such plants rarely set the market price, so cost reductions at these plants would not necessarily translate to reductions in overall prices. Indeed, that is part of the powerful incentive to reduce costs at such plants. Lastly, it is important to recognize that more *efficient* prices do not always translate into *lower* prices, particularly in the face of cost shocks to inputs such as natural gas. While retail prices in this industry remain far from marginal cost, it appears that this relationship may now be followed more closely in the markets with the highest portion of restructured generation.

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1 Introduction

The transformation of the electricity industry and the process of regulatory restructuring has proceeded unevenly over the course of the last three decades. While many saw the deregulation of the power industry as a natural extension of similar initiatives that had successfully transformed the airline, trucking, telecommunications, and natural gas industries, those closest to the industry anticipated the challenges and complications entailed in introducing competition into the power industry. In 1983, Paul Joskow and Richard Schmalansee (1983) published *Markets for Power* that, in some ways, marked the intellectual origin of the restructuring movement. The book in no way sugarcoated the challenges to creating a workable, competitive power industry. As one reviewer noted, the book "will be gravely disappointing to a good many economists and lawyers" currently pushing for dramatic deregulation of the industry.

Around that time, Fred Schweppe and his colleagues (1988) were writing *Spot Pricing of Electricity*, which developed methodology that incorporates the technical aspects of electricity system operation into a system of equilibrium prices. Schweppe *et al*. articulated a vision for market-based power system operations that has been adopted by electricity system operators around the world. It became the engineering analog to the economic and institutional vision of *Markets for Power*.

Nearly 30 years later, large parts of the United States electricity industry have gone down the road of structural change at least partially envisioned in these two early works. At the same time, the governance and oversight of the power industry in other parts of the US have changed only modestly since the mid-1980s. This variation in the commitment to, and experience with, electricity restructuring provides both a sign of its complexity and an opportunity to study its impact. The staggered introduction of a variety of changes has provided economists with several so-called "natural experiments" from which effects of restructuring can be estimated.

In this report, we review some notable contributions to this literature in order to identify some of the key insights regarding the impact of restructuring and to highlight several important questions that remain largely unanswered. As foreseen in *Markets for Power*, restructuring of the industry can be implemented at several different levels and with varying intensity. Our review of the economic literature it organized around these different industry segments and issues. We review five aspects: competitiveness; operational efficiency; generation investment; retail price impact; and environmental performance.

Before delving into the review of this literature, we provide some background. In Section 1.1, we discuss the industry's structure, review its primary segments, and explore how they can and have been transformed by regulatory restructuring. Then, Section 1.2 provides a brief discussion of the common methodological approaches adopted by the studies that we review. We summarize the findings of our review of the literature in Section 1.3.

1.1 The Structure of the Electricity Industry

The electricity supply industry comprises a sequence of several vertically integrated, though quite distinct, activities. A common grouping of these activities includes the following:

- *Generation* The production of power from large (or utility) scale generation plants.
- *Transmission* The high-voltage transmission of power within and between utility power control areas.
- *Distribution* The distribution of power to end-use customers over local low-voltage networks.
- *Retail* The metering, billing and resale of wholesale power to end-use customers.

1.1.1 Layers of Restructuring

One of the main challenges with describing the impacts of regulatory restructuring is that there is no single definition of what actually is "restructuring." There are as many variants to restructuring as there are segments to the industry. In their recent review of restructuring, Borenstein and Bushnell (2015) focus on three key layers of reform.

The first set of reform was the creation and expansion of independent Regional Transmission Organizations (RTOs) that are designed to promote non-discriminatory access to the high-voltage electricity grid.[1] The creation of RTOs also coincided with the adoption of market-based operations, or *dispatch,* as a means of coordinating the operations of many generation plants over a geographically large network. By 2014, these organizations covered roughly two thirds of the power control areas in the US, and roughly 60% of the large-scale generation (see Figure 1).[2] Importantly, the wholesale power markets overseen by RTOs contain both states and utilities that did not adopt any of the other aspects of restructuring, as well as those that adopted all aspects.

[1] This report uses the term RTO to also include any Independent System Operator (ISO).
[2] Source of this figure is http://www.ferc.gov/industries/electric/indus-act/rto/elec-ovr-rto-map.pdf

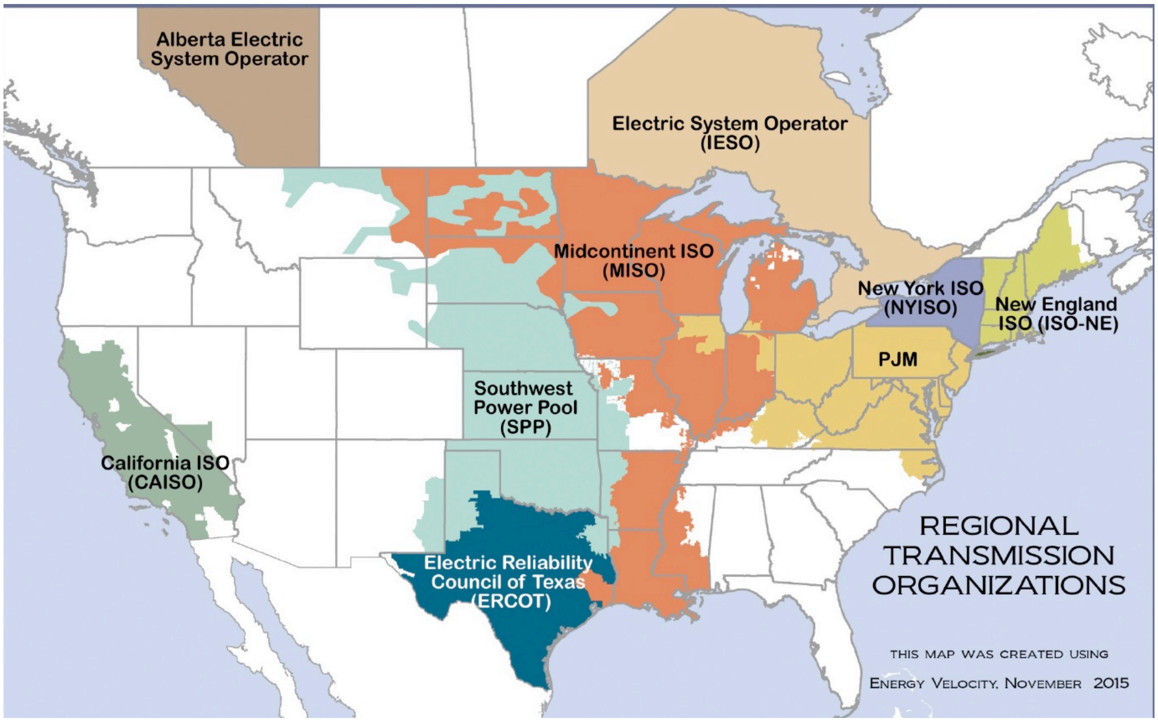

Figure 1: Map of US Regional Transmission Organizations

The second dramatic change in the industry was the adoption of retail competition for end-use customers in many states. Prior to these changes, most end-use customers could only purchase power from a local utility operating as a monopoly franchise. As we discuss in Section 5, the motivations for retail competition were varied and met with some skepticism, but retail "choice" was also a catalyst for other changes in the industry.

The third important transition in the industry was the migration of much of the generation sector from regulation to some form of market-based compensation. We use the word "deregulation" with caution, as many layers of regulation still apply to non-utility generators, but the key change was a movement away from regulated compensation based upon the cost of building, owning and operating a power plant, toward payment based upon some measure of the market value of the plant's output.[3] While it appears this transition has provided more powerful incentives to reduce costs, it comes with the risk of increased incentives for producers to exert market power to influence prices.

This shift in generation incentives has been both the most widespread and the most gradual of the three layers of reform. The migration of the generation sector to non-utility generation began with the adoption of the Public Utilities Regulatory Policy Act (PURPA) of 1978, and expanded

[3] This report uses non-utility generator and independent power producer interchangeably.

in various forms over the next few decades. The industry did go through a massive transformation between 1998 and 2004, however, when the share of non-utility (*i.e.* market-based) generation capacity grew from less than 5% to close to 40% of the nation's capacity.

1.2 Empirical Methods to Identify the Impacts of Restructuring

Prior to the wave of restructuring in the US, several economic studies attempted to predict how the upcoming changes would affect the electricity sector. These studies typically combined plant level data with economic models of firm-level competition in order to simulate how individual firms or generators would operate. While such prospective studies provided important insights into the potential impacts of restructuring, the predictions were dependent on strong, often untestable assumptions regarding how firms would react to an entirely new set of incentives.

In contrast to the forward-looking, simulation-based studies, a large body of empirical research now exists which looks back at the existing data and asks: What has been the impact of restructuring? In order to answer this question, researchers must estimate how markets or individual plants would have operated had various aspects of restructuring never occurred. To produce estimates of this *counterfactual* outcome, two main empirical strategies have been utilized: "before-versus-after" estimators; and "differences-in-differences" estimators.

The before-versus-after estimation strategy, which includes event study methods, uses outcomes that were observed prior to a change in market structure to estimate how the future would have unfolded had the market reform never occurred. Effectively, this approach assumes that any change in a market's performance that occurs immediately after an event (*e.g.*, an RTO expansion) is caused by the event itself. For this to be an effective estimation strategy, any other factors that could affect market outcomes – and which are not directly controlled for by the researcher – must not be changing at the same time as the event being studied. For example, if an RTO expansion occurred at the same time as a dramatic shift in fuel prices, then any observed changes in electricity trade flows may not be solely attributable to the RTO expansion.

While the before-versus-after estimation approach examines how markets or plants exposed to restructuring operate differently over time, the differences-in-differences strategy takes advantage of an additional source of variation. In particular, not all plants are affected by restructuring in the same way or at the same time. For example, some states restructured their electric sectors while others did not. In addition, within a restructured electricity market, some plants continued to be operated by regulated utilities while others were operated by unregulated, non-utility generators. In order to determine how generators exposed to new, market-based incentives were affected by market reforms, the differences-in-differences approach compares the before-versus-after changes among the "treated" generators – *i.e.* the plants directly affected by market reforms – to the before-versus-after changes among a set of "control" generators – *i.e.* similar plants that did not face new, market-based incentives.

1.3 Primary Findings of the Literature

We have discussed how restructuring has taken various forms and affected different segments of the industry. An assessment of the impacts of restructuring is best approached by examining its impacts on these different industry segments. Below, we summarize the findings that we discuss in detail in the rest of this report.

We examine the literature on competitiveness in Section 2. Ensuring wholesale power markets are sufficiently competitive is a challenge. Fundamental attributes of electricity require constant balancing of supply and demand, with relatively few economic options for storage and very little price response from consumers. Despite these challenges, and despite a notable failure of competition in California during 2000 and 2001, the level of market power in the industry as a whole has been relatively modest and transient. Two aspects of power markets appear to be important drivers of this performance: the large degree of forward commitments (through contracts or vertical integration with the retail sector); and the application of market power mitigation tools by RTOs. Important questions remain on the drivers of competition. While the impacts of forward commitments have been extensively studied, much less is known about the best ways to ensure such forward commitments are in place. Furthermore, while market power mitigation tools are omnipresent in RTO markets, the economics literature has not extensively studied their impacts, or their potential unintended side effects.

Section 3 reviews the literature on competitiveness. Economists anticipated that replacing cost-based payments with market prices would provide more powerful incentives for generation firms to operate more efficiently. Several studies provide evidence that this did indeed occur for several sectors of the industry. The expansion of market-based system operations through RTOs appears to have increased utilization of infrastructure and allocated responsibilities for production more efficiently. At the plant-level, availability at restructured nuclear generation stations has increased significantly relative to their regulated brethren. Labor productivity has increased substantially, resulting in a reduced power-plant workforce with no apparent reliability impacts. Finally, restructured firms appear to focus more on the prices paid for the acquisition of fuel, lowering their input costs.

In Section 4, we discuss the literature on investment. It was hoped that regulatory restructuring would also improve the efficiency of investment in generation in the industry. It is very difficult to estimate the extent to which this has happened. The industry did experience an enormous boom in investment as restructuring began, increasing capacity by nearly 50%. However, many firms have struggled to recoup an acceptable return on those investments, and studies indicate that marginal power plants have not received sufficient revenues from short-term markets to cover their capital costs. While this may be an indication that additional compensation for capacity is necessary, it also may reflect the fact that the industry, which experienced a series of major shocks over the last decade, still has not reached anything resembling a long-term equilibrium.

We examine the literature on retail effects in Section 5. Arguably, the most fundamental question regarding restructuring relates to its impact on consumers' electricity prices. Here again, the empirical research is somewhat muddled. The studies we review here find little impact on the changes in prices between restructured and non-restructured markets over the last 15 – 20 years. However this currently neutral finding masks several swings in the relative price relationship over the years. It appears that in markets with the most deregulated generation, retail prices more closely follow the prices of natural gas. When natural gas was rising, electricity rates in restructured states rose more quickly than in non-restructured ones. As gas prices have declined over the last half-decade, this trend has reversed.

Finally, Section 6 reviews the literature on environmental performance. The findings discussed above of more fuel efficient fossil plants and more productive nuclear plants suggests pollution reductions. However, if increasing trade across regions due to restructuring leads to more production from coal plants, this could have the opposite effect. Firms in restructured markets are more likely to respond to market-based environmental regulations, like cap-and-trade programs, in a more cost-effective manner. However, well-connected wholesale markets have the potential to exacerbate the potential of pollution leakage in settings where pollution regulations only apply to a subset of the generators in the market.

It may seem counter-intuitive that research has found improvements in both system-wide and plant-level operating efficiency, and reasonable competition (outside of California around 2000), but also that retail prices have seen little benefit from electricity restructuring. Part of the answer stems from the fact that retail prices cover many different expenses beyond the cost of generating electricity, and most of these additional costs are determined by traditional economic regulation. Any changes at the wholesale level are significantly diluted by the time they filter through to retail prices. Another explanation relates to the fact that much of the efficiency gains appear to be at baseload generation facilities. Such plants rarely set the market price, so cost reductions at these plants would not necessarily translate to reductions in overall prices. Indeed, that is part of the powerful incentive to reduce costs at such plants. Last, it is important to recognize that more *efficient* prices do not always translate into *lower* prices, particularly in the face of cost shocks to inputs such as natural gas. While retail prices in this industry remain far from marginal cost, it appears that this relationship may now be followed more closely in the markets with the highest portion of restructured generation.

This report is not a comprehensive coverage of the extensive literature concerned with the electricity industry. Given the enormous scale and scope of this topic, we have had to narrow our emphasis. We have focused on several of the most comprehensive and prominent studies, with an emphasis on the economics literature. We do this in the interest of brevity and in no way mean to diminish the many relevant and excellent studies coming from the operations research and engineering communities, as well as the extensive documentation and ongoing analysis from the electricity market monitoring community. We have also limited the topics we review to the areas in which the economics literature has had the most to say.

There are other important topics for which no strong signal of the impact of restructuring has emerged. For example, service quality and reliability remain topics of the highest importance and concern in the power industry. However, outside of the California electricity crisis, regulatory restructuring has had little impact in this area; the industry has maintained its traditional high standards of this regard. Other areas, such as the investment in transmission infrastructure, are important and are likely to be influenced by structural changes, like the move to RTOs, but have been understudied by academic economists.

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2 Competitiveness in Wholesale Markets

- **Wholesale electricity markets are more vulnerable to the exercise of market power than those for almost any other commodity; several markets around the world (most notably California) have experienced periods where market power was a severe, though transitory, problem.**
- **Despite the notable isolated failures of competition, US electricity markets are now found to be reasonably competitive overall based on empirical measures testing for market power in the short run.**
- **A primary driver of this competitive performance has been the extent and magnitude of forward commitments, through contracts and vertical integration, between generation firms and retail providers.**
- **More research is needed on the competitiveness of forward markets, the market elements that promote liquid and competitive forward markets, and the effectiveness and impact of the various market power mitigation measures commonly deployed in RTO energy and capacity markets.**

When electricity markets first restructured, many economic studies focused on questions of competitiveness. There were strong reasons for this focus, as the evolution of the industry from a series of parallel monopolies raised concerns about the concentration of generation ownership. Joskow and Schmalensee (1983) noted that "there is significant uncertainty as to the likelihood of effective competition in bulk power supply in many areas of the country." Simulations of oligopoly competition indicated potentially serious competition problems in some markets (Schmalensee and Golub 1984, Borenstein and Bushnell 1999).

Borenstein (2002) explains that restructured electricity markets are susceptible to firms exercising market power because of extremely inelastic demand in the short run and the limited ability to store electricity. A firm with even a small market share that has the incentive and ability to raise wholesale electricity prices can do so by offering power from some of its generating units that are likely to be on the margin at high prices or simply withholding some of its capacity from the market at any price.

This strategy is likely to be successful because customers have limited or no incentive to reduce consumption when hourly spot prices soar. In addition, competitors may be unable to undercut high prices if they are near full capacity across all power plants and have limited storage capacity available. This inherent vulnerability to supplier market power implied that traditional screens for acceptable levels of competitiveness would be misleading and insufficient in the context of power markets (Borenstein, Bushnell et al. 1999).

2.1 Empirical Studies of Market-Wide Competitiveness

Common metrics for describing the severity of market power include the Lerner Index, which compares market prices to a firm's marginal cost. In most markets, proprietary cost data are both difficult for researchers to access and complicated to derive due to complex and dynamic production processes. Economists are often able to estimate market power only indirectly in such cases. In the electricity industry, the legacy of cost-based regulation, as well as data made available through environmental agencies, provided researchers with an opportunity to directly estimate a hypothetical perfectly competitive price by attempting to reconstruct a least-cost dispatch and calculating the market-wide marginal cost, or *system lambda*, of that solution.

Catherine Wolfram first applied these techniques to examining competition in restructured electricity markets (Wolfram 1999). In the England and Wales electricity market, Wolfram (1999) finds significant, but arguably surprisingly modest market power given the highly concentrated ownership of generation in that market. Borenstein, Bushnell, and Wolak (2002), hereafter BBW, apply these techniques to the California market around the time of the crisis. In contrast to Wolfram (1999), BBW account for imported energy and hydroelectric generation. Rather than de-rate capacity, BBW use a Monte Carlo analysis of unit outages, which are based on outage rates of plant-specific technologies, in order to predict hourly competitive market outcomes. (With non-linear supply functions, the expected price in a competitive equilibrium differs from the price where demand and de-rated supply intersect). Figure 2 illustrates the monthly averages of both the predicted competitive prices and the (uncongested) prices in the California Power Exchange day-ahead market. From January to October, 2000, price-cost margins grew substantially. When monthly average prices peaked in the summer of 2000 at over $160/MWh, BBW estimate that a market with price taking firms would have resulted in market prices averaging less than $80/MWh. BBW estimate that the aggregate oligopoly rents, namely the payments above competitive market prices, amounted to roughly $4.5 billion during the first 10 months of 2000.

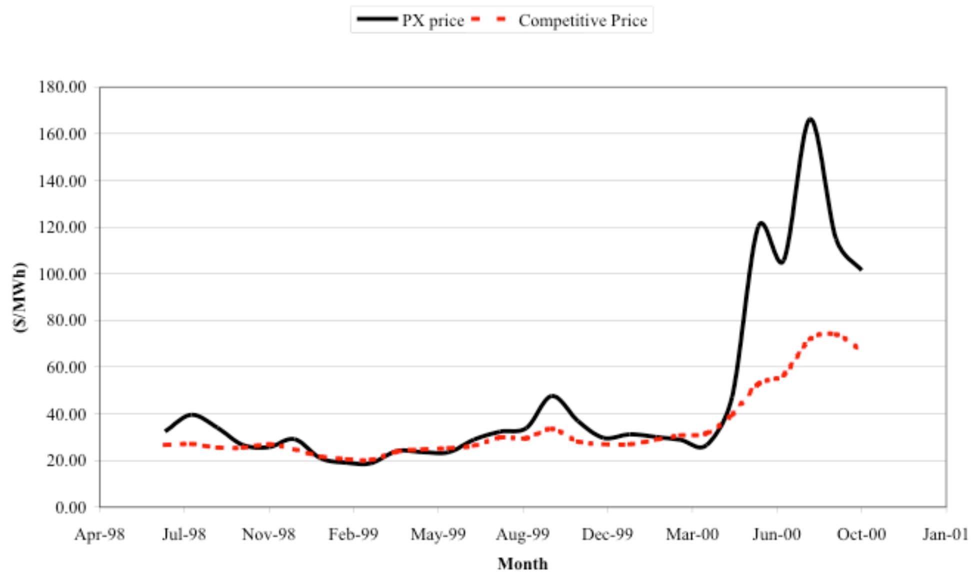


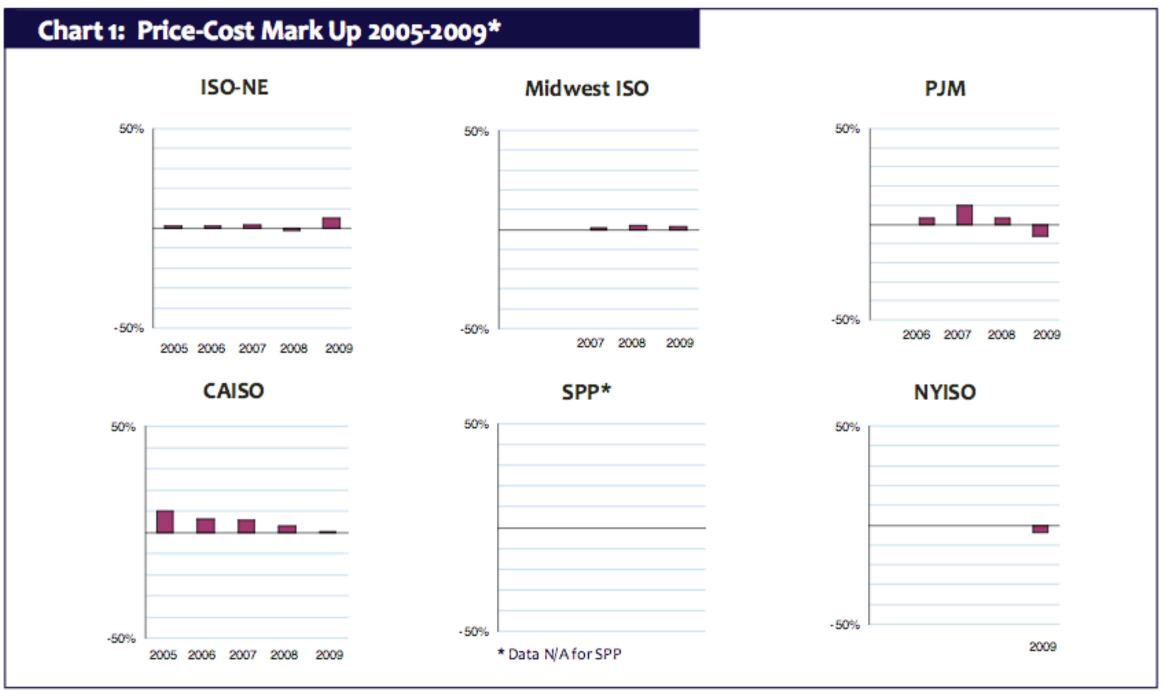
Figure 2: Monthly Average California Power Exchange Prices and Estimates of Competitive Prices (BBW)

The calculations in both Wolfram and BBW utilize several simplifying assumptions to deal with complexities of production such as ramping rates, start-up costs, and transmission congestion. In many cases, their assumptions are conservative and provide a lower bound on the magnitude of market power. However, these calculations have been criticized for portraying an over-simplified representation of system-wide production costs. Mansur (2008) posits that estimates of price-cost margins are less sensitive to the measurement errors produced by these over-simplifications, but demonstrates that estimates of welfare (or changes in total production costs) can be significantly affected. He finds that estimates of welfare losses from firms exercising market power in PJM were about three times larger when using a model that did not account for these intertemporal constraints in comparison to one that did.

Since the work of Wolfram and BBW, the concept of a competitive benchmark has been adapted and deployed in many different variants.[4] Market monitors in all organized RTOs perform some version of a competitive benchmark test. For example, the California ISO's Department of Market Monitoring routinely calculates a benchmark price by substituting estimates of marginal costs for units and re-running a version of the CAISO's market pricing software.[5] The Federal Energy Regulatory Commission (FERC) aggregates these calculations as one of a collection of consolidated performance metrics for RTOs.

[4] The literature on competition in power markets includes many important studies of other restructured electricity markets worldwide that were beyond the scope of this paper.
[5] Note that this method assumes that firms do not exercise market power by simply declaring a unit unavailable to produce at any price.

Figure 3, which is from a 2011 FERC Report to Congress (2011), summarizes the results of these calculations as expressed as price-cost markups. This figure captures the general conclusions of these calculations that all RTO markets are, for the most part, quite competitive today. Many of these approaches are sophisticated in capturing many of the elements of market pricing, such as transmission congestion and unit ramping constraints. However, some assume that the actual availability of generation units reflects a competitive outcome and therefore might understate market power if plant outages were declared strategically. Regardless of the specific method, these analyses confirm that no market in the US currently exhibits anything approaching the type of competitiveness problems experienced during the early 2000s in California.



* Price-Cost Mark Up Definition: Load-weighted average mark up on cost-based offer divided by load-weighted price offer, expressed as a percentage. Positive percentage indicates that the marginal price is higher than the marginal cost. Negative percentage indicates the marginal cost is higher than the marginal price.
Source: Derived from content presented in Appendices D through I

Figure 3: Markups in RTO Markets as Calculated by Market Monitors (FERC 2011)

2.2 Plant-Level and Firm-Level Studies of Competitiveness

While studies such as Wolfram and BBW calculate competitiveness impacts at a market level, other empirical approaches have focused on the behavior of specific firms or plants in an effort to identify behavior that is inconsistent with perfect competition. While these approaches generally cannot provide estimates of a market-wide impact, they can be more compelling in identifying the specific causes of market outcomes. In the case of the California crisis, several papers examining firm-level behavior helped complement BBW to paint a convincing picture of a market suffering from a lack of competition.

In addition to using different data sources to recreate market-wide impact estimates comparable to BBW, Joskow and Kahn (2002) also study plant-level availability during the summer of 2000. They use plant-level data from the EPA's Continuous Emissions Monitoring System (CEMS) to compare the hourly output of plants to the capacity of those plants in hours when prices were well above the estimated marginal cost of those plants. Joskow and Kahn find a consistent gap between the capacity and the output of plants owned by a set of non-utility generators during their selection of high-priced hours. They examined and rejected alternative explanations for the output gap, including transmission congestion, normal outage patterns, and needs of ancillary services. The paper also demonstrates that the withheld supply, on the order of a GW, would likely be sufficient to increase prices in the California Power Exchange significantly.

While Joskow and Kahn (2002) find evidence of at least unilateral market power on the part of some firms during 2000 in California, they do not formally test the behavior of firms. Puller (2007) examines alternative hypotheses of imperfect competition by testing whether firms were acting unilaterally in exercising market power in contrast to colluding, possibly by tacitly coordinating, in making output decisions during this same period. Using the EPA CEMS data, Puller constructs an estimate of the elasticity of the *residual demand* faced by the five large non-utility generators in the California market. The residual demand function for a group of potentially strategic firms equals the market demand minus the supply function of all other firms who are assumed to take prices as given. Using the residual demand elasticity, Puller tests for whether firms were setting output either in a manner consistent with unilateral profit maximization, or in a way consistent with tacit collusion. He rejects that any set of firms' behavior is consistent with collusion and does not reject that firms' actions were consistent with Cournot competition (the particular non-cooperative or unilateral game implied by choosing output of a homogeneous good). Puller concludes that the evidence that market power is primarily a unilateral phenomenon suggests solutions aimed at market structure, such as lower ownership concentration or increasing forward contracting, would be more effective at enhancing competition than those targeted to market design, such as the frequency of auctions.

Other tests of firm-level behavior examine the offer bids of generation firms and study how those offers vary with market conditions. A firm in a perfectly competitive market with a second price auction bids exactly the marginal costs of its generating units. Therefore, one might expect the offers of a price-taking firm to change only when variable costs change, but not when there are shocks to factors such as the availability of other plants or aggregate market demand. Wolfram (1998) implements a test of firm-level bidding in the England and Wales power pool, and finds that, for the largest firms, the margin (above marginal cost) of a unit's bid depended upon its place in the supply portfolio of that firm. Rather than bidding marginal cost, the gap between the offer price and marginal cost grew larger as firms were more likely to have more of their generation earning the market price. Using bid data from the California market, Wolak (2003) calculates an estimate of the residual demand faced by each firm, in the neighborhood of the market clearing price, using the supply offers of all other firms. A single firm's ability to raise prices will be a function of the aggregate market demand less the supply offers of these other firms. When there are many other firms willing to supply at prices near the market clearing price, the residual demand will be very "flat" (price elastic) and an individual firm will have very little potential market power. Conversely if there are few additional offers to supply around the market price, residual demand is inelastic and a firm could profit by increasing its own offer prices with less fear of losing sales volume. Wolak's calculations confirm that the five main non-utility generators possessed unilateral market power and concludes that their behavior in California was consistent with unilateral profit maximization.

2.3 The Role of Forward Commitments

Early research indicated that highly concentrated markets (*e.g.*, England and Wales), but also seemingly un-concentrated markets (*e.g.*, California), exhibit periods of significant market power. However, other research indicates that many markets have been reasonably competitive, even those that share seemingly fundamental characteristics with California. Using firm-level data, Mansur (2007) tests the competitiveness of the PJM electricity market when it first began. He finds that vertical integration partially mitigates a firm's incentive to exercise market power. An integrated firm acts as both a producer selling electricity into a wholesale market and also as a buyer in the market who is required to then resell the energy to its retail customers at set rates. Due to variation in state policy, two firms had few retail customers relative to the production capability while other firms had more balanced positions in the wholesale markets. Mansur's findings regarding the output decisions of the net-selling firms are consistent with the firms exercising market power in England (Wolfram 1998) and California (Wolak 2003). However, the large degree of vertical integration in this market led to much smaller gaps between market prices and estimates of competitive prices like those documented in Figure 2. A natural and important line of inquiry has been an exploration as to why some markets appear to have experienced more severe market power problems than others.

One central contributor to the problems in California was that buyers were heavily reliant on transacting in the spot market. Generation firms that committed to sell their output at fixed prices through forward contracts have little to no interest in taking costly actions to raise spot prices. Wolak (2000) finds a significant impact of hedged forward positions on supplier behavior in the Australian market. By contrast, regulated retail providers in California did not have an incentive to purchase power through any venue other than the California Power

Exchange (where most energy transacted in a daily market).[6]

In other regions of the US, much of the forward commitment to load manifests through vertical integration between generation firms and retail providers. For Eastern markets, wholesale restructuring typically required a transfer of generation assets from a regulated entity to an unregulated affiliate of the same holding company. Because holding companies retain substantial retail customer bases, both generation and retail supply were still under one corporate structure. In many cases, retail prices were fixed initially as part of a set of negotiated arrangements for the transition from regulation to restructuring. Bushnell, Mansur, and Saravia (2008), hereafter BMS, examine the impact of these commitments on market-wide competiveness by exploiting variation in the commitments of generation firms to serve retail load at fixed prices. Using system-wide demand and net import data and plant-level marginal cost estimates, BMS simulate hourly outcomes in three RTOs: California, PJM, and New England. In addition to modeling perfect competition as in BBW, BMS also examine market outcomes for two models of imperfect competition. One assumes that firms engage in Cournot competition, a standard model of unilateral market power. The other simulation assumes that firms compete *ala* Cournot competition but that they incorporate incentives due to their retail commitments as vertically integrated firms. Notably, a single model of competition best described prices in all three markets despite their different average prices and mark ups. The "best-fit" model is the Cournot that accounts for firms' vertical commitments. The fact that California had no commitments explains why it experienced much higher prices than the other markets, despite having comparable predictions of competitive prices.

2.4 Summary

Early concerns that wholesale power markets may be acutely vulnerable to suppliers exercising market power were largely borne out in the early years of the California market. Despite that experience, other US markets have experienced nothing like it. Today, even the California market appears to be reasonably competitive overall based on empirical measures testing for market power in the short run. Two aspects of power markets appear to influence competition in important ways: forward commitments by generators; and market power mitigation by RTOs.

Several papers explore the impacts of forward commitments, through either forward contracts or vertical integration into retail operations, and the importance of these commitments to the competitive performance of short-term wholesale markets is now widely accepted. Less is

[6] Towards the end of the California crisis, Joskow and Kahn (2002) note that "Duke Energy, which appears to have been fully contracted in forward markets for 90% of its potential output, behaved much differently" than other non-utility generators.

known, however about how best to ensure that a market maintains an appropriate level of forward commitments. As we discuss in Section 5, retail firms face complex incentives with regard to hedging, especially those obligated to be the Provider of Last Resort. Harvey and Hogan (2000) criticize the notion of requiring that retail firms sign firm energy contracts to cover a fixed percentage of their load, arguing that such restrictions simply push market power into forward markets. Yet to some degree, capacity markets and resource adequacy requirements are requiring a very specific type of forward commitment between generators and retailers. Given the apparent role of robust forward markets to healthy competition, this is an important area for continued research.

Another area that has received much less attention in the academic literature is the widespread use of market power mitigation in the operation of RTO energy and capacity markets. The current state of such mechanisms reflects a long shift during the 2000s away from relying largely on traditional competition policy tools towards more active monitoring of, and intervention with, the operations and bidding of individual firms. In an overview of competition policy in the power industry, Bushnell (2005) cited Alfred Kahn's comment on the application of specific behavioral rules that had been proposed as part of FERC's standard market design:

> *Alfred Kahn (2002) described the commission's proposal as a "substantial increase in regulation," of a "thoroughly novel kind, far more pervasive and intrusive than the institution we purport to be disassembling." He warned that the rules could "invite continuous scrutiny and second-guessing of what must inevitably be day-by-day, routine management decisions."*

Because these mechanisms have been implemented and adapted at the same time as other changes to both market structure and market rules in most RTO markets, it has been difficult to identify the specific impact of these measures in isolation from the other changes. However, given the widespread *potential*, if not actual, application of such measures, it is important to better understand the short and long-term impacts of market power mitigation tools. Since they represent a different and unusual form of regulation, it is possible that such mechanisms can impact the short-run operational decisions, input choices, and capital investment of impacted generators.

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3 Operational Efficiency

- **Studies have demonstrated that expansion of RTO footprints has increased trade and improved coordination among power plants.**
- **Variable operating costs at regulated investor-owned plants in restructuring states declined in the 1990s, but not at municipal owned plants unaffected by the prospect of restructuring.**
- **Deregulation of nuclear power plants lead to substantial increases in their availability and output.**
- **Deregulation of coal-fired power plants lead to substantial decreases in their fuel prices.**
- **The effects of restructuring are likely to differ by region thereby implying that estimated effects of restructuring in one market need not apply to regions that did not restructure.**
- **In order to compare the benefits and costs of introducing an RTO, more research is needed especially on their direct and indirect costs.**

Much of the policy pressure for restructuring arose from customer awareness of electricity "price gaps," both across states and between retail rates and observed wholesale market prices. While much of the response to these price gaps amounted to attempts to redistribute the costs of sunk, or *stranded* assets, rather than a pursuit of pure cost reductions, many economists did anticipate some potential for such savings. From a holistic viewpoint, such effects should be the main justification of restructuring.

The argument that restructuring could improve efficiency in the power sector was rooted in both theoretical and empirical observations of the inefficiencies that had been imposed by the economic regulation of the industry. Intuitively, a regulatory regime that sets prices based upon documented costs provides weak incentive to reduce those costs. Joskow and Schmalensee (1983) articulate the following areas of concern with regulatory efficiency:

1. "Failure to take full advantage of all opportunities to minimize costs by engaging in effective inter firm coordination and pooling.
2. Too many small firms building and operating facilities that are too small and too poorly integrated and coordinated to achieve all economies.
3. Inadequate incentives to produce efficiently in the long run and the short run.
    a. Input distortions
    b. Too much or too little capacity
    c. Inadequate incentive to purchase fuel cheaply
    d. Incentives to maintain and build plants at minimum cost
4. Uneconomical transfers of power in wholesale power transactions resulting from inefficient wholesale price regulation by FERC."

Many of the elements of this list reflect concerns that the utility industry was too bifurcated, with too many local monopolies that did not take adequate advantage of either economies of scale or opportunities to pool resources or trade with each other. We will characterize such opportunities as *system efficiencies* involving the coordination and use of multiple plants. These efficiencies are distinct from any *plant level* efficiencies - involving lower cost or higher availability at a specific plant - that might be gained. [7]

This discussion illustrates the difficulty in answering a question as basic as "did restructuring improve efficiency?" There are different types of potential efficiency gains and also quite different types of restructuring to which firms have been exposed.

At the system level, the most important restructuring measure is the expansion of the model of regional transmission organizations and independent system operators. We will refer to them as RTOs. These organizations built on their origins as regional power pools to continuously expand the reach of centralized, coordinated operations throughout the 1990s and 2000s. Figure 4 and Figure 5 illustrate the expansion of market-based dispatch over the past 15 years as defined in Cicala (2016).

[7] Another, and perhaps the most important, area of potential efficiency gain is in the area of investment in power plants and transmission infrastructure. As we discuss in Section 4 on this topic, we are unaware of any empirical study that convincingly demonstrates the impact of restructuring on the efficiency (rather than magnitudes) of investment in the power sector.

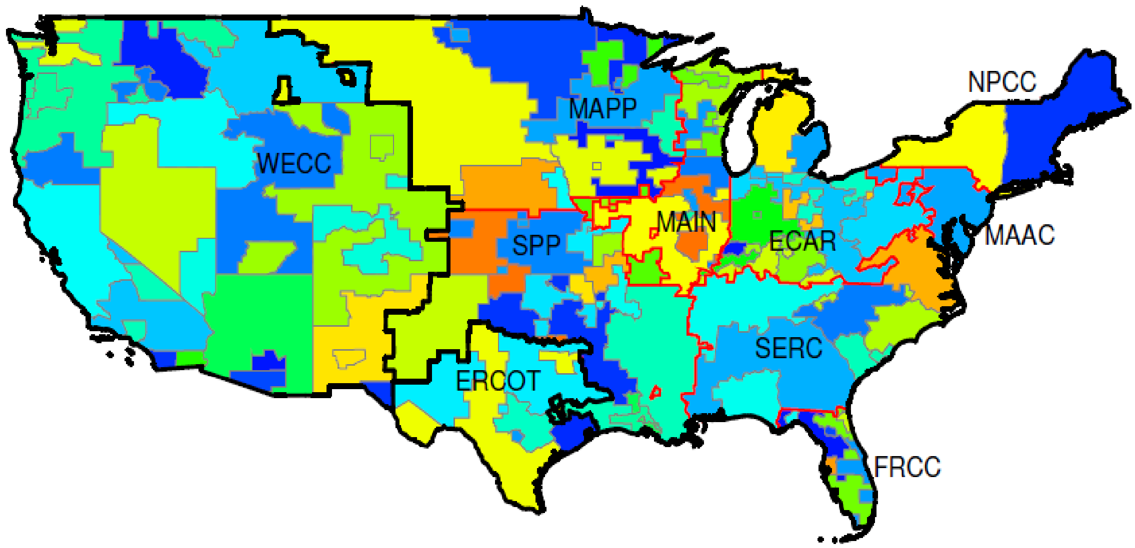

Figure 4: Power Control Areas in 1999 (thick black lines denote Interconnection boundaries, and red lines are NERC Regions in 1999). (Cicala 2016)

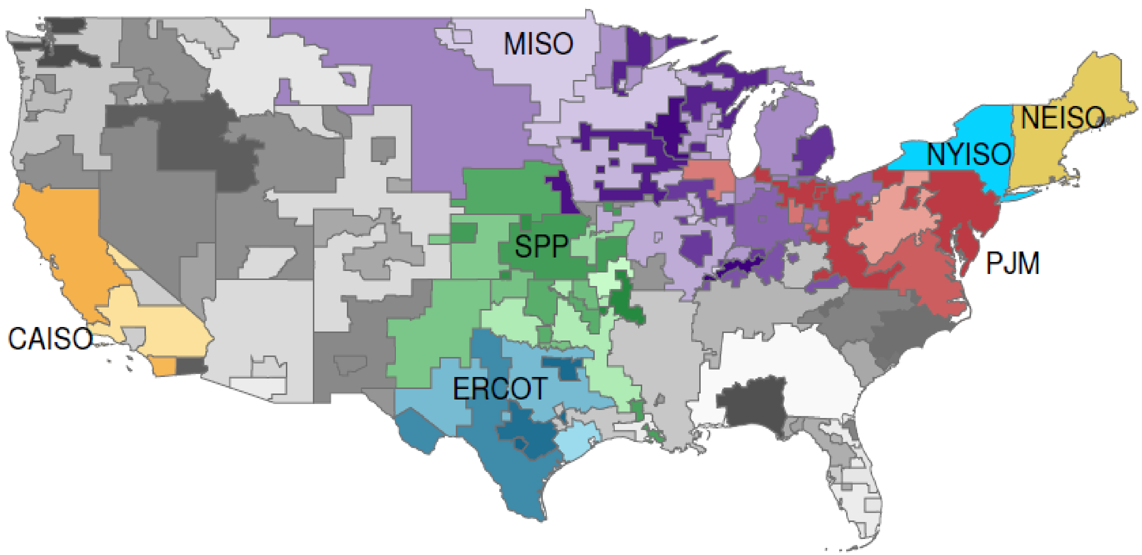

Figure 5: Power Control Areas by Market Dispatch in 2012 (Cicala 2016)

Importantly, RTO expansion did not necessarily entail or require other elements of restructuring such as retail competition or the deregulation of generation. In some cases, as in Texas, an RTO was a central element of a comprehensive restructuring program. In others, such as in the Midwest market (MISO), such reforms amounted in many cases to increased trade and coordination between utilities that remained traditionally regulated at the state level.

3.1 Empirical Studies of System Efficiency

The transition to RTOs potentially lowered transactions costs for trade between power (utility) control areas (at least within RTOs), as well as potentially improved efficient operations inside a control area. These are two of the areas identified 30 years ago by Joskow and Schmalansee as opportunities for improvement based upon the perception that some utilities can apply relatively ad-hoc procedures to balancing supply and demand within their own control areas, and that many institutional barriers raised the transactions cost of trade between areas. RTO markets aggregate information on potential trades that can be difficult for bilateral trades to realize because of congestion externalities.

We discuss here two recent studies of the impact of RTO transitions. Both take advantage of observations of outcomes before and after a region either adopts, or expands into a market-based RTO dispatch.

One of the largest such expansions was the integration of American Electric Power and Dayton Power into the PJM System on October 1, 2004. By studying this expansion, Mansur and White (2009) test whether the gains from trade are improved under centralized auction markets over decentralized bilateral trading.

The paper first examines whether the summary statistics of prices and price spreads change after the market expansion. The authors assume that the observed changes in price spreads are caused by the market expansion by focusing on a narrow time period and ruling out concurrent, discrete changes in costs, demand, production investment, and transmission investment. This is similar to the assumptions of a regression discontinuity approach. Next the paper examines data on day-ahead scheduled tie flows (quantities of power traded). Here the authors use semi-parametric methods to test for changes in daily trades from the AEP region into eastern PJM. A comparison is made with the year prior to test if October 1, 2003 reflected a similar break. Finally, the authors use non-linear least squares to estimate supply functions in the old part of PJM and the expansion part. This allows them to control for demand and cost shocks in measuring the gains from trade and to confirm the findings on price spreads.

Mansur and White (2009) find that price spreads across AEP and eastern PJM fell dramatically after the market expansion. During off-peak hours, the price spread between PJM and AEP fell approximately 70% after the market expansion. Furthermore, they find an abrupt change in the amount of power traded between these areas. Figure 6, as replicated from Mansur and White, plots daily net exports from the Midwest to the historic PJM territory over a two year period. The solid circles are from April 2004 to April 2005 while the open circles are for the previous year. The solid and dashed lines are their respective locally-weighted averages before and after the expansion. The figure shows that net flows from the Midwest to the east increased from 35 to 105 GWh per day after expansion. This combined evidence suggests that implementing an organized market design improved overall market efficiency.

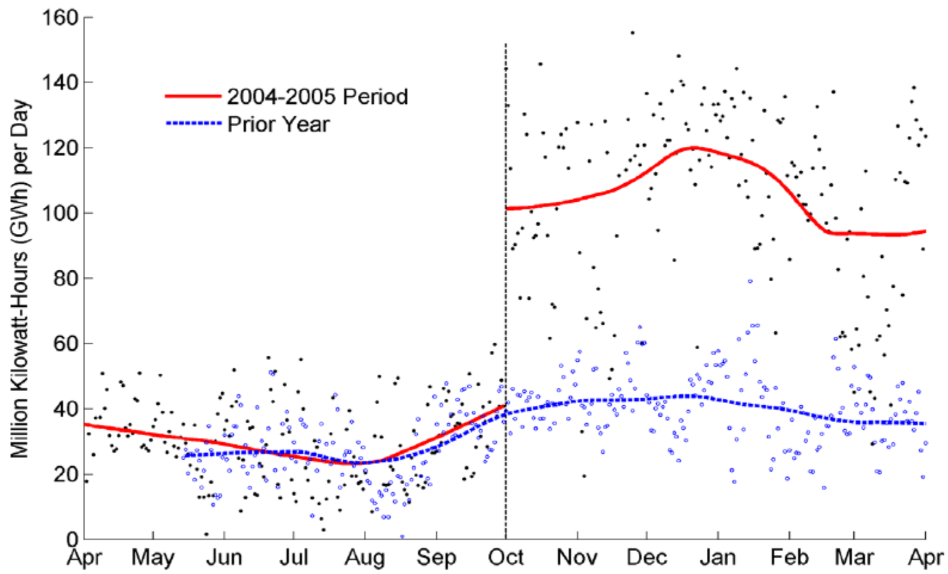

Figure 6: Day-Ahead Net Exports from Midwest to Eastern PJM (Mansur and White 2009)

Mansur and White (2009) also calculate the impacts of these increased trade flows on the relative production costs of serving demand in the joined regions, in essence estimating the gains from trade reaped by the PJM expansion. This metric calculates the savings to the combined region of being able to meet demand from lower cost generation in a neighboring region. They find that production efficiency over this region improved by $160 million per year.

In a recent study, Cicala (2016) uses a more all-encompassing approach to study RTO transitions. He assembles data on plant operations for all 99 major power control areas in the US and examines the impacts of RTO transitions. At various times, 60 of the areas converted to market-based operations. By observing operations before and after transitions, Cicala measures the impacts of the transition on the region undertaking it (the treated) in comparison to how the changes in neighboring regions that did not undertake the transition (the control group).

Cicala (2016) constructs two primary measures of performance. One measures the gains from trade similar to that of Mansur and White (2009). The second is a measure of the deviation from the "best-case" supply within a control area. Using data collected from EPA, EIA, and other sources, Cicala constructs an idealized supply curve that orders plants from least to highest cost (see Figure 7). If operations were perfect, demand would intersect this idealized supply curve and the cost of meeting demand would be minimized. Many factors prevent systems from meeting this idealized supply cost, including unit outages and other operating constraints that can be mitigated by better coordination between plants. This gap between the observed and the ideal operations is called the *merit-order gap*. The basic idea of his approach is that conversion to RTO methods could impact the extent to which operators can approach this idealized best-case.

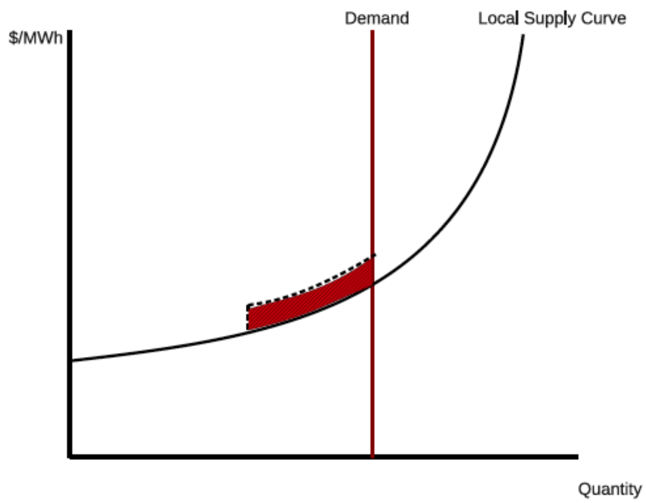

Figure 7: Least-Cost Dispatch Supply Curve with Merit-Order Gap (Cicala 2016)

After constructing his two measures of performance, trade and out-of-merit costs, Cicala examines the impact of a transition to RTO dispatch on these metrics. By using a difference-in-difference estimator, he measures the hourly improvement in these metrics in a RTO control area, *relative* to the performance of other control areas in the same NERC region that did not (or had not yet) transition to RTO dispatch.

He also estimates this effect with a policy function that controls for the impact of natural gas prices on these metrics. In other words, with his policy function, Cicala controls for any added benefit a higher gas price might provide to gains from trade or a dispatch closer to the ideal merit-order.

Using these methods, Cicala (2016) finds a 8% to 14% increase in the volume of trade between control areas coinciding with transitions to RTOs, which he estimates translates to a nearly 30% to 50% increase in value (cost savings) of trade. He estimates substantial savings of 10% to 15% in out-of-merit cost reductions coinciding with RTO transition. Given the roughly $4 billion in annual trade and $10 billion in out-of-merit costs, these percentages translate to roughly $4 to $4.5 billion in savings per year.

Together these complementary studies reveal that there have been improvements in both internal system operations and in inter-system trades when systems transition to an RTO-style market-based operations model. The studies are focused on observed changes in variables such as power flow and fuel consumption, and do not address the question of the cost of forming RTOs or the systems cost of adopting market-based dispatch.

Importantly, Cicala's method of identifying these impacts relies upon the dates upon which systems transitioned from traditional to market-based dispatch. To the extent that such transition dates also coincided with other important changes, such as the divestiture of generation to non-utility status, Cicala is likely measuring the combined impact of all those changes. For example, his $4 to $4.5 billion likely includes at least some of the billion dollar benefits of additional nuclear availability discussed below.

3.2 Empirical Studies of Plant Efficiency

While the expansion of RTOs and market-based dispatch resulted in more efficient production *across* generators, restructuring could also improve efficiency *within* individual generators. These plant level efficiency gains could manifest themselves in two ways. First, generators could reduce the use of – or expenditures on – inputs to production. Second, individual generators could increase their availability, expanding the total quantity of electricity that could be produced from the fixed capacity.

These plant level efficiency gains could be driven by two main channels: ownership changes and changes in incentives. Regulated utilities in several states were required to sell off, or divest, much of their generation capacity. During the wave of divestiture from 1998 through 2002, approximately 20% of generators in the U.S. were sold to independent power producers (IPPs). While some of these sales were internal transfers to the same utility holding company, many were to new firms. By itself, the change in ownership could affect the efficiency of the divested plants.

Restructuring of the generation sector also created very different incentives that could spur efficiency improvements. The fundamental change for divested generation was from a cost-based regulatory regime to one in which compensation was based upon the market value of the output of the plants. The decoupling of revenues from measured costs should have increased incentives to reduce costs. Restructuring could also affect the operations at generators that remain under the ownership of traditionally regulated utilities. For one, newly deregulated markets often froze retail rates, again decoupling the direct link between utilities' costs and the price they were paid for production.

Several empirical studies have attempted to uncover evidence of the various types of plant level efficiency improvements (*i.e.* input savings or availability increases) that could be achieved within divested and non-divested generators. Here we focus on the main contributions.

Fabrizio, Rose, and Wolfram (2007), hereafter FRW, performed one of the first large-scale studies of the impacts of restructuring on plant-level operating costs. While comprehensive in geographic scope, the paper illustrates a key data challenges in identifying the impacts of restructuring. Specifically, while there are extensive data available on the costs of regulated plants,[8] the data reporting requirements for deregulated (IPP) generators are much less extensive. Therefore, when plants are divested into non-utility status, researchers lose much of the ability to observe their costs. Faced with this data limitation, FRW examine how the operating costs of *utility-owned* plants are impacted in restructured states from the time legislative hearings on restructuring are held in those states up to the time those plants are divested and they disappear from the data. Their argument is that cost reductions over that time capture at least some of the efficiency gains possible from deregulation as the owners of regulated plants respond to looming competitive pressures.

Their primary comparison is therefore between plants in states that pass restructuring legislation and those in states that do not, captured in the window just prior to divestiture of the deregulated plants. As a further control, they also compare the performance of the to-be-restructured plants against those owned by municipal utilities, under the argument that this latter group would be largely insulated from the incentive effects of restructuring. Their specification employs plant level fixed effects, meaning that they are measuring the relative impact of restructuring on a specific plant's use of inputs, relative to any analogous change in input use at plants in the control groups.

FRW find that plants in states that eventually restructured reduce both their use of labor and their non-fuel expenses. They find that these to-be-restructured plants use 3% less employees and reduce their non-fuel expenses by 5-10%. The comparison with municipal plants is even more dramatic. FRW do not find any significant effect on fuel costs, which constitute the single largest operating expense for power plants. They also do not observe plant level wages, so they cannot evaluate how much of the reduction in non-fuel expenses represents a reduction in labor costs. In conclusion, the authors regard their analysis as important but still preliminary evidence on the potential impacts of restructuring, but suggestive that restructuring could yield "significant medium-run efficiency gains."

The data restrictions limit the analysis of FRW to studying, in effect, the *threat* of competition (restructuring), rather than direct effect itself. Analyses of the performance of plants after restructuring requires relying on more limited, or potentially confidential data. Two papers that examine the direct effect of restructuring, defined as transfer from utility to non-utility status, on power plants are Bushnell and Wolfram (2005) and Davis and Wolfram (2012). Bushnell and Wolfram utilize hourly data on the fuel consumption

[8] FRW rely primarily on the FERC form 1, which is a comprehensive survey form required from major electric utilities.

and gross output from power plants collected by the US Environmental Protection Agency to test whether fuel efficiency (BTU/MWh) improves at plants after divestiture. While imprecise, the author's estimates reveal that modest improvement in fuel efficiency (approximately 2%) occurred at divested plants. The authors also find that, over the same time period, similar fuel efficiency improvements were achieved among utility-owned plants in states that did not restructure but did impose retail rate freezes, providing utilities with a strong inventive to conserve fuel costs. Combined, these findings suggest that restructuring lead to modest plant level fuel efficiency improvements and these gains appear to be driven largely by the incentive changes, not ownership changes. Bushnell and Wolfram estimate that the fuel efficiency improvements among the divested fossil fuel plants resulted in approximately $550 million in fuel costs during 2003.

Davis and Wolfram (2012) identify perhaps the most dramatic impact of restructuring on plant operations in the nuclear power sector. Using techniques similar to the other analyses we discuss, Davis and Wolfram examine the plant specific performance of nuclear generation plants before and after their transition from utility to non-utility status. Like the other plant level analyses, they are able to use the set of plants that remained under utility status as a control group for comparison. They find that restructuring nuclear power plants increased their capacity factors on average by 10% -- primarily achieved by reducing the frequency and duration of outages. They estimate that the increased output translates to roughly $2.5 billion in extra revenue at prevailing market prices of electricity. To achieve this increase in revenue, the authors estimate that total production cost increased by less than $500 million, clearly highlighting that the increase in nuclear availability was a true efficiency gain.

In another important analysis of the impact of restructuring on plant-level operating costs, Cicala (2015) examines how the price paid for fuel changed after plants were divested. To do so, Cicala compares the fuel price paid by divested plants to the prices paid by nearby, non-divested plants using the same type of fuel. The estimates reveal that divested coal plants reduce the price paid for coal by an average of 12% relative to the matched, non-divested coal plants. This estimate implies that fuel costs fell at divested coal units by roughly $1 billion per year. By itself, the reduction in expenditure on coal by divested plants does not necessarily signal that restructuring induced efficiency gains. Instead, the price changes could simply represent a transfer of rents away from the coal producers. However, Cicala presents strong evidence that the coal price reductions in part reflect efficiency gains by demonstrating that, relative to the non-divested coal plants, the divested plants purchase from mines with lower extraction costs. This is evidence that restructuring the generation sector has also had spillover impacts on the vertical chain that supplies the power industry.

Combined, the preceding studies illustrate the range of impacts restructuring had on plant level operations. It is important to stress that each individual study does not definitively uncover plant level efficiency gains. In particular, no studies have been able to observe the full range of plant level inputs. Moreover, no study has observed the full range of potential outputs – not just the total quantity of electrical output, but also the provision of ancillary services (*e.g.*, voltage regulation or spinning reserves). As a result, observing that a plant requires fewer observed inputs for a given level of electrical output is not sufficient to conclude that efficiency gains were achieved. Instead, it is possible that the observed reductions in certain inputs (*e.g.*, labor) are combined with unobserved increases in other inputs (*e.g.*, capital) or unobserved decreases in other outputs (*e.g.*, certain ancillary services). Overall however, the evidence highlighted in the previous studies consistently points to restructuring causing meaningful plant level efficiency gains across a range of dimensions.

It is also important to note that the evidence suggests that the plant level efficiency gains were largely the result of incentives changing as opposed to ownership changes. This implies that the magnitude of the plant level efficiency gains caused by restructuring are largely dependent on the inefficiency of the regulation in place prior to restructuring. If the initial regulation provided little incentive for utilities to minimize costs, then restructuring could provide sizable gains. However, this does not mean that restructuring would achieve equally large gains in other regions. Moreover, it also raises an important and yet unanswered question – would similar plant level efficiency gains have been achieved by instituting incentive based regulation as opposed to restructuring? For example, previous work by Knittel (2002) suggests that, prior to the wave of restructuring, shifts away from cost-of-service utility regulation towards incentive based regulation resulted in plant level fuel efficiency improvements on par with the gains achieved by restructuring.

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4 Generation Investment

- **The industry experienced a massive expansion in generation capacity that coincided with the onset of restructuring between 1998 and 2002.**
- **This investment boom led to periodic gluts of capacity and contributed to the severe financial distress of many non-utility generation firms during the 2000s.**
- **The economics literature has yet to identify the causal effects of restructuring on either the levels or types of investment.**
- **Academic studies and RTO reports have calculated that revenues from short-term energy and ancillary service markets have, most of the time, been insufficient to recover the full average cost of power plant construction and operations.**
- **Findings on the shortfalls of short-term markets may provide evidence on the need for supplemental resource adequacy policies, but also reflect the disequilibrium of an industry that has undergone shocks to regulatory treatment, fuel prices, and renewable policies over the last decade.**

Given the capital-intensive and long-lived nature of assets in the electricity industry, investment has been the area of largest promise from regulatory restructuring. “Restructuring for competition and regulatory reform is unlikely to lead to significant short-run cost savings,” observed Joskow (1997), who added “the most important opportunities for cost savings are associated with long-run investments in generating capacity.” Much of the pressure for restructuring in the 1990s was driving by consumer groups who were responding to a growing price gap between regulated rates and wholesale market prices (White 1996). But much of that gap was in turn driven by sunk investment costs, a “capacity overhang” created by investment choices that, at least at the time and with hindsight, appeared to be mistakes. If the price gaps that were spurring competition were to be closed, then the primary culprit, investment, must be addressed. “Since the bulk of the rate disparities in this country are due to investment decisions that turned out badly, it stands to reason that what is ‘broke’ in this industry is the process that produced those poor investment decisions” (Borenstein and Bushnell 1999).

For the bulk of the industry, the process responsible for most of those investment decisions was rate-of-return regulation. A long literature, going back to the 1950s, discusses the potential distortions created by such regulation. A prominent hypothesis by Averch and Johnson (1962) relates a firm’s choice of input mix (*e.g.,* capital, fuel, and labor) to the relationship between the firm’s true cost of capital and the rate of return on capital allowed by the regulator. The “Averch-Johnson effect” is the bias in favor of “gold-plated” inflated capital investment and excessive capacity margins. While the empirical evidence on the extent and scope of this effect is unclear (Joskow and Noll 1981), the standard practice of allowing the guaranteed recovery of all prudently incurred investment costs, at the very least, likely skewed the perception of risk. Joskow (1997) notes: “Traditional regulatory principles, based on the prudent investment standard and recovery of investment costs, implicitly allocates most of the market risks associated with investments in generating capacity to consumers rather than producers." This skewed perception of risk appeared to be most apparent in the adoption and choice of nuclear technologies. There is a strong correlation between states with the largest "price gaps" in the late 1990s and the level of investment in nuclear energy (White 1996).

Much of the hope for cost reductions from the industry rested upon potential benefits from changes to investment decisions and the allocation of investment risk. For example, Borenstein and Bushnell (1999) posit that "firms that do not have the security of a guaranteed rate of return on their investments will be more prudent in their capital expenditures and the way they manage risk." In the late 1990s, it remained unclear the exact process that would replace the traditional regulatory planning model. While many assumed investment decisions would mimic that in other capital-intensive commodity industries, the full implications of this assumption only became apparent as restructuring unfolded.

4.1 Scarcity Pricing

When firms sell a good or service and the only compensation comes from a single market price (namely no non-linear or two-part tariff exists), then investors either implicitly or explicitly determine the market value of capacity using the concept of scarcity pricing (Borenstein 2000). Peak-load pricing is an example of scarcity pricing that occurs in markets that are capital intensive, have limited economic storage and where demand fluctuates, like markets for hotels and electricity. As demand shifts, prices adjust to clear the market and avoid shortages. The result is relatively volatile short-term prices (even in perfectly competitive markets) as small shocks to demand can translate to large price swings with inelastic supply (when the supply curve is very steep). When capacity binds and prices are set by the demand curve, prices will rise above the average variable costs of all operating plants. This allows for a contribution towards the recovery of fixed costs (see Figure 8). Note that low marginal cost generating units also earn positive contributions during hours when more expensive generating units are on the margin.

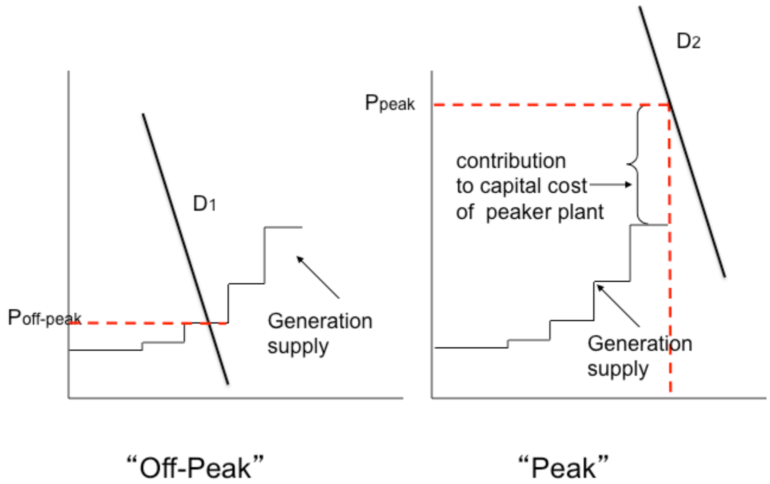

Figure 8: Supply and Demand for Peak and Off-Peak Hours

This concept is called scarcity pricing because the quantity demanded would exceed the quantity supplied if price just equaled the average variable cost of the most expensive generating unit. The component of the price necessary to reduce demand to the point where it can be met by available capacity is often called the *scarcity rent.* In a competitive market that satisfies several other conditions, firms will build new capacity as long as the cumulative scarcity rents exceed the cost of capacity. Free-entry would drive the scarcity rents to equal (on average) the cost of new capacity over time.

From the very early stages of market operations, researchers noted several aspects of power markets that challenged the adequacy of the scarcity pricing paradigm for new investment (Hogan 2005, Oren 2005, Cramton and Stoft 2006, Joskow 2006). Systemic problems include the following:

1. Price-caps on energy and ancillary services markets that could suppress prices below the needed scarcity levels.
2. Rigidities in retail (consumer) prices that severely limit the possible from consumers to real-time prices.
3. Physical network characteristics that require a balance of supply and demand with more frequency than that for which prices could practically be calculated (*e.g.,* "missing markets").
4. Pricing rules that mechanically suppress prices in times of scarcity or operating reserve deficiency.

In addition, Joskow (2006) documents the common practice of system operators to take "out-of-market" actions in the spirit of maintaining reliability that had a side effect of suppressing market prices. For example, from 1999 to 2002, the New England market declared an operating reserve deficiency in 46 hours but prices only reached the price cap in six of those hours.

4.2 Experience with Investment in Restructured Markets

Despite these deficiencies with elements of the market design and implementation, investment in generation capacity was extremely robust in the early years of restructuring. Following a decade of very little new investment, almost 140 GW of new generation capacity was added to the US power system between 1999 and 2002 (Joskow 2006). In some regions, this was an impressive increase of over 50% of installed generation capacity. Figure 9 draws upon EIA data to calculate the new generation added by fuel type between 1990 and 2013. The vast majority of the new capacity is comprised of natural gas-fired generation. As can been seen, the investment boom in gas plants largely dissipated after 2004. While more investment occurred after the late 1990s, we are unaware of any empirical paper that tests for the causal effects of restructuring on either the type or magnitude of investment.

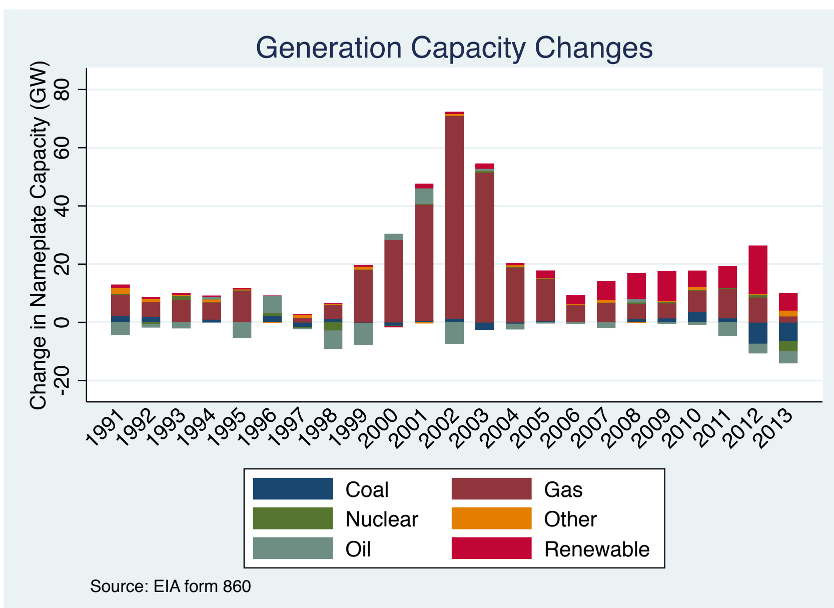

Figure 9: Change in Nameplate Capacity by Fuel Source

Another major shift during this time was the wholesale divestiture of power plants from utilities to non-utility generators. This change in ownership included both external divestitures as well as transfers within holding companies from regulated utilities to unregulated generation affiliates. Ishii and Yan (2007) investigate the effect of large-scale divestiture on investment by non-utility generators. While on the one hand, divestiture provides an immediate entry by new firms into a newly restructured market, the availability of existing plant for sale could crowd out investment in new generation. Indeed the quantity and location of new plant investment is inversely correlated with the amount of generation being divested in a state between 1996 and 2000. Ishii and Yan construct a structural model in which firms must choose whether and how to enter a market, either through new construction or through the purchase of generation being divested by an incumbent utility. Their identification depends upon the assumption that a firm can only choose one route to new capacity (make or buy) each year. Using upon a panel of observed firm level investment choices across multiple years and states, along with data on firm and plant attributes, they estimate a function representing dynamic choice of each firm that includes key unobserved variables such as a firm's capital cost and its operating costs of various plants. They estimate that Independent Power Producers (IPPs) unaffiliated with utility holding companies had on average a lower cost of capital and IPPs affiliated with utilities could operate older divested plants at lower cost. This is consistent with the pattern that the bulk of divested generation was purchased by utility affiliated power producers. They estimate little to no crowding out of new investment due to divestiture.

Ishii and Yan (Ishii and Yan 2010) also investigate the more ambitious question of how regulatory policy influenced investment decisions throughout the restructuring transition period. They focus on the relative investment lull during the mid to late 1990s. Using both a reduced form and structural model of firm level investment, their results indicate that much of this lull can be attributed to the looming uncertainty over cost-recovery signaled by the many restructuring proceedings underway in many states. Their results imply a different interpretation of the post-restructuring investment boom. Rather than signaling that restructuring suddenly unleashed the previously untapped investment power of IPPs, this period reflects more of a catching up response to the period of artificially depressed investment that preceded it.

4.3 Ensuring Resource Adequacy

In the period following the boom in natural gas generation capacity in 2005, most investors struggled financially. As Joskow (2005) noted, "what had been a tremendous boom has turned into an enormous bust," leaving the merchant generation sector in "terrible financial shape." This was largely an appropriate market response to a condition of oversupply. "As new generating capacity was completed and demand slowed, market prices softened. The market responding to these prices signals with reductions and delays in investment is what we should expect from a competitive market." Joskow, however, believed that more than just oversupply was at work. "Changes in capital market conditions and imperfections in wholesale market design are likely to create barriers to stimulating efficient investment."

Joskow (2006) and Cramton and Stoft (2006) evaluate the sufficiency of market prices for energy and ancillary services to support the long-run average cost of generation. They find that the implied revenues from these markets fall short of the levels necessary to support new investment. Market monitors in RTOs have also adopted a somewhat standardized measure tracking the potential revenues of a hypothetical marginal generator (FERC 2011).

However, several caveats provide caution against treating these findings as definitive evidence that energy and ancillary services prices will always be incapable of supporting investment. First, many of these calculations are being made in the context of markets that already have some form of capacity or resource adequacy mechanism. Second, it is extremely difficult to define the appropriate time horizon necessary for cost-recovery of assets that last multiple decades. The fact that a plant has not fully covered its capital cost over an annual or even half-decade period is not necessarily a sign of market failure. Last, the industry has been continuously buffeted by significant changes to design, regulation, and policy; the most recent being a surge in support for renewable generation that has largely dominated investment since 2006. These shocks make it unlikely that the data on investment result from anything approaching a stable equilibrium.

4.3.1 Resource Adequacy Policies

In the face of continued evidence that short-term energy markets were not producing sufficient revenues for generation to recover their capital cost, pressure grew during the mid-2000s to expand or adopt policies that would supplement the revenues of generation and other resources. Several Eastern RTO markets had featured forms of capacity payments, but their design and implementation of these first generation capacity instruments has been criticized as inadequate at both funding generation and providing correct incentives for performance (Cramton 2003).

During this period several studies documented the shortcomings of existing energy and ancillary service markets (Hogan 2005), and many made a case for the necessity of some form or resource adequacy requirement or capacity payment (Cramton and Stoft 2006, Joskow 2008). Joskow and Tirole (2007) construct an analytical framework that allows for a portion of electricity demand is price-inelastic, and examine the conditions under which a second best (optimal considering the inelasticity of consumers) set of prices and investment could occur. They conclude that those conditions are quite unlikely. They then allow their model to include price-caps, and represent the possibility of a cascading, system failure, resulting from a supply demand imbalance. They demonstrate how price-caps can reduce scarcity rents and lead to sub-optimal investment, leading to a need for capacity payments. They note that "capacity obligations and associated capacity payments can restore investment incentives if all generating capacity is eligible to meet capacity obligations and receive capacity payments and all consumer demand is subject to capacity obligation."

A primary source of concern with market-based generation investment, therefore, is a combination of demand that is unresponsive to prices and of price-caps, or pricing "penalty values" that become computationally necessary to determine prices in the absence of elastic demand. Price-caps are also motivated by market-power mitigation, but have been raised in some places since the early 2000s and invoked more frequently due to changes that allow markets to reach scarcity pricing levels during periods of reserve deficiency (Hogan 2005). Still, if current price-caps prove to be too low, or invoked too infrequently, additional compensation in form of capacity payments is necessary in the long run to ensure capital recovery of generation investments.

4.4 Summary

While restructuring-induced changes in generation investment was hoped to be a major potential source of efficiency improvement, the reality has proved to be more complex. Early research identified several important elements to restructured power markets that theoretically prevent fully efficient market-based investment. These elements include a continuing low-level of demand side participation, the presence of explicit and implicit price-caps, and even conflicts between operator driven reliability concerns and the need for markets to properly reflect scarcity conditions.

Despite these elements, which seemingly work to discourage capital investment, the industry as a whole experienced a substantial boom in non-utility generation investment during the early 2000s. The subsequent glut of capacity, perhaps combined with these market design elements, has kept power prices overall below levels that appear necessary for the recovery of capital costs, at least through short-term energy and ancillary services markets.

Important work during the 2000s, much of it based upon theory, has helped advance the understanding of the conditions necessary for efficient investment under either a short-run market focused "energy-only" paradigm or a paradigm that allows for compensation for capacity. It is much more difficult to empirically demonstrate whether one approach has produced "better" investment overall. Due to the long-lived nature of generation assets, and the continuing changes in regulation, market design, and environmental policies experienced in the industry, even rigorous comparisons of investment in different markets are unlikely to identify the impacts of specific resource adequacy policies.

Further, it is best to think of today's power industry as providing examples of three models—traditional regulation, energy-only markets, and capacity-based markets—each with known flaws to its implementation. Therefore results demonstrating the theoretical superiority of either an energy-only or capacity oriented market design cannot be tested empirically when the ideal design of either has yet to be implemented. Under all these paradigms, market participants and operators have found ways to ensure sufficient generation has been built and maintained to ensure adequate resources under all but the most extreme conditions. Whether this has been done more efficiently in one market or another, due to the specific RA paradigm, is a much more difficult question to answer, and we are not aware of any empirical study that has been able to do so.

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5 Retail Competition and Retail Price Impacts

- **Retail electricity prices are more tightly linked to natural gas wholesale prices in states that have restructured generation than in states that do not.**
- **Evidence of the impact of restructuring on retail price *levels* is inconclusive.**
- **Residential customers exhibit large choice frictions, and retail switching by residential customers has been relatively infrequent.**
- **Most residential customers purchase energy from Providers of Last Resort (POLR).**
- **More data and research are needed on the size and nature of retail margins, the impact of retail market structures on wholesale markets, the influence of vertical integration on retail competition, and on the methods of procurement (competitive and regulated) for POLR customers.**

It is appropriate to divide the discussion about consumer impacts into two areas; the impact of upstream changes on retail consumer prices, and the impact of the restructuring of retailing itself. It is natural to expect that any reforms designed to improve the efficiency of the industry would ultimately be reflected in lower (than otherwise) consumer prices. This was indeed the hoped-for bottom line emphasized by many policy makers and consumer groups who championed restructuring.

As we discuss in this section, however, more *efficient* prices do not always translate into *lower* prices, particularly in the face of cost shocks to inputs such as natural gas. In addition, economists have long recognized the inefficiencies in the structure and timing of electricity prices.[9] Restructuring proponents speculated that retail competition might spur more innovation in pricing, but such innovation requires adequate metering infrastructure and, has not seemed to be a priority for competitive retailers or their customers.

5.1 Retail Price Impacts of Restructuring: Empirical Results

The bottom-line question of the impact of restructuring on average prices has been periodically examined in the peer-reviewed literature and a series of industry reports (Kwoka (2008) reviewed of many of these studies). The general approach in all these studies is to identify a given set of states as "restructured" and to compare the growth of

[9] Much has been written on the inefficiency of retail prices that vary little over time and geography relative to the marginal costs of supply (Borenstein, 2002) as well as the fact that the marginal retail rate usually exceeds marginal costs due to the inclusion of fixed and sunk costs (Joskow and Schmalensee 1983).

prices in those states to those in states that did not restructure. Kwoka discussed the challenges in identifying an impact of restructuring on prices, including the disparate definitions of what actually is restructuring. Kwoka also highlighted the confounding impacts of transition arrangements that coincided with restructuring in many states:

> *There is inadequate attention in these studies, among other things, to the important data issues of post-restructuring price freezes, stranded cost recovery charges, and excess capacity, and hence none offers very reliable and convincing evidence with respect to the effects of restructuring.*

As Kwoka notes, the results from these studies were decidedly mixed in both methodology and their results, although more found a negative effect on prices from restructuring (*i.e.* lower prices in restructured states) than did not.

One important source of differences in these studies is the sector (generation, retail) that is the focus of restructuring. Su (2015) focuses specifically on the availability of retail choice using two measures: the adoption of legislation allowing choice and the share of total sales revenues earned by retail power marketers. Su adds controls for generation supply and preexisting trends in retail prices. He also distinguishes between a short-run transition period and a longer-run post-transition period greater than either three or five years. He generally finds little or no impact of retail restructuring on average prices for industrial or commercial customers. He does find some reduction in prices for residential customers, but only in the short-run. He attributes this effect to the transition arrangements, such as rate freezes, that typically accompanied regulatory restructuring in many states.

We focus here on two papers that econometrically examined effects of various levels of restructuring on retail prices. Joskow (2006) builds a model of state-level prices using panel data on key cost drivers such as fuel prices, PURPA contracts, and the share of hydro and nuclear generation as well as two restructuring treatments: a dummy variable for the year retail competition was introduced and a variable capturing the share of energy generated from unregulated generators in the state:

$$P_{it} = \beta_0 + \beta_1 EWG_{it} + \beta_2 RETAIL_{it} + \gamma X_{it} + \mu_i + v_t + \epsilon_{it},$$

where X_{it} are state level cost controls, *EWG* is the share of unregulated generation, and *RETAIL* is an indicator variable of the year a state adopted retail competition. Joskow examines residential and industrial prices separately using time series from 1970-2004 and 1983-2004. Overall, his results indicate that both unregulated generation and the legal status of retail competition lowered electricity prices at both the residential and industrial levels. However, he notes many of the caveats covered by Kwoka above, and adds that the pricing data collected by the energy information administration during this time may not have consistently accounted for the unbundling of energy prices from other elements of bills.

Borenstein and Bushnell (2015) also deploy a relatively simple model to estimate the impacts of *generation* restructuring on retail prices. They were in part responding to studies from 2007 that argued (in contrast to Joskow) that prices had risen more sharply in restructured states by that point. Their primary specification interacts the share of energy from unregulated generation with the local natural gas price:

$$\Delta P_{it} = \beta_0 + \beta_1 EWG_{it} + \beta_2 \Delta GAS_{it} + \beta_3 EWG_{it} * \Delta GAS_{it} + \epsilon_{it}.$$

Borenstein and Bushnell (2015) study annual price changes from 1997-2012. They find that once the changes in gas prices are controlled for, the extent of restructured generation has no significant effect on retail prices. The interaction of gas prices and the amount of restructured generation was significant. Their main point was that the deregulation of generation linked retail prices to natural gas prices to a degree that was largely unappreciated at the time of restructuring. The subsequent dramatic movements in gas prices during the 2000's were therefore much more strongly reflected in retail prices in restructured states. Much of the dissatisfaction with high retail prices in restructured states during the period of 2006-2008 was due to a combination of dramatically higher gas prices combined with the expiration of rate freezes that may have contributed to Joskow's results in 2004. Figure 10 shows the average rates in states with high penetration of unregulated generation against those with largely regulated generation, as well as the natural gas price as measured at the Henry Hub. The green dashed line indicates the price spread between a collection of states that restructured and those that did not. Prior to 1998, the gap was about two cents/kWh higher in (soon to be) restructured states. After an initial narrowing, the gap rose to nearly four cents in 2007, but then receded to about the same two cent gap that existed before restructuring began.

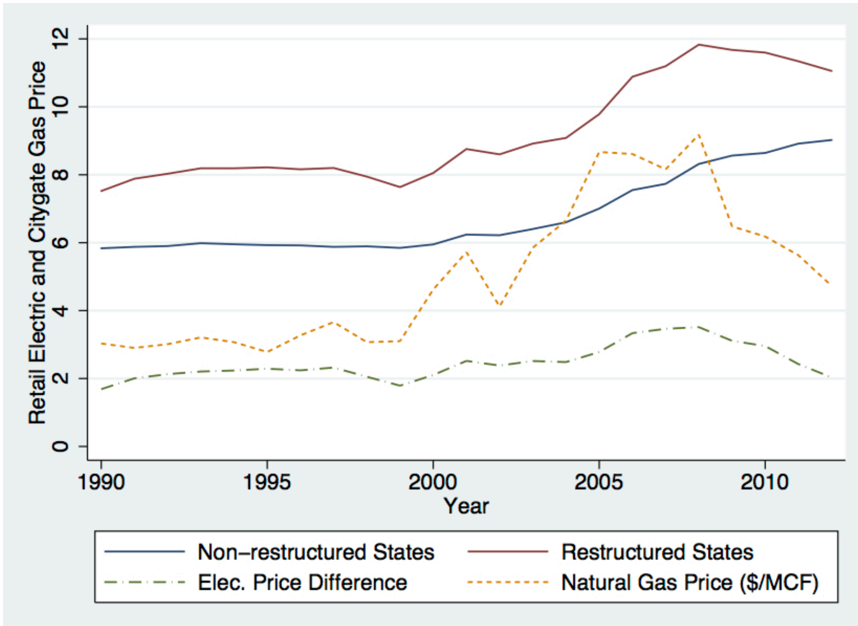

Figure 10: Average Electricity and Natural Gas Prices (Borenstein and Bushnell 2015)

By 2014, the industry had gone through cycles where prices grew more modestly first in restructured states, then dramatically so in regulated states, to a period post 2010 where rates climbed much more quickly in regulated than restructured states. The net result after these cycles has left little aggregate discernable impact on prices after 15 years of active restructuring. The current neutral result masks two important facts however.

First, at different points during the last 15 years one group of states or the other was the clear "leader" in price growth. Second, such differences can be dominated by exogenous factors, such as the price of natural gas. It is misleading to claim restructuring a failure or a success if such a result is largely dependent upon the serendipitous movement in exogenous input costs. More importantly, most economists would argue that a goal of restructuring is not to lower prices, but to make prices more reflective of marginal costs. In this sense the tighter link between wholesale and retail prices present in restructured states can be viewed to be a sign of success.

5.2 Retail Competition

The restructuring of the retail function has been more controversial and much more uneven than the changes to other segments of the industry. From the early stages of electricity restructuring, there has been some skepticism about the full deregulation of retailing. Joskow and Schmalensee (1983) largely dismissed retail competition in

Markets for Power. Yet the prospect of retail choice was a prominent selling point by proponents of restructuring, as highlighted by Joskow (2000):

> *The popular focus on retail competition in electricity has been motivated by the view that allowing retail customers to choose their retail supplier from among many competing ESPs is the only way that small residential and commercial consumers can and will benefit from electricity competition. This view in turn reflects concerns (real or imagined) that smaller customers have not benefited greatly from the introduction of competition in sectors like telecommunications and natural gas supply which have gone through industry transformations similar to what is now taking place in electricity.*

Skeptics, such as Joskow, noted that electricity supply does not require many of the roles retailers fill in other markets, such as providing convenient locations, same day delivery, low-hassle returns, etc. In electricity, the quality and physical attributes of the electrons flowing to residential consumers do not depend upon the identity of their specific retailer. Further, retailing itself comprises a very small share of overall regulated utility service costs, estimated by Joskow to be between 0.3 and 0.4 cents/kWh out of a then-average rate of 7.5 cents/KWh.[10]

Given the relatively modest direct costs involved in the delivery retail services, and the ambiguous interplay between competitive retailing and efficient price structures, the most important potential role for retail competition comes indirectly through its ability to influence the purchase cost of wholesale generation. Most of the literature agrees that a competitive and efficient wholesale market requires active buyers who are motivated to seek out low wholesale market prices. The question is whether retail competition is necessary to provide those motivated wholesale buyers.

Here again there are two schools of thought. One view, articulated by Littlechild (Littlechild 2000) is that "A retailer exposed to competition knows that it has already lost customers and may lose more if its prices are not competitive. … In contrast, a retailer with monopoly over all or most of its customer base… knows that (subject to the detail of regulatory process) its profit is broadly independent of its wholesale purchasing strategy."

Joskow observes, however, that competitive wholesale power pools already fill the role of discovering the market clearing prices that, like an equity index fund, should be for active purchasers to consistently beat in the long-run. In this view, it is quite plausible that the costs of customer acquisition, and possibly uncompetitive retail margins earned from relatively uninformed and unmotivated small customers, could outweigh other potential cost savings and value added services provided by competitive retailers. Using

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[10] Even those figures include the costs of metering and billing, much of which has remained a part of distribution service charges.

public or ratepayer funds to subsidize retail search could be wasteful and unproductive. Joskow proposed instead that, at least during a transition period, residential customers be given access to a Basic Electric Service, which effectively passes through the wholesale pool price.

Both authors recognized more subtle yet important roles for competitive retailers, however. Joskow noted that "participation in the wholesale markets by multiple ESP buyers with varying demand patterns, contractual obligations, and risk preferences can increase wholesale market liquidity and improve wholesale market performance with forward contracting." Indeed, the lack of such active multiple buyers in California appears to have contributed to an overemphasis on spot purchases by California retailers that was a major contributor to the California crisis (Bushnell 2004).

Overall, the role and impact of retail market designs has been relatively under-examined in the economics literature. The difficult empirical question is to compare the retail margins observed in restructured markets to any benefits competing retailers provide to the competitive health of wholesale markets. While there is some research described in this section that has examined the former, it is very difficult to quantify the latter, more subtle wholesale price impacts of retail competition.

5.3 Empirical Studies of Retail Competition

Several high level reviews of retail competition in the US have concerned themselves with the causes, measuring, and implications of the amount of retail switching seen in different markets. Overall, while retail search and switching has been relatively robust in the industrial segments of restructured markets, residential switching has lagged far behind. Figure 11 illustrates a calculation by Borenstein and Bushnell (2015), who use EIA data to tabulate the fraction of load served by retail power marketers in 2012.

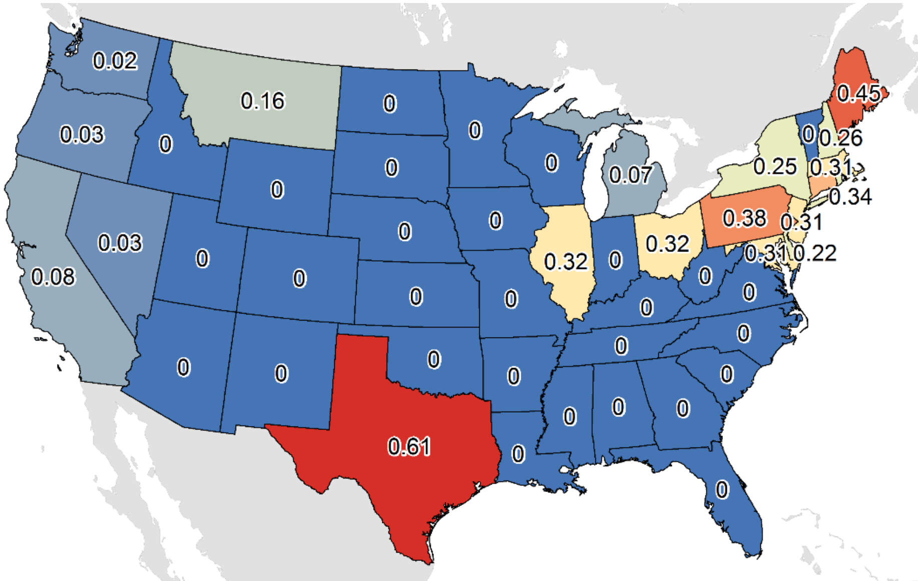

Figure 11: Fraction of Load Served by Retail Power Marketers in 2012

Opinions over the causes and meaning of the rather tepid response to retail choice by residential consumers vary somewhat. One factor has been the availability and attractiveness of the basic service provided to customers who do not switch. Most attribute the large switching percentages seen in Texas to the relatively unattractive (to customers) default price offered to customers by incumbent utilities, known as the *price to beat.* In other regions, default rates were fixed for several years as part of restructuring transition arrangements. Joskow (2005) documents how customers in PJM states were initially attracted to competitive retail prices, but then returned to default service when wholesale (and competitive retail) prices began to climb in the early 2000s.

There are several other reasons based on consumer theory why residential customers may be disinclined to switch electricity retailers. Consumers can be understandably reluctant to devote their limited time and attention to acquiring the necessary information for an informed retail choice. Brennan (2007), invoking the concept of search costs, argues that encouraging or forcing customers to switch can decrease welfare. The logic in this argument is that, if choosing a new retailer requires a non-trivial investment in time and hassle by customers (as evidenced by low switching rates), the gains from competition must be large to outweigh these costs.

Hortaçsu, Madanizadeh, and Puller (2014) decompose the consumer task into both search costs (*e.g.*, inattention) and switching costs (*e.g.*, incumbent brand advantages). They perform one of the only detailed attempts at measuring the magnitude of these costs in the context of the Texas market. They utilize meter level data on retailer identity and consumption quantities to model the consumer choice problem as one of first deciding to search for a possible alternative and then deciding whether to execute the switch of retailers, requiring possible additional costs in time and hassle. These costs are usually difficult to separately identify since both will translate into lower switching rates. The structural choice model utilized by Hortaçsu *et al*. allows them to separate the probability of search and the probability of switching retailers upon a decision to search. Their model structure is supported with evidence from customers who have newly moved into a retail market and are therefore forced to search for a new retailer.

They find both sizable search costs as well as a strong incumbent brand bias, such that, after four years of retail choice, over 60% of residential customers remain with their incumbent service despite the fact that some new entrants had consistently been offering lower prices. They provide some estimates of significant consumer surplus gains from measures that could reduce these choice frictions. Hortaçsu *et al*. do not attempt to quantify the benefits or cost of retail competition itself, nor do they estimate the implications for the choice frictions they find for retail competition and the resulting retail margins. Work from other countries indicates that choice frictions do translate into increased retail market power. Giulietti, Price, and Waterson (2005) using survey data on natural gas retail customers in the United Kingdom, calculate an implied equilibrium margin of 33% above competitive levels given the rate of switching indicated in their data.

5.4 Provider of Last Resort

Large segments of residential customers have failed to embrace retail choice. This has forced regulators to confront the need for policies addressing the retailer responsible for serving customers who either do not switch or whose retailers go bankrupt: the Provider of Last Resort (POLR). Some states, such as California, have returned to a largely regulated procurement model; regulated utilities solicit proposals and sign contracts with suppliers under the supervision of their local regulatory agencies. Many Northeastern states have adopted a hybrid retail competition approach where responsibility to serve POLR customers is divided up and procured through periodic auctions. This model appears to combine some of the attractive elements of retail choice, namely competition for low cost wholesale supply and hedging, with the concept of a basic electricity service proposed by Joskow in 2000.

Despite the fact that a majority of residential customers in many restructured states derive their service from some form of POLR procurement, little empirical work has been directed at evaluating how well such procurement is working. There are many variants in both the design of the product being procured, and the process through which it is procured. Loxley and Salant (2004) review the process of product design in New Jersey and discuss the various auction types deployed in different states. There is a perception that such auctions are clearing at prices that are higher than might be expected in a fully competitive market. Negrete-Pincetic and Gross (2007) document the Illinois POLR auction from 2006 and observe that prices were notably higher that historic averages for that region of PJM. They do not explore the potential causes of any differentials.

Elements of both price and quantity risk apply to providers of POLR services since customers are most likely to return to the POLR when market prices (and POLR costs) are relatively high. More expansive research is required on this topic to carefully document the relationship between POLR auction prices and the appropriate counter-factual, and to attempt to identify the causes of any perceived price premiums in procurement of POLR services.

5.5 Summary

After roughly 15 years of experience with retail choice in various US states, the results are still largely inconclusive. Both economic logic and empirical evidence suggest that retail prices in states with restructured *generation* are more tightly linked to natural gas prices than those in other states. This translated into a relatively unfavorable view of restructuring in those states in the mid-2000s, but such restructuring "penalties" have completely dissipated with the subsequent decline of gas prices.

The incremental impact of retail competition itself is very difficult to identify and remains inconclusive. Summary statistics confirm that retail choice has failed to draw the interest of large shares of residential customers. Empirical work on the early years of the Texas market confirmed that customers are both hesitant to search, and reluctant to switch when they do search. Whenever such choice frictions are prominent, it creates a concern that retail markets would be relatively uncompetitive. However, we are not aware of a major academic study of retail margins or competition in the United States and this remains an important area for future investigation.

Another area that deserves more research emphasis is the role of Providers of Last Resort, the firms responsible for providing retail energy to customers who do not actively switch from their incumbent, or whose competitive retailer goes bankrupt. Given the large share of residential customers not actively participating in the retail market, such functions have a large impact on both retail customers and wholesale markets. Many states with restructured retail sectors employ auctions of some form to essentially subcontract the responsibility for these customers to a variety of financial and competitive generation firms. The designs of both the products being auctioned and the format of the auctions themselves vary widely, yet there is little empirical work evaluating the effectiveness of these various designs.

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6 Environmental Performance

- **Restructuring-driven increases in plant-level fuel efficiency and nuclear availability have provided sizable reductions in pollution.**
- **Increased inter-regional trade caused by RTO expansions has potentially increased total production from coal units, possibly negating pollution reductions achieved by plant-level efficiency gains.**
- **Regulated utilities and IPPs respond to pollution cap-and-trade programs very differently; regulated firms invest in capital-intensive abatement technologies while IPPs pursue lower cost abatement options – suggesting that cap-and-trade is more efficient in restructured markets.**
- **While cap-and-trade programs are most effective when combined with competitive electricity markets, well-connected wholesale markets have the potential to exacerbate the potential of pollution leakage in settings where pollution regulations only apply to a subset of the generators in the market.**
- **More research is needed to determine whether restructured markets are better able to integrate high volumes of intermittent, renewable electricity generation**.

The literature that we review in Section 3 examines how restructuring affected *private* costs. In particular, Section 3.1 notes how RTO expansions have increased trade across regions that reduced system-wide private generation costs. Then Section 3.2 examines literature finding that restructuring has spurred improvements in plant-level operations that further reduced private costs. It is important to note, however, that the private cost of generating electricity does not capture the full, social cost. Instead, generating electricity imposes external costs – stemming largely from pollution created by fossil fuel generators – that have not been fully internalized in the firms' private costs. Therefore, to understand how restructuring has affected the efficiency of the electricity sector, it is important to determine not only how the private generation costs have changed, but also how the external pollution costs have changed.

Restructuring can affect the environmental performance of the electricity sector in two broad ways. First, restructuring can *directly* affect the quantity of pollution emitted by the electricity sector by inducing changes in plant and system-wide operations, long-run capacity investment, and retail pricing. Second, restructuring can *indirectly* affect environmental performance by altering how firms respond to environmental regulations targeted at the electricity sector.

6.1 Direct Impacts on Environmental Performance

One of the main outcomes of restructuring has been an increase in trade across regions (Mansur and White 2009, Cicala 2016). As trade increases, production shifts away from units with high private generation costs and towards units with lower private generation costs. Given that emission rates vary dramatically across generators, the shift in the distribution of production can directly alter the amount of pollution emitted. If production moves away from fuel-inefficient units to more fuel-efficient units burning the same fuel source, then total pollution could fall. Alternatively, if production shifts away from high private cost natural gas units and towards lower private cost coal-fired units, then the total pollution may increase.

Prior to the wave of restructuring, a number of studies simulated the potential impact of increased inter-regional trade on emissions. Palmer and Burtraw (2005) provide an overview of the *ex-ante* simulations. While there was a wide range in the predicted impacts on pollution, many of these studies forecasted a large increase in emissions as electricity flows from the Midwest to the East Coast increased. These expected emission increases were to be driven by an increase in production from underutilized, emission-intensive coal units. While we are not aware of any empirical analyses that examine the *ex-post* impact RTO expansions have had on emissions, there are reasons to expect that the original predictions overstate the ultimate increase in emissions. Specifically, beginning in 1999, the EPA imposed a limit on the aggregate quantity of NO_X that could be emitted by large, point sources in the eastern US – primarily fossil fuel electricity generators – throughout much of the year. Similarly, the EPA had imposed a nationwide cap on SO_2 emissions. Because these programs' caps on regional emissions were initially binding, the scope for restructuring-induced increases in pollution was limited. Changes in trade patterns could impact the *location* of the emissions, however, which would be more consequential for local criteria pollutants than for greenhouse gasses.

Restructuring can have environmental effects due to changes in plant-level operations. Davis and Wolfram (2012) estimate that capacity factors at divested nuclear units increased by 10 percentage points more than non-divested units. The increased nuclear production certainly reduced output, and therefore emissions, from fossil-fuel units. However, determining precisely how much pollution has been avoided requires identifying which fossil units are on the margin in different markets at different points in time (see, for example, Graff Zivin, Kotchen, and Mansur (2014)). Instead, Davis and Wolfram approximate the avoided pollution by assuming that the production avoided by the increased nuclear generation had an emission rate equal to the national average. Under this assumption, the authors estimate that 35 million metric tons of CO_2 has been avoided annually. Using a conservative estimate for the social cost of carbon ($20/tonne), this represents a reduction in external costs of $700 million per year. Hausman (2014) finds that this greater availability did not come at the cost of public safety: in fact, safety improved at nuclear plants that were divested.

Plant-level operations also improved at fossil-fired power plants. Bushnell and Wolfram (2005) present evidence of a potential increase in fuel efficiency among divested fossil fuel units. Again, determining how this change would affect pollution is difficult. If the total generation from the divested fossil units had remained unchanged, then an increase in fuel efficiency would decrease the total emissions. However, if an increase in fuel efficiency resulted in a redistribution of output among generators, the impact on pollution would again be ambiguous. There is currently no available evidence to suggest which affect has dominated.

The overall effects of plant improvements tend to be positive for the environment. Under a restructured market, all operators have incentives to lower costs and improve availability. If this improves the capacity factors of power plants that are relatively clean (like nuclear power), this could reduce emissions. However, if coal-fired power plants are now more productive, they may crowd out relatively clean natural gas plants and increase emissions. Evidence supports the former effect but has not rejected the latter. Finally, as with the system-wide effects, the aggregate effect depends on whether there are binding caps on regional emissions.

Restructuring can also have a range of other direct impacts on pollution. The introduction of imperfect competition can have ambiguous effects on emissions. When firms began to exercise market power in PJM, they reduced output from their coal plants during low demand times. System load was met by relatively clean, but more expensive, natural gas power plants owned by other firms resulting in lower emissions in the market (Mansur 2007). In addition, changes in retail pricing (*e.g.*, real-time pricing) can reshape daily load profiles, which can increase or decrease emissions depending on the location (Holland and Mansur 2008). Perhaps most importantly, restructuring can alter firms' incentives to invest in different types of generating capacity with very different emission rates. Again, the ultimate impact on pollution is ambiguous. Independent power producers may be more likely to invest in natural gas units which, compared to coal units, have lower upfront fixed costs and lower emission rates. Alternatively, regulated utilities may be more likely to invest in zero-emitting nuclear units.

6.2 Interactions with Environmental Policies

In addition to the direct impacts on pollution, restructuring can also indirectly affect the environmental performance of the electricity sector by altering the efficacy of the environmental regulations in place. Over the past two decades, efforts to reduce emissions from the electricity sector have relied heavily on the use of cap-and-trade programs. From a theoretical standpoint, the appeal of cap-and-trade programs is that they provide firms with the flexibility, and the incentive, to reduce pollution as cheaply as possible. However, several theoretical analyses highlight that cap-and-trade programs may fail to induce the lowest cost pollution abatement from *regulated* firms (Bohi and Burtraw 1992, Coggins and Smith 1993, Fullerton, McDermott et al. 1997). In particular, firms facing both environmental regulation and rate-of-return regulation will have an incentive to invest in expensive capital upgrades to reduce pollution rather than undertake less capital-intensive options, even if they have lower costs, like switching to cleaner fuel or purchasing allowances. This is consistent with the Averch-Johnson effect (Averch and Johnson 1962).

The empirical evidence seems to support the theory analyses. In their study of the US market for SO_2 allowances during a period that predates industry restructuring, Carlson et al. (2000) find that apparent gains from emissions trading were not taken advantage of, and hypothesize that this is due to "features of utility regulation that have limited incentives to participate in the SO_2 market." Two more recent empirical studies provide direct evidence that, when faced with a cap-and-trade program, regulated generators do in fact exhibit a bias towards capital-intensive abatement strategies. Fowlie (2010) examines the impact of the EPA's NO_X cap-and-trade program in the eastern US on plant-level abatement strategies. Specifically, the compliance decisions at generating units in restructured states are compared to compliance decisions at similar units located in states that remained regulated. Fowlie finds that generators in restructured markets were much less likely to invest in capital-intensive forms of NO_X abatement (*e.g.*, selective catalytic reduction) and were much more likely to pursue lower cost compliance options (*e.g.*, combustion modification, purchase pollution permits). Similar evidence is uncovered by Cicala (2015), who finds that coal plants in regulated states were far more likely to invest in capital-intensive scrubbers in order to comply with the EPA's SO_2 cap-and-trade program.

While the preceding studies provide strong evidence that firms' pollution abatement decisions are distorted by regulation, it is unknown how much total abatement costs would fall, if at all, by implementing cap-and-trade programs in restructured markets as opposed to regulated markets. Fowlie uses the empirical estimates of the plant-level compliance decisions to predict the total NO_X abatement costs in two counterfactual cases: one in which all states are assumed to have regulated electricity markets and another where all states are assumed to be deregulated. In the specific case of the NO_X cap-and-trade program, Fowlie surprisingly predicts that the total cost of complying with the pollution cap would not be significantly reduced by switching from complete regulation to complete deregulation. Whether a similar result would be found in the case of the SO_2 cap-and-trade program is unknown.

While Fowlie (2010) does not suggest that restructuring dramatically affected the total cost of abatement, the results do highlight an important interaction between restructuring and cap-and-trade programs. Specifically, cap-and-trade programs are often implemented in regions that contain both regulated and deregulated markets. Given that plants in the regulated states are biased in favor of making costly, but effective, capital-intensive pollution control upgrades, pollution permits – and therefore emissions – will end up being more heavily concentrated in restructured states. Therefore, the asymmetric adoption of restructuring over space will affect *where* the capped amount of pollution is ultimately emitted. In the case of the NO_X cap-and-trade program, Fowlie highlights that if the heterogeneity in economic regulation across states was removed, roughly 2% to 4% of the permitted NO_X emissions would shift away from regions where NO_X caused high damage to human health and towards regions where low damages were incurred. This suggests that by *partially* deregulating the electric grid in the eastern US, the efficacy of the NO_X cap-and-trade program was reduced. Whether a similar result would be found in the case of the SO_2 cap-and-trade program is unknown.

The interaction of the restructuring of regional markets with such regulations is a complex topic. When the environmental regulations have important shortcomings, such as limited jurisdictional reach, reduced trade frictions (such as that stimulated by RTOs) can exacerbate those weaknesses. Several simulation based studies stress that, in settings where cap-and-trade programs only apply to a subset of generators in a region, electricity production, and therefore emissions, will likely shift away from the capped region towards the uncapped region (*e.g.*, Fowlie (2009)). At the same time, more regionally cohesive environmental regulations can benefit from more efficient regional trade. Studies of the possible impacts of the US EPA's Clean Power Plan demonstrate that the cost of coordinated action amongst a region of states can be considerably lower than achieving the same reductions on a state-by-state basis (Bushnell, Holland et al. 2015). A more subtle effect involves the interaction of restructuring with a state's choice of environmental regulations, in terms of both stringency and form. Again, this is an important question for future work.

Just as more work is needed to understand how the benefits and costs of implementing cap-and-trade programs are affected by restructuring, there is also scant evidence on how restructured markets impact the efficacy of other environmental policies. In particular, policymakers are focusing heavily on reducing emissions from the electric sector by increasing the amount of generation from intermittent renewable energy sources (*i.e.*, wind and solar). An important topic for future work is to examine whether restructured markets have been able to integrate these intermittent streams of output with lower total costs. For example, do markets for ancillary services (*e.g.*, reserves, voltage regulation) efficiently respond to short-run swings in renewable output?

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7 Conclusion

This report reviews some well-cited papers in the economics literature that examine the effects of restructuring the US electricity industry. While additional papers would undoubtedly add to this discussion, the papers that we do examine provide a rich overview of the US experience. That said, other countries have also restructured their electricity markets in ways that help everyone better understand how these markets can be successful in improving consumer surplus and social welfare overall, as well as provide lessons learned on what does not help achieve policy-makers' goals.

Since Joskow and Schmalensee (1983), economists have been discussing the potential beneficial outcomes of restructuring as well as warning of possible pitfalls. The literature reviewed in this report suggests that there is some good news regarding the welfare effects of restructuring. These markets are pricing near marginal cost, power plants are becoming more fuel efficient and more wary of procurement costs, and system operators are able to dispatch power plants to lower costs over larger geographic areas. At the same time, there have been important lessons learned in understanding what leads to more competitive markets and that retail prices do not simply reflect cost savings in wholesale markets. Finally, there are topics, such as investment, where we still do not know what have been the effects of restructuring. In each section, we have outlined areas that we think economists can continue to provide careful, informative, and policy-relevant research as these markets continue to amend rules and introduce new policies.

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