Journal of Regulatory Economics (2019) 56:1–32
https://doi.org/10.1007/s11149-019-09386-9

ORIGINAL ARTICLE

What can deregulators deregulate? The case of electricity

Tin Cheuk Leung[1] · Kwok Ping Ping[2] · Kevin K. Tsui[3,4]

Published online: 5 August 2019

Abstract
We revisit Stigler and Friedland's (J Law Econ 5:1–16, 1962) seminal paper by examining how competitive generation affects prices, sustainability, and reliability in the electricity industry. Exploiting state and year variation in the introduction of regional transmission organizations (RTOs) that facilitate open access to transmission, we first show that wholesale market deregulation significantly increases the prevalence of independent power producers (IPPs). Using RTO membership as an instrument, we find that IPP entry fails to cut electricity prices paid by consumers. This non-result is also robust to using initial electricity tariffs as an instrument for changes in IPP in a long-difference specification. We provide suggestive evidence that the absence of consumer gain can be attributed to efficiency loss due to mandated divestiture of generation assets or simply higher upstream transaction costs. But, increased prevalence of IPPs is associated with more solar and hydropower, although the use of non-fossil fuel as a whole remains unchanged because less nuclear power is used. More IPPs, however, is also associated with less reliable electricity supply. A review of the origins of electricity deregulation suggests that this tradeoff between environmental sustainability and energy security is not likely to have been the major determinant of the deregulation. Rather than a pro-consumer deregulation, the regulatory change is perhaps more appropriately interpreted as a regulatory capture that benefits IPP entrants and existing energy marketers.

Keywords Energy trilemma · Independent power producers · Deregulation

JEL Classification K23 · L22 · L25 · L43

We would like to thank Bill Dougan, Nic Tideman, Maggie Wang and seminar participants at Clemson University for helpful comments.

✉ Kevin K. Tsui
ktsui@clemson.edu

1 Wake Forest University, Winston-Salem, USA

2 Virginia Tech, Blacksburg, USA

3 Clemson University, Clemson, USA

4 Zhongnan University of Economics and Law, Wuhan, China

1 Introduction

The Energy Trilemma—a term coined by the World Energy Council—highlights the tradeoffs among energy equity (i.e., affordability of energy supply), environmental sustainability (i.e., development of energy supply from renewable and other low-carbon sources), and energy security (i.e., reliability of energy infrastructure). Among the ten action areas suggested to resolve this trilemma, minimizing policy and regulatory risk is recommended because stable regulatory and legal frameworks are essential for long-term investments. However, after a wave of state-level regulatory reforms aimed at introducing competition in the U.S. electricity industry started in the mid-1990s, the process encountered a significant backlash after the 2000–2001 California electricity crisis. What does the experience of electricity deregulation teach us about the energy trilemma? On the other hand, are the deregulation outcomes consistent with the economic theory of regulation?

In their seminal work, Stigler and Friedland (1962) examined the effect of state regulation on electricity prices. Since then, several thousand scholarly studies of the effects of economic regulation have been conducted. Jarrell (1978), for instance, argued that state regulation in the early twentieth century served to isolate private utilities from the competitive policies of municipal regulators. Joskow and Rose (1989) provided an excellent survey of the literature on the effects of economic regulation, including a small literature on the effects of regulation on product quality just before the dawn of the electricity deregulation. The survey reported that deregulation of the airline industry, for example, reduced average service quality (e.g., increasing delays), because price regulation induced too much non-price service competition.[1] However, they also admitted that the quality effects remain uncertain in the case of a natural monopoly such as electricity.[2] Furthermore, compared with some other industries that had been more successfully deregulated earlier, the electricity industry has received much less attention when evaluating the theory of endogenous deregulation (Peltzman 1989).

In this paper, we study how wholesale competition in electricity, measured by the increased prevalence of independent power producers (IPPs), affects the energy trilemma. While economists have pointed out that deregulation in wholesale electricity markets do not always result in prices at competitive levels because of plant inflexibility and repeated interactions among firms,[3] and that there could be significant

[1] See Mulligan and Tsui (2016) for a theoretical discussion on how price regulation affects quality choice in a competitive environment.

[2] In an interesting recent study, Boylan (2016) found that storms disrupt electricity consumption in areas served by municipal utilities but do not disrupt those served by IOUs. Some of our results are complementary to his in the sense that, instead of comparing public versus private ownership of utilities, we examine whether the entry of IPPs in deregulated states affects the number and duration of outages.

[3] Joskow (2001) and Borenstein et al. (1999) use the California experience to illustrate that deregulation in the wholesale market is challenging and might not bring the prices down to competitive level. McRae and Wolak (2009) and Domah and Pollitt (2001) show that privatisation in the England Wales' electricity market could lead to higher cost in the beginning due to higher institutional costs caused by the creation of new buiness and markets.

lost economies of vertical integration resulting from restricting,[4] many economists still believe that IPPs, which can specialize in running certain types of plants, face clearer incentives to minimize costs and make efficient long-run investments in generating capacity, and these efficiency gains for the industry should ultimately lead to cost savings for households and businesses.[5] Before the mid-1990s, however, most electricity customers in the U.S. had been served by investor-owned, vertically-integrated monopoly utilities (IOUs) that provided generation, transmission, distribution and retailing. To promote IPPs, independent system operators (ISOs) and regional transmission organizations (RTOs) were developed to encourage competitive generation through open and non-discriminatory access to transmission. Variations of this centralized-market approach predominate in the Northeast, Mid-Atlantic, Midwest, Texas, and California.

Because these different regional markets have somewhat different features and characteristics, it is difficult to evaluate the direct effects of "deregulation" (Electric Energy Market Competition Task Force 2007).[6] However, to the extent that the formation of these different centralized markets is associated with an increased prevalence of IPPs, they are useful in identifying the competitive effects of IPPs on electricity market performance.[7] We view our approach, which examines state-level electricity market performance, as complementing the growing literature that focuses on efficiency at the power-plant level. Market performance indicators such as electricity prices and power outages are usually determined by all individual plants as well as power transmission and distribution in a given market.[8] To evaluate

[4] Kasermand and Mayo (1991) was among the first that empirically estimate the economies of vertical integration in the electricity market. Since then, various studies have estimated the economies of vertical economies can range from 6 to 20% in the U.S. and European markets. See Arocena et al. (2012), Gugler et al. (2017), and Meyer (2012).

[5] Right before the California electricity crisis, for instance, Joskow (2000) wrote "[c]ompetitive entry of new unregulated generating facilities owned by developers that assume construction and operating cost risks and that have incentives to use the lowest-cost technologies is likely to be one of the most important long-term benefits of competitive electricity markets." Even long after the crisis, this view is still shared by the FERC, which claimed "[e]ffective wholesale competition protects consumers by providing more supply options, encouraging new entry and innovation, spurring deployment of new technologies, promoting demand response and energy efficiency, improving operating performance, exerting downward pressure on costs, and shifting risk away from consumers" (Federal Energy Regulatory Commission, 2008).

[6] A problem is further complicated by the fact that even under the regulated regime, there was variation in the specific regulatory approaches of different states. The widely-used dummy-variable approach, in which regulation is measured by a dummy variable indicating whether a state is "regulated" or "unregulated," has also been criticized because both regulation and deregulation are often lengthy and incremental processes (e.g., Joskow and Rose 1989). When the "regulated" dummy variable is subject to severe measurement error, standard estimation method is likely to produce biased results.

[7] Measurement error is much less of an issue with IPP prevalence. Our panel dataset enables us to take advantage of within-state variation in IPP prevalence, because the share of generation from IPPs was essentially zero in most of the states at the beginning of our sample period. For instance, at the national level, the share of generation from IPPs has increased from a trivial amount in the early 1990s to almost 40% today. Today, the share is as low as less than 1% as in South Carolina, and it can also be as high as more than half as in California.

[8] Moreover, efficiency improvement among the infra-marginal plants may have little impact on prices, which are determined by the marginal plants.

whether consumers benefit from competition among IPPs, therefore, it is useful to go beyond the efficiency of individual power plants. Exploiting state and year variation in the introduction of ISO/RTO, we show that open access to transmission indeed encourages IPP entry. Using ISO/RTO membership as an instrument for IPP prevalence (i.e., the fraction of electricity generated by IPPs), we estimate the competitive effects of IPPs on electricity prices and quality of power services, measured by use of clean fuel and electricity outages.

Our results indicate that state-membership of ISO/RTO is strongly correlated with IPP prevalence. For instance, in our full specification that controls for income, population, and state and year fixed effects, a state joining an ISO/RTO effectively increases the market share of IPPs by more than 10 percentage points. On the other hand, we also find that IPP prevalence is statistically associated with higher electricity prices paid by consumers in a simple pooled cross-sectional and time-series setting. The magnitude of the correlation, however, decreases by 75% once we include state and year fixed effects to control for unobserved state- and time-specific heterogeneities, although the correlation remains statistically significant. Interestingly, using ISO/RTO membership as an instrument for IPP prevalence, our instrument-variable (IV) estimation shows that the entry of IPPs no longer significantly increases electricity prices. Indeed, compared with the fixed-effects estimate, the magnitude of the IV estimate further decreases by 80%, and is highly statistically insignificant.[9] Neither do we find that the rise of IPPs is associated with lower residential or industrial prices. When we focus on deregulated states that also provide retail choice, we indeed find some evidence that consumers are facing slightly higher prices. Moreover, in states where utilities were forced to divest their generating plants, a higher prevalence of IPPs is associated with significantly higher prices.

Although the increased prevalence of IPPs triggered by the transmission access reform fails to bring down electricity prices paid by consumers, consumers may benefit from improvement in electricity services. Our results also indicate that IPP prevalence also fails to improve sustainability, measured by the use of non-fossil fuel. Interestingly, we find that states with higher IPP prevalence tend to use more solar and hydropower but less nuclear power. Finally, when we consider the effects on supply reliability, we find a positive relationship between IPP relevance and the number of outages, although the estimate is rather imprecise once we control for state and year fixed effects. When we examine the length of outages, we find that higher IPP prevalence is associated with longer duration of outages.

To the extent that replacing nuclear power by solar and hydropower is desirable, our findings reveal that *ex post* there is a regulatory tradeoff between environmental sustainability and energy security. Can the origins of deregulation be explained by the demand for such a regulatory tradeoff? While a detailed quantitative analysis of

[9] Our non-results are broadly consistent with the earlier literature that examines the direct price effects of deregulation (Kwoka 2008). The earlier literature concluded that there is little reliable evidence that electricity prices become lower as a result of deregulation. More recently, by focusing on states that have not restructured their electricity markets, Kury (2013) showed that there is no robust relationship between the formation of ISO/RTO and electricity prices. In terms of retail competition, Su (2015) found that introducing retail choice does not lower electricity prices across the board or over time.

the origins of the electricity deregulation is beyond the scope of this paper, we think our analysis can shed some light on this question. Although electricity deregulation is not generally regarded as a complete failure,[10] our results indicate that competitive generation did not result in any obvious gain to consumers, even industrial ones who actively lobbied for the change. Because the deregulation protected incumbents from significant losses through stranded cost recovery, and the breakup of the traditional IOUs implied markets superseding firms, IPP entrants and existing energy marketers became the major winners of the electricity deregulation.[11] A review of the origins of electricity deregulation suggests that the deregulation (or reregulation) is perhaps more appropriately interpreted as a regulatory process captured by these IPPs and energy marketers.[12]

The rest of the paper is organized as follows. Section 2 reviews the history of electricity deregulation and the rise of IPPs in the U.S. Section 3 describes our data and estimation strategy. Section 4 presents our results on prices of electricity. The results on clean fuel and supply reliability are reported in Sect. 5. We conclude in Sect. 6 with an economic interpretation of our results.

2 Wholesale electricity restructuring and the rise of independent power producers

Practically speaking, IPPs did not exist before the Public Utility Regulatory Act (PURPA) of 1978. To conserve electric energy in the time of oil crisis, PURPA established a class of IPPs that were permitted to produce power for resale. These IPPs, known as Qualifying Facilities, were primarily cogenerators and small power plants using renewable fuels. Due to technological constraints and the collapse in energy prices in the mid-1980s, however, IPP participation in the grid did not really take off until almost 2 decades later.

After the passage of the Energy Policy Act of 1992, Orders 888 ("Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and

[10] For instance, England and Wales have become more competitive since the late 1990s, which have increased efficiency and have conveyed more benefits to consumers (Newbery 2006). In many developing countries, electricity reform appear to have increased operating efficiency and expanded access to urban customers (Jamasb et al. 2005). In the U.S. market, Borenstein (2002) argues that restructuring in electricity market is challeging. "The difficulties in outcomes so far, however, should not be interpreted as a failure of restructuring, but as part of the lurching process toward an electric power industry that is still likely to serve customers better than the approaches of the past." Hogan (2002) notes that "[t]he benefits of reform may be substantial, but they require careful attention to market design." Joskow (2008) and Brennan et al. (2002), in reviewing the historical experience, concludes that even though incompletely or incorrectly implemented reform can carry risk of significant potential costs, electricity sector reforms still have significant potential benefits.

[11] Unlike a decentralized market where buyers and sellers can simply rely on bilateral agreement, in centralized electricity wholesale market there is a demand for energy marketers. For example, Enron is such an energy marketer that benefited from the emergence of centralized electricity wholesale market.

[12] The regulatory experience of local phone service is perhaps also consistent with this interpretation of the capture theory of regulation. See Sect. 6 for more details.

Transmitting Utilities") and 889 ("Open Access Same-Time Information System and Standards of Conduct") published by the Federal Energy Regulatory Commission's (FERC) in 1996 accelerated the transmission access reform.[13] Promulgation of these two orders was followed by divestiture of generation plants by traditional electric utilities in some states and, more importantly, establishment of a number of ISOs as managers of large parts of the transmission system.[14] These ISOs, which are independent entities established to coordinate regional transmission in a non-discriminatory manner, were believed to have great potential to assist the industry in remedying undue discrimination and mitigating market power.[15]

A review of evidence on continued discrimination in the provision of transmission services by vertically integrated utilities in 1999, however, led FERC to publish Order No. 2000 which proposes the formation of RTOs to further address the existing impediments to efficient grid operation and competition.[16] RTOs are independent, membership-based, non-profit organizations that promote efficiency in wholesale electricity markets by centralizing them. It is important to note that RTOs operate, but not own, grids.[17] RTOs are funded by a grid management charge approved by FERC and paid by all generators. Moreover, cost recovery for transmission investments need to be approved by State Public Utilities Commission and

[13] The basic principles of Order No. 888 are simple: "transmission owners must provide access to third parties to use their transmission networks at cost-based maximum prices and non-discriminatory terms and conditions, make their best efforts to increase transmission capacity in response to requests by third parties willing to pay for the associated costs, and shall behave effectively as if they are not vertically integrated when they use their transmission systems to support wholesale market power transactions" (Joskow 2000a, b). Order No. 889, on the other hand, specifies information availability rules and various behavioral rules designed to guard against discriminatory practices by the transmission owner.

[14] While some states mandated divestitures, others adopted stranded-cost recovery mechanisms that provided financial incentives to encourage utilities to sell their generating plants. There were also state reform programs that encouraged utilities to transfer their generating plants to unregulated affiliate companies. According to Wolfram (2005), "[b]y the end of 2001, 305 plants accounting for over 156,000 MWs, or nearly 20% of US generating capacity had been transferred from utilities to merchant generators."

[15] During the same period of time, some states began to develop retail competition. Moreover, there was an increase in the number of mergers among traditional electric utilities and among electric utilities and gas pipeline companies. According to Order 888, however, "[a]mong the many issues that are important to competitive bulk power markets are: independent system operators (ISOs); regional transmission groups; generation market power; utility merger policy; and the development of innovative transmission pricing alternatives, such as flow-based, distance-sensitive transmission pricing methodologies that reflect incremental costs. In particular, we believe that ISOs have great potential to assist us and the industry to help provide regional efficiencies, to facilitate economically efficient pricing, and, especially in the context of power pools, to remedy undue discrimination and mitigate market power." (pp. 51–52).

[16] Order 2000 proposed four minimum characteristics (independence, scope and regional configuration, operational authority, and short-term reliability) and eight minimum functions of an RTO (tariff administration and design, congestion management, parallel path flow, ancillary services, OASIS and total transmission capability and available transmission capability, market monitoring, planning and expansion, and interregional coordination).

[17] To date, the majority of the power grids are still owned by IOUs. The number of transmission owners also varies across RTOs. Moreover, each of them has its own governance structure. For instance, while some have all independent members as board of directors, some also have stakeholders in their board. Some, not all, also have committees with representatives from IOUs, IPPs, state and federal agencies, public consumer advocates, environmental advocates, etc.

FERC. According to the FERC, the primary difference between an ISO and an RTO is that there is no scope requirement associated with ISO status.[18]

Among the major regulatory and structural reforms in the U.S. electricity sector over the past few decades, the creation of ISO/RTO is regarded by many as the most important one in promoting upstream competition.[19] From the late 1990s to the early 2000s, there was indeed a boom in construction of new power plants by IPPs. This increase of IPPs was driven by (a) a demand for significant new generating capacity after a decade of virtually no new construction, and (b) utilities in some states were required to divest massive amounts of generating assets.[20] However, the IPPs abruptly stopped constructing new facilities as a result of the 2000–2001 California electricity crisis and the recession following the 9/11 attack. The California electricity crisis, in particular, was also responsible for a number of states repealing, delaying, or even suspending their processes of deregulation.[21] Accordingly, between the early 2000s and the early 2010s, the market penetration by IPPs remained more or less static, and the remaining IPPs are largely engaged in consolidation rather than growth.

3 Data description and empirical strategy

We combine data from the following sources for our analysis. We focus on the lower 48 states. Data on net generation from IPPs, annual average retail prices (residential, commercial, and industrial) and generation from various energy sources, which covers the period 1990–2013, are obtained from the U.S. Energy Information Administration.[22] Data on electric emergency incidents and disturbances over the 2000–2013

[18] FERC defines scope requirement as: "Order No. 1000 requires public utility transmission providers to improve transmission planning processes and allocate costs for new transmission facilities to beneficiaries of those facilities. It also requires public utility transmission providers to align transmission planning and cost allocation. These changes will remove barriers to development of transmission facilities." See the details at https://www.ferc.gov/media/news-releases/2013/2013-1/02-21-13-E-1.asp. Over time, some ISOs have evolved into RTOs or organizations similar to RTOs.

[19] In other states that allow wholesale competition but are not part of any ISO/RTO (e.g., states in the Northwest and Southeast), their approach to competition is to base trades exclusively on bilateral sales negotiated between suppliers.

[20] We note that deregulation at the retail level can also be relevant to our analysis. By early 2001, 22 states and the District of Columbia had adopted retail competition legislation. These states tended to view the separation of power generation ownership from power transmission and distribution ownership as a prerequisite for retail competition. Among them, California, Connecticut, Maine, New Hampshire, and Rhode Island passed laws requiring IOUs to divest their power plants. Other states encouraged divestiture to arrive at a quantifiable level. In our analysis, we provide robustness checks to examine if deregulated states with and without retail choice have different market performances.

[21] States that suspended their plans of retail market restructuring were Arizona, Arkansas, California, Nevada, New Mexico, Virginia, Wyoming.

[22] According to the EIA website, the average price of electricity is calculated by dividing the electric revenue from ultimate consumers by the corresponding sales of electricity. The average price is calculated for all consumers and for each end-use sector. In other words, it represents a weighted average of consumer revenue and sales, and does not equal the per kWh rate that individual consumers is being charged under peak-load pricing that is commonly practiced by electric utilities.

period are provided by Inside Energy, which compiles raw data from the Department of Energy.

Not all RTOs started operating at the same time. In the Northeast, the RTOs evolved from power pools that had coordinated utility operations for decades. In the Midwest, California and Texas, however, RTOs grew up to meet both state and federal policies on competitive generation and open transmission access. After a careful review of the history of the wholesale electricity restructuring, we construct an ISO/RTO membership variable, where a state is defined as an RTO state after it becomes a member of any ISO or RTO. Currently, there are four RTOs in the U.S.:

(1) *PJM Interconnection*, which includes Delaware, Illinois, Maryland, New Jersey, Ohio, and Pennsylvania, was first granted ISO status in 1997, and it became the nation's first fully functioning RTO in 2001 (PJM has only served substantially parts of Virginia and West Virginia since 2005 and Kentucky since 2013).
(2) *ISO New England*, which covers Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont, was granted ISO status in 1997, and began its operation as an RTO in 2005.
(3) *MISO*, which includes Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, and Wisconsin, was granted ISO status in 1998 and RTO status in 2001, but only began centrally dispatching generating units throughout much of the central U.S. based on bids and offers cleared in the market in 2005. (Arkansas, Mississippi, Louisiana, Missouri, and Texas's market did not operate until 2013).
(4) *Southwest Power Pool (SPP)*, which includes Arkansas, Kansas, Louisiana, New Mexico, and Oklahoma, was first granted RTO status in 2004 (Nebraska joined in 2008, and SPP expanded significantly in 2015).

   Moreover, there are three additional ISOs:

(5) *California ISO* (*CAISO*) was created in 1998.
(6) *New York ISO* (*NYISO*) was created in 1999.
(7) *Electric Reliability Council of Texas (ERCOT)* was first created as ISO in 1996, although it did not operate under the new electric industry restructuring guidelines until 2001.

It is useful to note that the way we construct our ISO/RTO variable attempts to capture some core functions that all centralized wholesale electricity markets provide. Under this less centralized form of wholesale market, known as *Day 1 RTO*, RTOs simply manage the administration of real-time energy markets and some basic forms of congestion management.[23] In our full specification, we control for state-level GDP per capita and population. In the sustainability regressions, we also control for the number of financial and regulatory incentives for renewable programs. Data on GDP and population are obtained from the Bureau of Economic Analysis's

[23] Day 2 RTO offers a fully functioning centralized market for day-ahead and real-time energy, capacity and ancillary services, and market-based congestion management. The major source of heterogeneity among different RTOs comes from these additional market functions.

Regional Economic Accounts. The NC Clean Energy Technology Center provides a database of state incentives for renewables and energy efficiency.

Table 1 reports the summary statistics. Over the sample period, the market share of net generation from IPPs is about 20%. There are also significant variations in IPP prevalence, electricity prices, shares of non-fossil fuel, and the number and duration of outages. Using these data, we first consider the main regression model:

$$Price_{it} = \beta_0 IPP_{it} + X'_{it}\gamma_0 + \delta_{0,i} + \lambda_{0,t} + \varepsilon_{0,it}$$

where $Price_{it}$ measures average electricity prices of state i in year t.[24] Our variable of interest IPP_{it} measures the fraction of net electricity generation from IPPs in state i in year t. β_0, therefore, measures the impact of IPP prevalence on electricity prices. Potentially, if one wants to investigate the impact of competition pressure on the outcomes in the electricity market, one can use other measures of competition level such as the Herfindahl index or the number of IPPs in a state-year market, instead of IPP prevalence, as the independent variable. Using these measures of competition level as independent variables can have different interpretations compared to using IPP prevalence. For instance, there could be one dominant IPP that has a high IPP prevalence in the market. Because the focus of this paper is to evaluate the impact of vertical disintegration resulting from the deregulation, and because of the lack of data on other measures of competition level, we therefore use IPP prevalence as our preferred independent variable, and leave the idea of investigating the impact of competition as future research.[25] Because electricity prices may be determined by other factors that are correlated with IPP prevalence, X'_{it} represents a set of control variables (GDP per capita and population, in particular) that potentially affect prices. Unlike some earlier studies, we do not control for fuel mix, because fuel mix can be endogenous to the entry of IPPs. For unobserved time-invariant factors that may affect prices (such as access to a river), state fixed effects $\delta_{0,i}$ are included to mitigate omitted variable bias. Year fixed effects $\lambda_{0,t}$ are also included to control for factors such as federal energy policies and natural gas prices that change over time. $\varepsilon_{0,it}$ is an error term capturing all other omitted factors.

Although the above fixed-effects specification exploits within-state variation in IPP prevalence, it may not identify the causal effects if the error term is correlated with IPP even after controlling for state and year fixed effects as well as other covariates. In particular, we may be omitting time-varying state variables that are correlated with both electricity market performance and the prevalence of IPP. To further mitigate other endogeneity biases, we consider the following first-stage regression model:

$$IPP_{it} = \beta_1 RTO_{it} + X'_{it}\gamma_1 + \delta_{1,i} + \lambda_{1,t} + \varepsilon_{1,it}$$

24 The regressions with different outcomes variables share similar structure.

25 We thank a referee for raising this point. We did indeed try to contact the EPA for the relevant data. However, the data would be very difficult to come by, and would merit an entirely new project.

where RTO_{it} is a dummy variable indicating whether state i in year t is a member of any ISO/RTO.[26] The rest of the equation is similar to the main regression model defined earlier. Replacing the observed IPP_{it} in the main regression model by the predicted value of IPP_{it} from the first-stage equation, our two-stage least squares estimation identifies the causal effect β_0 under the assumption that, once controlling for state and year fixed effects and other covariates, ISO/RTO membership affects electricity market performance *only through the entry of IPPs*.[27] While it is possible that ISO/RTO have some direct effects on the dependent variables of interest, unless ISO/RTO itself has the tendency to increase prices, reduce renewables or lower reliability, our results are likely to bias *towards* finding desirable effect of IPP on electricity market performance.

4 Price effects of competitive IPPs

4.1 Estimation

The results on average electricity prices are presented in Table 2. The simple OLS results reported in column 1 show that states with higher IPP prevalence are associated with significantly higher average electricity tariffs. A one standard deviation increase in IPP prevalence, for example, increases average prices by 1.72 cents per kilowatthour. Controlling for year fixed effects does not affect the result much. Once controlling for state fixed effects, however, the point estimate becomes four times smaller in magnitude, although it is still statistically significant. The result is robust to adding income and population as controls.[28]

Our fixed-effects estimates suggest a positive relationship between IPP prevalence and average electricity prices. However, entry of IPPs may not cause higher price of electricity, as IPP prevalence may be endogenous. In Fig. 1, we plot the average IPP prevalence from states that are members of some ISO/RTO and states that are not. Apparently, the rise of IPPs is consistent with the formation of ISO/RTO since the late 1990s. Table 3 shows that there is a robust positive relationship between ISO/RTO membership and IPP prevalence, and, as we will show in the following Tables, the first-stage F-statistics are all well above critical values suggested for small samples (e.g., Stock and Yogo 2005).

[26] As Bresnahan and Reiss (1991) and Berry (1992) suggested, cost shifters that cause entries/exits would be a good instrument in a first-stage model. However, the lack of data on market competition prevents us to employ this approach.

[27] Some earlier studies considered the reduced-form $Price_{it} = \beta_r RTO_{it} + X'_{it}\gamma_r + \delta_{r,i} + \lambda_{r,t} + \epsilon_{r,it}$. For instance, Taber et al. (2006) find that wholesale competition (measured by ISO membership) does not reduce retail prices. Lenard and McGonegal (2008) find that wholesale competition (measured by RTO membership) does not reduce wholesale prices. Our two-stage least squares estimate can be interpreted as the ratio of the reduced-form coefficient and the first-stage coefficient (i.e., $\beta_0 = \beta_r/\beta_1$).

[28] We have also experimented with cross-sectional specifications using early price as instrument for IPP prevalence. None of these specifications suggest IPP prevalence reduces electricity prices.

Table 1 Summary statistics

	Mean	S.D.	Min	Max	Obs.
IPP prevalence	0.209	0.327	0	1.004	1152
RTO day 1	0.370	0.483	0	1	1152
RTO day 2	0.287	0.453	0	1	1152
Average electricity tariffs	7.693	2.538	3.37	18.070	1152
Residential tariffs	9.218	2.738	4.36	20.330	1152
Commercial tariffs	7.977	2.337	4.15	17.120	1152
Industrial tariffs	5.705	2.133	2.24	14.990	1152
Number of outages	2.640	4.093	0	29	672
Duration of outages	5.374	13.365	0	160.144	621
Share of non-fossil fuel	0.310	0.243	0	0.965	1152
Share of nuclear	0.183	0.185	−0.007	0.808	1152
Share of solar	0.0002	0.001	0	0.020	1152
Share of hydropower	0.108	0.208	0	0.943	1152
Log income	10.282	0.306	9.495	11.047	1152
Log population	15.126	0.990	13.025	17.464	1152

Non-fossil fuel includes hydropower, wind, solar, nuclear, geothermal, and biomass

Our two-stage least squares estimates of the effect of IPP prevalence on average electricity prices are presented in Table 4. In our preferred specification with the full set of controls, a point estimate of 0.214 implies that a one standard deviation increase in IPP prevalence increases average prices by only 0.07 cents per kilowatthour. Moreover, the estimate is statistically insignificant (with standard error 0.553).

Figure 2 shows the reduced-form relationship between ISO/RTO membership and average electricity prices over time. The raw data are indeed consistent with our regression results that consumers in states belonging to ISO/RTO pay higher prices, but the difference is not triggered by their membership (and hence the increased prevalence of IPPs). Finally, similar non-results using residential, commercial, and industrial prices as dependent variables are reported in Table 5. In other words, wholesale electricity competition does not lead to cost savings for households and businesses, especially for large industrial consumers who tend to be politically more influential.

Before providing further discussion on why wholesale competition fails to reduce retail prices, we conclude this section by addressing the potential endogeneity of ISO/RTO membership. If ISO/RTO status has any effect in addition to its relationship to IPP, by facilitating competition, discouraging discriminatory practices, ensuring reliability (some of the official FERC goals), it is likely to reduce prices, increase renewables and raise reliability. In this sense, using ISO/RTO status as an instrument tends to bias against our conclusions. One may also be concerned that ISO/RTO membership as an instrument is endogenous to electricity tariffs that states with higher tariffs are more likely to introduce wholesale competition. To the extent that electricity tariffs in high-tariff states are high due to geographical factors such as resource endowment that are fixed over time, we have already captured such heterogeneity in our fixed-effects specification.

As an alternative specification to address the endogeneity problem, we consider a long-difference specification that compares changes in electricity tariffs with respect to changes in IPP prevalence, using tariffs in 1990 as an instrument.[29] The identification assumption being that, high initial tariffs induces the introduction of IPP, and that high initial tariffs themselves do not lead to faster increase in tariffs in the far future.[30] Table 6 shows that higher initial tariffs predict more growth in IPP prevalence, and that the non-results from the long-difference specification are broadly consistent with the results from the panel regression analysis.

5 Quality effects of competitive IPPs

Hazlett and Spitzer (1997) document that deregulating cable rates led to price increases driven by quality upgrades in the package (measured by the number of channels, program costs, etc.). In our case of electricity, although price competition among the traditional IOUs and the IPP entrants fail to benefit consumers, non-price competition among them may improve the quality of their services.

One measure of quality of power service is the use of clean fuel. Figure 3 plots the fraction of electricity generated from non-fossil fuel (i.e., hydroelectric, wind, solar, nuclear, geothermal, and biomass) in states that belong to some ISO/RTOs and states that do not over the period since 1990. Over the sample period, ISO/RTO states tend to use less non-fossil fuel, and they do not seem to increase the usage of non-fossil fuel faster. Results reported in Panel A of Table 7 are consistent with the figure. Once we control for unobserved heterogeneity through state and year fixed effects, the entry of IPPs does not seem to increase the usage of non-fossil fuel.

While nuclear power is a low-carbon non-fossil fuel, whether it is considered as renewable energy is a subject of debate. Panel B of Table 7 shows that greater IPP prevalence is associated with less dependence on nuclear power. Because the entry of IPPs does not increase the use of non-fossil fuel, we expect that the decrease in nuclear power dependence is associated with an increase in dependence on some renewable energy. Panels C and D of Table 7 show respectively that the entry of IPPs is associated with the use of more solar and hydropower for electricity generation.[31] Panel E shows more dependence on non-fossil fuel excluding nuclear power, consistent with the other results. In other words, although the rise of IPPs induced by deregulation fails to increase the usage of non-fossil fuel, it appears to affect the fuel mix with nuclear being replaced by solar and hydropower. If consumer considers

[29] The results are not sensitive to the choice of sample periods.

[30] To evaluate if this assumption holds as well as we can, we regress the change in tariffs from 1993 to 1995 (before the appearance of the first RTO/ISO) on the initial tariffs in 1990 and the changes in log income and population over the same period. The results are shown in Table 15 in the "Appendix", and they indeed show that initial tariffs do not predict changes in tariffs in the further future.

[31] None of the effect on other renewable fuel is significant.

Table 2 Estimates of the effect of IPP prevalence on average electricity tariffs

	Dependent variable is average electricity tariffs			
	(1)	(2)	(3)	(4)
IPP prevalence	5.263*** (0.230)	4.752*** (0.202)	1.241*** (0.150)	1.289*** (0.151)
Year FE	No	Yes	Yes	Yes
State FE	No	No	Yes	Yes
Income and population	No	No	No	Yes
Number of observations	1152	1152	1152	1152
R^2	0.460	0.553	0.922	0.929

Electricity tariffs are measured in cents per kWh. Robust standard errors in parenthesis

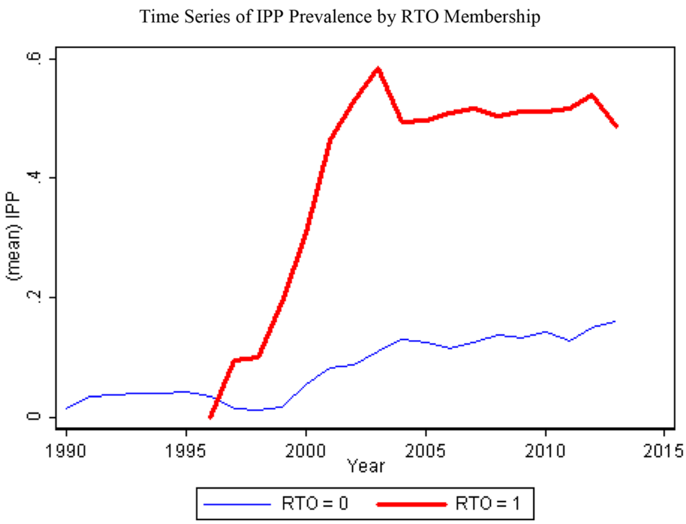

Fig. 1 Time Series of IPP Prevalence by RTO Membership

solar and hydropower to be "cleaner" than nuclear power, the rise of IPPs has indeed improved the quality of the energy mix.[32]

Another measure of quality of power service is supply reliability. Figures 4 and 5 plot respectively the number and duration of outages in states that have ISO/RTO membership and states that do not over the period 2000–2013. The raw data suggest that power supply reliability is deteriorating over time, especially among the states with RTO membership. Quantitative results regarding the effects of IPP prevalence on power supply reliability are summarized in Table 7. Panel A of Table 8 suggests a

[32] We thank one referee for pointing this out.

Table 3 Estimates of the effect of RTO membership on IPP prevalence (first stage)

	Dependent variable is IPP prevalence			
	(1)	(2)	(3)	(4)
RTO membership	0.386*** (0.016)	0.332*** (0.019)	0.163*** (0.019)	0.128*** (0.021)
Year FE	No	Yes	Yes	Yes
State FE	No	No	Yes	Yes
Income and population	No	No	No	Yes
Number of observations	1152	1152	1152	1152
F stat	552.79	28.73	42.71	42.37
R^2	0.325	0.366	0.737	0.742

Robust standard errors in parenthesis

Table 4 Two-stage least squares estimates of the effect of IPP prevalence on average electricity tariffs

	Dependent variable is average electricity tariffs			
	(1)	(2)	(3)	(4)
IPP prevalence	6.909*** (0.334)	6.739*** (0.405)	0.203 (0.416)	0.214 (0.553)
Year FE	No	Yes	Yes	Yes
State FE	No	No	Yes	Yes
Income and population	No	No	No	Yes
Number of observations	1152	1152	1152	1152
R^2	0.415	0.501	0.923	0.923

Robust standard errors in parenthesis

positive association between IPP prevalence and the number of outages. In our preferred fixed-effects two-stage least squares specification, a point estimate of 7.890 implies that a one standard deviation increase in IPP prevalence increases the number of outages by more than two times per year, although the effect is imprecisely estimated. Panel B of Table 8 shows that IPP prevalence increases the duration of outages. In particular, our preferred fixed-effects two-stage least squares specification suggests a one standard deviation increase in IPP prevalence increases the duration of outages by 30 min. Thus, non-price competition among the traditional IOUs and the new IPPs in an environment of separation of ownership and control of grids also fails to improve the reliability of services provided.[33] We do not have

[33] Note that in the IV estimation reported in Table 8, our first-stage regression has the "wrong" sign because data on reliability are only available after year 2000, when IPP prevalence in the deregulated states was about to decline. However, ISO/RTO membership is still a valid instrument for IPP prevalence because the two variables are significantly correlated.

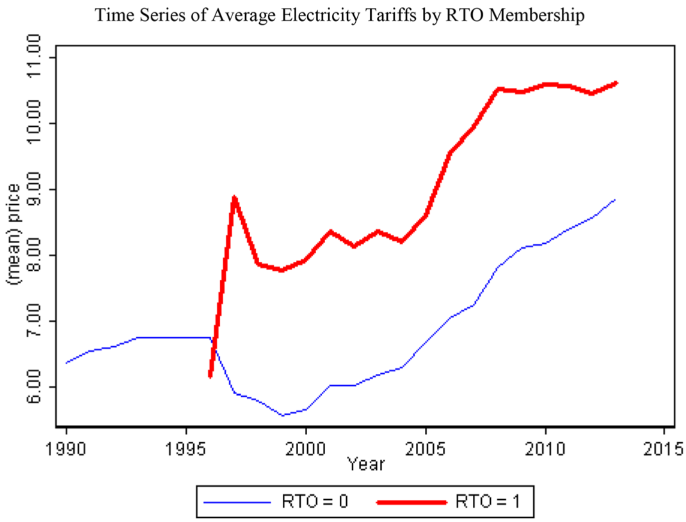

Fig. 2 Time Series of Average Electricity Tariffs by RTO Membership

the micro-level data to investigate the mechanism behind the relationship between IPPs and outage. One possible reason is that the separation of ownership might associate with an increase in ex post renegotiation costs in responding to weather emergencies.[34]

6 Potential mechanisms

Our instrumental-variable results suggest that, at least over the sample period that we have examined, the increased prevalence of IPPs did not improve energy equity measured by affordability of electricity supply. Given the expectations that IPPs face better incentives to minimize costs and to make efficient generating capacity, it is useful to better understand the mechanism behind our non-results.[35]

The earliest explanation was market power, and hence various forms of price caps have been imposed gradually on almost all centralized wholesale electricity markets to restrict the exercise of it. Another potential explanation is the lack of competition at the retail level.[36] Indeed, even in the presence of retail competition,

[34] Januszeski Forbes and Lederman (2009) argue that such vertical economies can explain the better responses to weather emergencies in the airline industry.

[35] Indeed, Fabrizio et al. (2007) showed that wholesale electricity deregulation increases nuclear operating performance. More recently, Chan et al. (2017) found that deregulation also increases efficiency of coal-fired power plants.

[36] All retail choice states (except Oregon) are located in regions where wholesale electricity prices are set through ISOs or RTOs. However, not all states with centralized wholesale markets have retail competition.

Table 5 Estimates of the effect of IPP prevalence on electricity tariffs

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Panel A: Dependent variable is residential tariffs				
IPP prevalence	5.532*** (0.244)	0.962*** (0.166)	1.016*** (0.168)	−0.108 (0.606)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.436	0.923	0.924	0.919
Panel B: Dependent variable is commercial tariffs				
IPP prevalence	4.684*** (0.213)	1.194*** (0.148)	1.227*** (0.150)	−0.154 (0.597)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.429	0.912	0.912	0.902
Panel C: Dependent variable is industrial tariffs				
IPP prevalence	4.456*** (0.210)	1.126*** (0.141)	1.273*** (0.142)	0.906* (0.504)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.466	0.904	0.904	0.904
First stage. Dependent variable is IPP prevalence				
RTO membership				0.128*** (0.021)
F stat				42.37

All tariffs are measured in cents per kWh. Robust standard errors in parenthesis

most of the deregulated states require the local utility to continue offering service under regulated “provider of last resort” (POLR) rates as a default option. Over time, however, these POLR rates have become higher than market ones and are only meant to be temporary when customers involuntarily lose their service.[37] Interestingly, when we exclude states which have wholesale but not retail competition in our sample, we find that IPP prevalence is associated with marginally significant higher prices (a point estimate of 0.906, with standard error 0.504)! A related explanation is that incumbent utilities were typically allowed to recover

[37] A related reason is the presence of search friction in the retail market (Hortaçsu et al. 2015).

Table 6 Long-difference estimates of the effect of IPP prevalence on electricity tariffs

	Average (1)	Residential (2)	Commercial (3)	Industrial (4)
Panel A: Ordinary least square estimates				
Change in IPP prevalence	0.319	0.011	−0.223	−0.544
	(0.517)	(0.638)	(0.546)	(0.536)
Number of observations	48	48	48	48
Panel B: Instrumental variable estimates				
Change in IPP prevalence	0.386	−1.123	−0.906	1.785*
	(0.816)	(0.967)	(1.045)	(1.010)
Number of observations	48	48	48	48
First-stage. Dependent variable is change in IPP prevalence				
Initial tariffs	0.112***	0.116***	0.111***	0.117***
	(0.029)	(0.026)	(0.032)	(0.033)
F stat	7.39	8.97	6.11	6.42

All tariffs are measured in cents per kWh. Change in IPP Prevalence is the difference in IPP between year 2013 and year 1996. Initial tariffs are measured in year 1990. The regression also includes differences in the log income and population over the same period. Robust standard errors in parenthesis

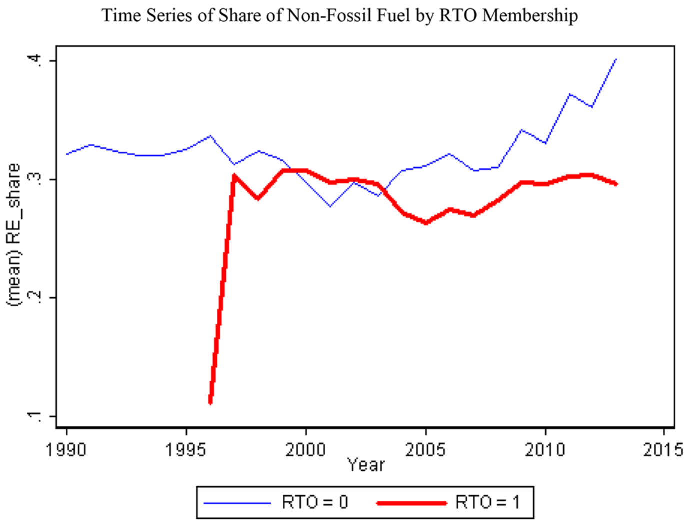

Fig. 3 Time Series of Share of Non-Fossil Fuel by RTO Membership

their stranded costs, and hence many deregulated states implemented rate freeze during the transitional period. When we exclude observations from 2002 to 2006 so that prices in the sample were less subject to this problem, we again find IPP prevalence is uncorrelated with electricity prices (a point estimate of 0.827, with standard error 0.715).

Table 7 Estimates of the effect of IPP prevalence on the share of non-fossil fuel

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Panel A: Dependent variable is share of non-fossil fuel				
IPP prevalence	0.057*** (0.021)	−0.004 (0.011)	−0.014 (0.012)	0.011 (0.067)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.006	0.958	0.959	0.959
Panel B: Dependent variable is share of nuclear power				
IPP prevalence	0.081*** (0.020)	0.003 (0.011)	−0.002 (0.012)	−0.145** (0.070)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.020	0.949	0.949	0.933
Panel C: Dependent variable is share of solar				
IPP prevalence	0.0003*** (0.0001)	0.004*** (0.001)	0.003** (0.001)	0.004*** (0.001)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.007	0.423	0.433	0.272
Panel D: Dependent variable is share of hydropower				
IPP prevalence	−0.038*** (0.012)	0.012*** (0.004)	0.007 (0.004)	0.177*** (0.049)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.004	0.981	0.981	0.962

Table 7 (continued)

	OLS	FE-OLS	FE-OLS	FE-2SLS
	(1)	(2)	(3)	(4)
Panel E: Dependent variable is share of non-fossil fuel excluding nuclear				
IPP prevalence	−0.024** (0.012)	−0.007 (0.005)	−0.013** (0.005)	0.156*** (0.051)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1152	1152	1152	1152
R^2	0.001	0.977	0.978	0.960
First stage. Dependent variable is IPP prevalence				
RTO membership				0.101*** (0.020)
F stat				44.99

Robust standard errors in parenthesis

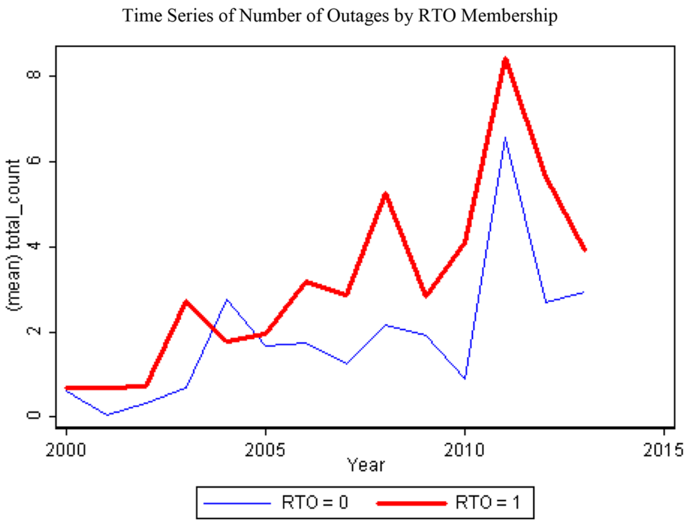

Fig. 4 Time Series of Number of Outages by RTO Membership

Much less attention has been paid to the regulatory impact on the efficiency of electricity transmission and distribution, which ultimately impact the prices of electricity. Recall that the creation of ISO/RTO was associated with "separation of ownership and control" of grids. When orders within firms are substituted by market transactions, there is no presumption that the net efficiency gain has to be positive.

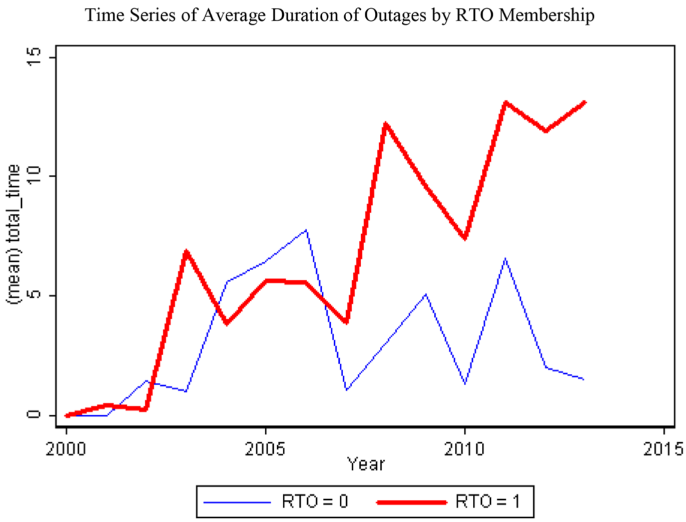

Fig. 5 Time Series of Average Duration of Outages by RTO Membership

The increased prevalence of IPPs from the late 1990s to early 2000s was partially driven by state legislation actions that mandate unbundling generation from transmission and distribution of electricity. When we restrict our sample to states that passed law requiring utilities to divest their power plant and other regulated states, Panel A of Table 9 shows that IPP prevalence significantly increases electricity prices.[38] In our preferred IV specification, a point estimate of 2.157 (with standard error 0.519) implies that a one standard deviation increase in IPP prevalence significantly increases electricity prices by 0.701 cents.[39] These results provide suggestive evidence that vertical separation not only can raise transaction costs upstream but may also reduce downstream efficiency (Kwoka et al. 2010). Alternatively, our results are also consistent with the explanation that vertical integration of firms can partially mitigate market power (Mansur 2007).

While we do not have access to microeconomic data on the IPPs, we can still test for potential heterogeneity among IPPs of different sizes. We drop the five states that require divestiture in order to focus on IPPs that tend to be larger in Panel B. The results are more or less the same as those from the full sample. (While we would like to look at results for IPPs that tend to be smaller, data from just the 5 states are not enough for us to carry out the same empirical analysis.)

Finally, transaction cost economics reminds us that markets are not costless, and centralized wholesale electricity markets are no exception (Federal Energy

[38] According to EIA (2000), "California, Connecticut, Maine, New Hampshire, and Rhode Island are examples of States with laws explicitly requiring utilities to divest their fossil and hydroelectric generation assets and, potentially, any ownership in nuclear power generating assets."

[39] If instead we exclude California, Connecticut, Maine, New Hampshire, and Rhode Island in our sample, the point estimate is 0.214, with standard error 0.553.

Table 8 Estimates of the effect of IPP prevalence on power supply reliability

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Panel A: Dependent variable is number of outages				
IPP prevalence	1.442*** (0.399)	0.028 (1.161)	−0.052 (1.184)	7.890 (7.202)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	672	672	672	672
R^2	0.017	0.542	0.548	0.521
First stage. Dependent variable is IPP prevalence				
RTO membership				−0.055*** (0.019)
F stat				182.00
Panel B: Dependent variable is duration of outages				
IPP prevalence	2.476** (1.168)	3.394 (4.301)	0.962 (4.391)	86.130** (39.867)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	642	642	642	642
R^2	0.005	0.283	0.304	0.063
First stage. Dependent variable is IPP prevalence				
RTO membership				−0.052*** (0.019)
F stat				206.49

Robust standard errors in parenthesis

Regulatory Commission, 2016). To the extent that these centralized wholesale markets exhibit economies of scale, consumers tend to suffer more the smaller the markets are. When we exclude states from the two largest RTOs (namely, PJM and MISO) from our sample, Panel C of Table 9 shows that the magnitude of our point estimate becomes more than double, although it remains statistically insignificant (a point estimate of 0.567, with standard error 0.673).[40]

It is also possible that the sharp rise in prices in California are driving the results, but Panel D of Table 9 shows that it is not the case. The results are more the less the same with or without California.[41]

[40] Restricting our sample to the states from PJM and MISO as well as other regulated states, we still obtain a positive point estimate of 0.234, with standard error 0.481. Note also that states in PJM such as Pennsylvania, New Jersey, and Maryland do not require retailers to divest their generating assets.

[41] Excluding California also does not the results for outages and non-fossil fuel. See Tables 13 and 14 in the “Appendix”.

Table 9 Estimates of the effect of IPP prevalence on average electricity tariffs (different subsamples)

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Panel A: States that passed law requiring utilities to divest their power plant and other regulated states				
IPP prevalence	6.105*** (0.359)	1.655*** (0.283)	1.521*** (0.290)	2.156*** (0.519)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	504	504	504	504
R^2	0.486	0.945	0.946	0.945
First stage. Dependent variable is IPP prevalence				
RTO membership				0.340*** (0.034)
F stat				52.37
Panel B: Exclude states that passed law requiring utilities to divest their power plant (California, Connecticut, Maine, New Hampshire, and Rhode Island)				
IPP prevalence	4.672*** (0.274)	1.100*** (0.160)	1.118*** (0.161)	−0.186 (0.622)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	1032	1032	1032	1032
R^2	0.386	0.920	0.922	0.911
First stage. Dependent variable is IPP prevalence				
RTO membership				0.116*** (0.021)
F stat				31.63
Panel C: Exclude states from the two largest RTOs				
IPP prevalence	6.643*** (0.276)	1.967*** (0.198)	2.046*** (0.203)	0.567 (0.673)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	888	888	888	888
R^2	0.519	0.940	0.941	0.935
First stage. Dependent variable is IPP prevalence				
RTO membership				0.131*** (0.020)
F stat				46.67
Panel C: Exclude California				
IPP prevalence	5.176*** (0.230)	1.247*** (0.150)	1.293*** (0.151)	−0.052 (0.575)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes

Table 9 (continued)

	OLS	FE-OLS	FE-OLS	FE-2SLS
	(1)	(2)	(3)	(4)
Number of observations	1128	1128	1128	1128
R^2	0.463	0.926	0.927	0.919
First stage. Dependent variable is IPP prevalence				
RTO membership				0.127*** (0.021)
F stat				41.73

Robust standard errors in parenthesis

Also, we do not have enough micro-level data to determine whether it's due to plant inflexibility or lost economies of vertical integration from restructuring. Though it is beyond the scope of this paper, we think our results are also consistent with the standard theory of regulation by Peltzman (1989), which implies that, unless it is associated with a decline in service quality, deregulation does not guarantee significant price reduction because endogenous deregulation is triggered by the diminishing gap between regulated equilibrium and unregulated one. In other words, deregulators can deregulate industries in which being regulated is no longer important.[42] Another interpretation is that "deregulation" can be reinterpreted as "a threat of reregulation."[43] In other words, regulators can reregulate entry and price to protect and favor the economic interests of some incumbent producers and entrants.

The falling share of nuclear power and the rising share of solar and hydropower associated with the increased prevalence of IPPs can perhaps be explained by the origins of deregulation—"overinvestment" in nuclear power plants in an environment of unanticipated tight safety standards and cheap natural gas.[44] Higher deadweight losses associated with suboptimal fuel mix for power generation could be an additional reason for deregulation.[45] Nonetheless, however large the efficiency gains among some individual power plants, our results on electricity market performances indicate that these gains are either captured by upstream producers or dissipated through additional costs of power transmission and distribution.

[42] Notice that this implication implies asymmetric effects of endogenous regulation and deregulation, because prices are expected to go up in the former case.

[43] White (1996) observed that "in no state entertaining electric utility regulatory reforms have regulators offered to withdraw their authority to intervene with the visible hand should market forces fail to perform in a suitably equitable fashion."

[44] A number of studies have discussed that electricity deregulation had its origins in overinvestment in nuclear. For example, Weare (2003) notes that "In the early 1990s, interest in restructuring the California electricity sector was spurred by the high cost of electricity. In 1995, because of expensive investments in nuclear power and high-priced contracts for QF power, California consumers paid the highest rates in the western continental United States."

[45] See Becker (1983) for his analysis of interest group competition where deadweight losses are a constraint on inefficient regulation.

Table 10 Potential mechanisms behind the results and possible empirical tests

Potential mechanisms	Empirical Findings: No effects on prices, less share on nuclear and more on other renewables, and less reliable energy supply
Lack of retail competition	*Our Test* We exclude states which have wholesale but not retail competition, and results remain the same, with weak evidence that prices are actually higher. Our test contradicts with this mechanism *Other Possible Tests* With microeconomic data on the number of firms at the retail level, and the entries and exits of them, we could directly measure the effects of retail competition on prices
Stranded cost recovery	*Our Test* We exclude observations during the transitional period from 2002 to 2006, during which the regulated states implemented rate freeze. We again find no results, suggesting that this mechanism is not important *Other Possible Tests* With microeconomic data on the incumbent status of individual IPPs, we could directly measure rate changes from IPPs that were not affected by rate freeze
Loss of economies of vertical integration	*Our Test* When we restrict the sample to states that passed law requiring utilities to divest their power plants and other regulated states, IPPs show stronger positive effect on prices, suggesting that there is loss of economies. The less reliable energy supply is also possibly caused by the higher transaction cost due to the lack of vertical integration *Other Possible Tests* With microeconomic data on utilities that were required to divest versus those they were not, this mechanism could be tested by the method of difference-in-difference between these two types of utilities
Economies of scale in wholesale markets	*Our Test* We exclude states from the two largest RTOs, and results show that the coefficients double in size though still statistically insignificant, weakly supporting this mechanism *Other Possible Tests* With microeconomic data on utilities that were required to divest versus those they were not, this mechanism could be tested by the method of difference-in-difference between these two types of utilities
Regulatory capture	*Our Test* We have discussed the case of Enron *Other Possible Tests* Ideally we could have looked at the lobbying efforts of individual utilities, and if they are publicly listed, looked at their stock prices after deregulation
Peltzman's theory of regulation	*Our Test* Our results on the fuel mix are consistent with its prediction *Other Possible Tests* To see if there was lobbying for the consumers, we could have looked at how environmental group behaved before and after deregulation

Finally we would like to mention that, due to the lack of data, our results are sometimes only suggestive and we are not able to directly test all possible mechanisms behind our results. To give the readers a clear picture of the forces that might be at work, we have listed the possible mechanisms, what we have done with our data, and what ideally could have been if done if we had more data in Table 10.[46]

7 Conclusion

In this paper, we revisit Stigler and Friedland's (1962) seminal paper by examining how competitive generation caused by deregulation affects prices, sustainability, and reliability in the wholesale electricity industry. We find that IPP prevalence, our measure of competition, does not have a statistically significant relationship with prices, increases the share of sustainable energy sources (use more solar and hydropower but less nuclear power), and reduces reliability of energy supply. Our results are robust to various specifications.

As mentioned in Table 10, more data are needed to conclusively differentiate some of the possible mechanisms behind our results. This paper is only the first step towards understanding the economics behind the deregulation of the electricity markets.

[46] We thank one referee for this suggestion.

Appendix

See Tables 11, 12, 13, 14 and 15.

Table 11 RTO/ISO membership

State	Significant wholesale market operations began (Lenard and McGonegal 2008)	RTO or ISO status starting (included only if a significant area is served)
Alabama	–	–
Alaska	–	–
Arizona	–	–
Arkansas	2007	2004
California	1998	1998
Colorado	–	–
Connecticut	1999	1997
Delaware	1998	1997
Florida	–	–
Georgia	–	–
Hawaii	–	–
Idaho	–	–
Illinois	1998	1997
Indiana	2005	1998
Iowa	2005	1998
Kansas	2007	2004
Kentucky	*2013*	2013
Louisiana	2007	2004
Maine	1999	1997
Maryland	1998	1997
Massachusetts	1999	1997
Michigan	2005	1998
Minnesota	2005	1998
Mississippi	*2013*	2013
Missouri	*2013*	2013
Montana	–	–
Nebraska	*2008*	2008
Nevada	–	–
New Hampshire	1999	1997
New Jersey	1998	1997
New Mexico	2007	2004
New York	1999	1999
North Carolina	–	–
North Dakota	2005	1998
Ohio	1998	1997
Oklahoma	2007	2004
Oregon	–	–

Table 11 (continued)

State	Significant wholesale market operations began (Lenard and McGonegal 2008)	RTO or ISO status starting (included only if a significant area is served)
Pennsylvania	1998	1997
Rhode Island	–	1997
South Carolina	–	–
South Dakota	–	–
Tennessee	–	–
Texas	2001	1996
Utah	–	–
Vermont	1999	1997
Virginia	2005	2005
Washington	–	–
West Virginia	2005	2005
Wisconsin	2005	1998
Wyoming	–	–

The first variable is defined as in Lenard and McGonegal (2008), with a few updates (in italics) for states that changed status after 2006. The second variable is defined by the first year of a switch to RTO or ISO status, and only if the state is significantly covered

Table 12 Summary statistics for different subsamples

Panel A: RTO day 1 = 1					
IPP prevalence	0.452	0.401	0	1.004	426
RTO day 1	1	0	1	1	426
RTO day 2	0.777	0.417	0	1	426
Average electricity tariffs	9.373	2.890	5.04	18.070	426
Residential tariffs	11.125	2.964	6.21	20.330	426
Commercial tariffs	9.465	2.645	5.29	17.120	426
Industrial tariffs	7.052	2.508	3.71	14.990	426
Number of outages	3.394	4.463	0	25	371
Duration of outages	7.569	15.896	0	160.144	350
Share of non-fossil fuel	0.290	0.219	0	0.949	426
Share of nuclear	0.216	0.199	− 0.007	0.808	426
Share of solar	0.0003	0.001	0	0.019	426
Share of hydropower	0.046	0.070	0	0.353	426
Log income	10.515	0.203	10.013	11.047	426
Log population	15.274	1.099	13.300	17.464	426
Panel B: RTO day 1 = 0					
IPP prevalence	0.067	0.142	0	0.987	726
RTO day 1	0	0	0	0	726
RTO day 2	0	0	0	0	726
Average electricity tariffs	6.707	1.673	3.37	11.720	726
Residential tariffs	8.100	1.834	4.36	14.120	726

Table 12 continued

Commercial tariffs	7.104	1.582	4.15	12.130	726
Industrial tariffs	4.915	1.359	2.24	9.560	726
Number of outages	1.711	3.368	0	29	301
Duration of outages	3.157	9.125	0	68.790	292
Share of non-fossil fuel	0.321	0.255	0	0.965	726
Share of nuclear	0.164	0.174	−0.001	0.768	726
Share of solar	0.0001	0.001	0	0.020	726
Share of hydropower	0.145	0.243	0	0.943	726
Log income	10.145	0.272	9.495	10.862	726
Log population	15.040	0.910	13.025	17.296	726

Non-fossil fuel includes hydropower, wind, solar, nuclear, geothermal, and biomass

Table 13 Estimates of the effect of IPP prevalence on the share of non-fossil fuel (excluding California)

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Panel A: Dependent variable is share of non-fossil fuel				
IPP prevalence	0.055** (0.022)	−0.003 (0.012)	−0.015 (0.012)	0.019 (0.068)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1128	1128	1128	1128
R^2	0.005	0.959	0.960	0.959
Panel B: Dependent variable is share of nuclear power				
IPP prevalence	0.081*** (0.020)	0.003 (0.011)	−0.002 (0.012)	−0.146** (0.072)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1128	1128	1128	1128
R^2	0.020	0.949	0.950	0.934
Panel C: Dependent variable is share of solar				
IPP prevalence	0.0002*** (0.0001)	0.004*** (0.001)	0.004** (0.001)	0.004*** (0.001)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes

Table 13 (continued)

	OLS (1)	FE-OLS (2)	FE-OLS (3)	FE-2SLS (4)
Financial policies	No	No	Yes	Yes
Number of observations	1128	1128	1128	1128
R^2	0.004	0.345	0.356	0.140
Panel D: Dependent variable is share of hydropower				
IPP prevalence	−0.040*** (0.012)	0.012*** (0.004)	0.006 (0.004)	0.179*** (0.050)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1128	1128	1128	1128
R^2	0.004	0.981	0.982	0.963
Panel E: Dependent variable is share of non-fossil fuel excluding nuclear				
IPP prevalence	−0.028** (0.012)	−0.006 (0.005)	−0.013** (0.005)	0.165*** (0.053)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	Yes	Yes	Yes
Regulatory policies	No	No	Yes	Yes
Financial policies	No	No	Yes	Yes
Number of observations	1128	1128	1128	1128
R^2	0.002	0.978	0.978	0.960
First stage. Dependent variable is IPP prevalence				
RTO membership				0.101*** (0.021)
F stat				44.41

Robust standard errors in parenthesis

Table 14 Estimates of the effect of IPP prevalence on power supply reliability (excluding California)

	OLS	FE-OLS	FE-OLS	FE-2SLS
	(1)	(2)	(3)	(4)
Panel A: Dependent variable is number of outages				
IPP prevalence	1.234*** (0.392)	0.603 (1.095)	0.504 (1.120)	5.378 (6.849)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	658	658	658	658
R^2	0.015	0.495	0.500	0.488
First stage. Dependent variable is IPP prevalence				
RTO membership				– 0.055*** (0.019)
F stat				182.00
Panel B: Dependent variable is duration of outages				
IPP prevalence	2.400** (1.167)	3.910 (4.334)	1.423 (4.429)	86.142** (39.267)
Year FE	No	Yes	Yes	Yes
State FE	No	Yes	Yes	Yes
Income and population	No	No	Yes	Yes
Number of observations	635	635	635	635
R^2	0.005	0.278	0.299	0.058
First stage. Dependent variable is IPP prevalence				
RTO membership				– 0.053*** (0.018)
F stat				209.17

Robust standard errors in parenthesis

Table 15 Do initial tariffs predict electricity tariffs growth in the future?

	Ordinary least square estimates			
	Average	Residential	Commercial	Industrial
	(1)	(2)	(3)	(4)
Initial tariffs	0.034	0.053	0.021	-0.029
	(0.035)	(0.040)	(0.032)	(0.038)
Number of observations	48	48	48	48

All tariffs are measured in cents per kWh. Initial tariffs are measured in year 1990. The dependent variable is the change in tariffs from 1993 to 1995. The regression also includes differences in the log income and population over the same period. Robust standard errors in parenthesis

References

Arocena, P., Saal, D. S., & Coelli, T. (2012). Vertical and horizontal scope economies in the regulated U.S. electric power industry. *Journal of Industrial Economics, 60*(3), 434–467.

Becker, G. S. (1983). A theory of competition among pressure groups for political influence. *Quarterly Journal of Economics, 98*(3), 371–400.

Berry, S. T. (1992). Estimation of a model of entry in the airline industry. *Econometrica, 60*(4), 889–917.

Borenstein, S. (2002). The trouble with electrcity markets: understanding California's restructuring disaster. *Journal of Economic Perspectives, 16*(1), 191–211.

Borenstein, S., Bushnell, J., & Wolak, F. (1999). *Diagnosing market power in California's deregulated wholesale electricity market*. University of California Energy Institute Working Paper.

Boylan, R. T. (2016). Power to the people: Does ownership type influence electricity service? *Journal of Law and Economics, 59*(2), 441–476.

Brennan, T. J., Palmer, K. L., & Martinez, S. A. (2002). *Alternating currents: Electricity markets and public policy*. New York: Routledge.

Bresnahan, T. F., & Reiss, P. C. (1991). Entry and competition in concentrated markets. *Journal of Political Economy, 99*(5), 977–1009.

Chan, H. R., Fell, H., Lange, I., & Li, S. (2017). Efficiency and environmental impacts of electricity restructuring on coal-fired power plants. *Journal of Environmental Economics and Management, 81,* 1–18.

Domah, P., & Pollitt, M. G. (2001). The restructuring and privatisation of electricity distribution and supply businesses in England and wales: A social cost-benefit analysis. *Fiscal Studies, 22*(1), 107–146.

Electric Energy Market Competition Task Force. (2007). *Report to congress on competition in wholesale and retail markets for electric energy: Pursuant to section 1815 of the energy policy act of 2005.*

Energy Information Administration. (2000). *The changing structure of the electric power industry 2000: An update.* Office of Coal, Nuclear, Electric and Alternate Fuels. Washington, DC: Department of Energy.

Fabrizio, K. R., Rose, N. L., & Wolfram, C. D. (2007). Do markets reduce costs? Assessing the impact of regulatory restructuring on US electric generation efficiency. *American Economic Review, 97*(4), 1250–1277.

Federal Energy Regulatory Commission. (2008). *Wholesale competition in regions with organized electric markets* (*Order No. 719*).

Federal Energy Regulatory Commission. (2016). *Common metrics report: Performance metrics for regional transmission organizations, independent system operators, and individual utilities for the 2010–2014 reporting period.* Staff Report.

Gugler, K., Liebensteiner, M., & Schmitt, S. (2017). Vertical disintegration in the European electricity sector: Empirical evidence on lost synergies. *International Journal of Industrial Organization, 52,* 450–478.

Hazlett, T. W., & Spitzer, M. L. (1997). *Public policy toward cable television: The economics of rate controls.* AEI Press. Retrieved from http://www.jstor.org/stable/2937925. Accessed 1 Apr 2019.

Hogan, W. W. (2002). Electricity market restructuring: Reforms of reforms. *Journal of Regulatory Economics, 21,* 103–132.

Hortaçsu, A., Madanizadeh, S. A., & Puller, S. L. (2015). *Power to choose? An analysis of consumer inertia in the residential electricity market*. NBER Working Paper No. 20988.

Jamasb, T., Mota, R., Newbery, D., & Pollitt, M. (2005). *Electricity sector reform in developing countries: A survey of empirical evidence on determinants and performance*. Washington: World Bank.

Januszeski Forbes, S., & Lederman, M. (2009). Adaptation and vertical integration in the airline industry. *American Economic Review, 99*(5), 1831–1849.

Jarrell, G. A. (1978). The demand for state regulation of the electric utility industry. *Journal of Law and Economics, 21*(2), 269–295.

Joskow, P. I. (2000a). Deregulation and regulatory reform in the U.S. electric power sector. In S. Peltzman & C. Winston (Eds.), *Deregulation of network industries: What's next?* (pp. 113–188). Washington, DC: Brookings Institution Press and AEI.

Joskow, P. L. (2000b). Deregulation and regulatory reform in the U.S. electric power sector. In S. Peltzman & C. Winston (Eds.), *Deregulation of network industries: The next steps* (pp. 113–188). Washington, DC: Brookings Institution Press.

Joskow, P. L. (2001). California's electricity crisis. *Oxford Review of Economic Policy, 17,* 365–388.

Joskow, P. L. (2008). Lessons learned from the electricity market liberalization. *The Energy Journal, 29*(1), 9–42.
Joskow, P. L., & Rose, N. L. (1989). The effects of economic regulation. In R. Schmalensee & R. D. Willig (Eds.), *Handbook of industrial organization* (Vol. II, pp. 1449–1506). Amsterdam: North Holland.
Kasermand, D. L., & Mayo, J. W. (1991). The measurement of vertical economies and the efficient structure of the electric utility industry. *Journal of Industrial Economics, 39*(5), 483–502.
Kury, T. J. (2013). Price effects of independent transmission system operators in the United States electricity market. *Journal of Regulatory Economics, 43,* 147–167.
Kwoka, J. (2008). Restructuring the U.S. electric power sector: A review of recent studies. *Review of Industrial Organization, 32,* 165–196.
Kwoka, J., Pollitt, M., & Sergici, S. (2010). Divestiture policy and operating efficiency in U.S. electric power distribution. *Journal of Regulatory Economics, 38*(1), 86–109.
Lenard, T. M., & McGonegal, S. (2008). *Evaluating the effects of wholesale electricity restructuring*. Washington, DC: Technology Policy Institute.
Mansur, E. T. (2007). Upstream competition and vertical integration in electricity markets. *Journal of Law and Economics, V, 50*(1), 125–156.
McRae, S., & Wolak, F. (2009). Merger analysis in restructured electricity supply industries: The proposed PSEG and Exelon merger. In J. E. Kwoka & L. J. White (Eds.), *The antitrust revolution: Economics, competition and policy*. Oxford: Oxford University Press.
Meyer, R. (2012). Vertical economies and the costs of separating electricity supply—A review of theoretical and empirical literature. *The Energy Journal, 33,* 161–185.
Mulligan, C. B., & Tsui, K. K. (2016). *The upside-down economics of regulated and otherwise rigid prices*. NBER Working Paper No. 22305.
Newbery, D. (2006). Electricity liberalization in Britain and the evolution of market design. In F. P. Sioshansi & W. Pfaffenberger (Eds.), *Electricity market reform: An international perspective* (pp. 109–144). Amsterdam: Elsevier.
Peltzman, S. (1989). The economic theory of regulation after a decade of deregulation. *Brookings Papers on Economic Activity: Microeconomics*, *1989*, 1–59.
Stigler, G. J., & Friedland, C. (1962). What can regulators regulate? The case of electricity. *Journal of Law and Economics, 5,* 1–16.
Stock, J., & Yogo, M. (2005). Testing for weak instruments in linear IV regression. in *Andrews DWK Identification and Inference for Econometric Mdoels* (pp. 80–108). New York: Cambridge University Press.
Su, X. (2015). Have customers benefited from electricity retail competition? *Journal of Regulatory Economics, 47*(2), 146–182.
Taber, J., Chapman, D., & Mount, T. (2006). *Examining the effects of deregulation on retail electricity prices.* Ithaca: Cornell University Working Paper 2005–14.
Weare, C. (2003). *The California electricity crisis: Causes and policy options*. California: Public Policy Institute of California.
White, M. W. (1996). Power struggles: Explaining deregulatory reforms in electricity markets. *Brookings Papers on Economic Activity: Microeconomics*, *1996*, 201–267.
Wolfram, C. (2005). The efficiency of electricity generation in the United States after restructuring. In J. M. Griffin & S. L. Puller (Eds.), *Electricity deregulation: Choices and challenges* (pp. 227–255). Chicago: University of Chicago Press.