



## RESEARCH SUMMARY

# Imperfect Markets Versus Imperfect Regulation in U.S. Electricity Generation

by Steve Cicala

### KEY TAKEAWAYS

1. With two-thirds of the electricity produced in the United States currently sold via wholesale markets, policymakers are confronted with an important question: Are markets reducing the cost of electricity generation relative to command-and-control regulated dispatch? This research uses a natural experiment to answer this question.
2. The author constructs a virtually complete hourly characterization of U.S. electric grid supply and demand from 1999 to 2012 to infer gains from trade across power regions and the savings from using the lowest-cost power plants at any moment of time. The author then compares the data in wholesale electricity market versus regulated command-and-control areas before and after the market was introduced.
3. The study finds that markets reduce the cost of generating electricity by about \$3 billion per year through increased efficiencies and coordination both within and across areas.
4. By using the lowest-cost plants 10 percent more often, markets reduce the costs from using uneconomical units by 20 percent per year. Additionally, the cost reductions from trading electricity across regions increases by 20 percent per year.
5. The greatest gains occur in temperate months when this increased efficiency and coordination can best be utilized.
6. As policymakers are faced with the question of whether the de-regulation of electricity markets should be expanded or scaled-back, these findings suggest the benefits realized by more efficient allocation of output through market-based dispatch have far outweighed any imperfections in the market system.

“Some policymakers are right now deciding whether their state should join a market system, while others are deciding whether they should return to the regulated approach,” says Cicala. “While these markets are certainly vulnerable to market power, this study shows that previously unmeasured cost reductions far outweigh those losses.”

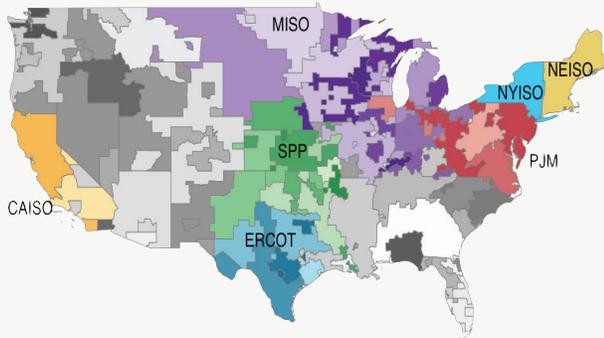
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## Introduction

Local monopolies—a mix of investor-owned utilities, government agencies (municipal, state, and federal), and non-profit cooperatives—were historically the principal architects of the U.S. electricity grid. These organizations were vertically integrated, so they owned the power plants, the transmission system, and the delivery network within their respective, exclusively-operated territories, and interconnections between them existed largely to maintain reliability. This began to change with the passage of the Energy Policy Act of 1992, which was codified by the Federal Energy Regulatory Commission (FERC) in 1996. The Act required the separation of transmission system owners and power marketers, allowing independent power generators access to the wires and allowing greater potential for wholesale electricity markets to form.

A new decentralized market approach soon did form, where multiple companies came together and bid in auctions that would determine who would operate their power plants to meet electricity demand on any given day. Only those who bid below the price needed to meet projected demand were called on to operate. Such power markets formed first in Pennsylvania, New Jersey and Maryland (the PJM system), and separately in California. Others formed in a piecemeal fashion as the Federal government encouraged market adoption. Today, more than 60 percent of U.S. electricity generation is determined by market-driven auctions.

**Figure 1** • U.S. Electricity Markets



There are seven regional electricity markets in the United States. Gray areas represent regions not currently operating within a market system.

Source: Cicala (2017)

## Research Design

Do power markets lower the cost of generating electricity? Research to date on production decisions has focused on the exercise of market power. That is, at times of high energy demand, companies may take economical plants offline—guaranteeing that expensive plants operate, which drives up

the price of electricity. This suggests markets are an inefficient approach to electricity generation.

This study goes beyond studying market power to determine if markets—despite such imperfections—still lower the cost of generating electricity in comparison to command-and-control regulations. The author constructs a virtually complete hourly characterization of supply and demand of the U.S. electrical grid from 1999 to 2012. The 14 years of data includes production costs and operations of virtually every generating unit in the country, and the demand for every one of the power control areas for every hour of the day for every day of the year. This data is then used to study two aspects of cost: so-called “out of merit” costs and trade.

The merit order is a ranking of available power supply by cost. Typically, electricity system operators are assumed to meet incremental demand according to the merit order—that is, each incremental unit of demand is met by the lowest-cost available capacity. At times, however, the system operates out of merit order, bringing more expensive units online first. This could occur when plants must occasionally go off-line for maintenance, or are forced to shut down unannounced, causing more expensive units to fill the gap; and when transmission constraints make it infeasible for the least-cost units to meet local demand. The additional cost of output from these units relative to dispatching the lowest-cost units is what is called the out-of-merit cost. The author measures out-of-merit costs by isolating instances in the data set when more economical generators—determined by heat rate, cost of fuel, and emissions fees—were not used.

The trade of electricity is also an aspect of cost. When importing electricity from another area, one could save having to fire up a more expensive unit. When exporting, one could gain any additional revenue beyond that required to generate the power. To measure these transactions, the author infers that if an area were paying more (or less) than their marginal cost of generating, they would reduce (increase) their imports until these costs were in balance. Similarly, an exporting area must at least be covering its production costs—and if they are more than doing so, they would increase their exports until the analogous balance were reached.

Using 14 years of historical data, the author compares out-of-merit and trade effects in market dispatch areas to areas still using the command-and-control approach. The author also compares the cost changes in the market dispatch areas both before and after the switch to the market occurred.

However, because of the changing cost of fuel, using historical values alone to estimate what the counterfactual outcome would have been if not for the markets is riddled with flaws. For example, when fuel prices are high, the value of substituting a higher cost generation unit with a lower cost generation unit is a lot greater than when prices are low.

To account for the impact of the price of fuel, the author uses a machine learning algorithm to estimate system operators’ rules for deciding which power plants to run at any moment in time. Having estimated that rule, the author predicts what system operators would have done if they had continued to follow the

rules they used in the past. This allows a comparison of the predicted pattern of production to the observed production in order to say what the outcome would have been if they had continued operating as they had in the past.

## Findings

**1. Markets reduce the cost of generating electricity by about \$3 billion per year.** Previous studies have found that market imperfections—such as market power—cause markets to increase the cost of generating electricity. This study found that, despite their imperfections, markets better allocate output to lower-cost units. The use of lower-cost units saves about \$3 billion a year in generating electricity.

**2. Markets reduce the cost due to using more expensive units by nearly 20 percent per year.** Power plant generators operating within markets are more likely to ensure their power plants are available to run when it is most economical for them to run. This means the lowest-cost plants are used 10 percent more often in market regions—reducing out of merit costs by nearly 20 percent.

**3. The volume of electricity traded across areas increases by 10 percent, yielding a 20 percent increase in the gains associated with coordinating operations across areas.** Generators operating within markets are able to better identify low-cost generators across areas and better coordinate the dispatch of power, increasing trade by 10 percent. The savings from this additional electricity trading increases by as much as 20 percent a year.

**4. Markets save the most in temperate months because they offer improved efficiency and coordination.** During the temperate months in spring and fall, when demand is lower because there is less need for electricity to heat or cool buildings, large generating plants are typically shut down for maintenance. In market areas, plant generators reduce the time they are shut down for maintenance and better coordinate their shut-down schedules with other generators across areas.

## Policy Implications

Two-thirds of the country now uses markets to determine electricity production. But some states (i.e. Ohio) are deciding whether they should return to the command-and-control regulated approach. Other states are deciding whether they should join the market system (i.e. Washington and Oregon may join the California market). Neither system is perfect, with clear regulatory shortcomings and market failures. However, as states evaluate which approach to use, this study provides some of the first evidence that the benefits of joining a market far outweigh the costs.

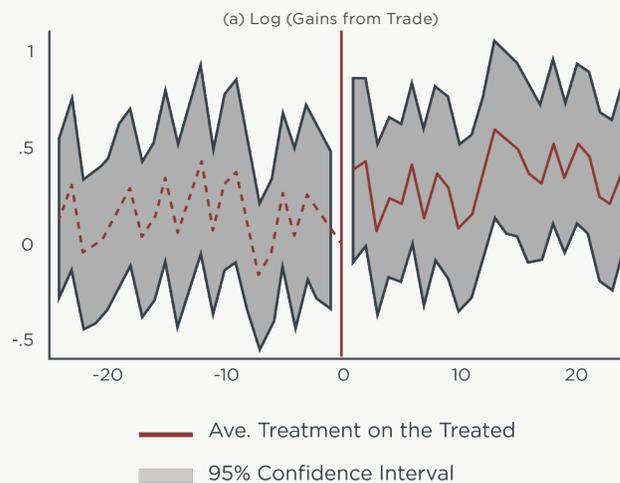
Further, the study makes important observations about the broader value of a market approach—whether it be in the energy sector or beyond. Markets remain more efficient and effective than command-and-control regulations.

**Figure 2** • The Decline in “Out of Merit” Costs After Market Introduction



The market system was introduced at time zero on the horizontal axis. Left of zero represents the 10 and 20 months before the market started. Right of zero represents the 10 and 20 months after the market started. “Out of merit” costs declined after the market system was introduced.

The Gains from Trade After Market Introduction



The market was introduced at time zero on the horizontal axis. Left of zero represents the 10 and 20 months before the market started. Right of zero represents the 10 and 20 months after the market started. Gains from trade increased after the market started.

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