Research Proposal for NBER Pre-Doctoral Fellowship on Energy Economics

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The US electricity restructuring has centered on using market competition to efficiently sustain power supply. The bid-based wholesale market was hence created, opening transmission access to all power producers and organizing auctions for electricity trade. Along its practice, more designs came up, either as a complement to wholesale market, such as retail deregulation, or as a fix to its imperfection, such as capacity market. However, inadequate attention was paid to how these designs interact with wholesale market, either in popular discussions or academic research.

I am currently working on two projects that aim to examine the impacts of capacity market design and retail market policy on wholesale market efficiency. The first project examines whether the new incentive scheme on capacity market improves generators' performance in wholesale market. The second project explores whether retail deregulation brought strategic buyers into wholesale market, by exploiting retail policy variation across states in US midwest.

1 "Availability-Based versus Performance-Based Capacity Market Design in US Electricity Market"

In today's US deregulated electricity market, power plants have two main revenue sources: they can compete in daily auction-based wholesale market and get paid for electricity they produce; they can also bid in capacity market auction and receive compensation for yearly capacity obligation[1]. Capacity auction is designed to clear enough capacity to meet predicted peak load in the future schedule year. Cleared generators are compensated in exchange for their obligations to be available to supply whenever needed. In bid-based daily energy market, this obligation means generators need to bid no less than their committed amount.

Although most power plants now get large compensation from capacity market [2], there is a question about whether it truly ensures sufficient power supply. This availability-based compensation has gameable loopholes for producers: when it is not profitable to produce in energy market, generators could bid a sufficiently high offer price. Then it will not be called to produce but still counted as "available". Besides, even when the generators are unavailable, there is no penalty imposed. Market monitors at most take away the capacity payment for that unavailable hour.

[1] The main justification for capacity market compensation is, the price formation in energy market (price cap, marginal-cost-based bidding, etc.) creates gap between market price and true value of scarcity during peak hours. Thus without extra payment, the energy market cannot keep enough generators to meet peak demand since energy revenue can not recover all the costs.

[2] For example, according to its 2016 SEC 10-K report, NRG, the US largest independent power producer, makes $4469 million from energy market, and $1970 million from capacity market.

This project focuses on two neighboring electricity markets, Pennsylvania-New Jersey-Maryland Interconnection (PJM) and Midwest ISO (MISO). They are two of the seven US market operators, organizing energy and capacity market auctions in different regions. While MISO keeps running the availability-based capacity design, PJM transitioned to performance-based incentive scheme starting June 2016. Generators that commit in capacity market are now strictly assessed for their performance in energy market. During peak hours, their actual production, compared to what they commit, cannot be lower than market level, which is the ratio of metered output/committed capacity for all capacity resources. Otherwise, they will be charged extreme penalty. In 2016-2017, the penalty is $1,896/MW-hour, far higher than the capacity compensation ($134/MW-day).

This project aims to study how this new incentive scheme affects capacity market and energy market. Intuitively, the loopholes in availability-based design allow generators to maximize their capacity compensation without considering how much they actually produce in energy market. They could offer their nameplate maximum in capacity auction first, then contribute less than that in actual production by adjusting offer prices or other bidding parameters to avoid dispatch.

The performance-based design, however, will impose real capacity obligation on generators' production. To avoid under-performance penalty, they will bid more truthfully in capacity market, committing less than they used to claim. Then capacity market will clear more resources that really contribute to the peak hours. The performance assessment and penalty should also make generators less likely to offer unreasonable high prices in energy market. Instead, they will offer more production than before because now they are facing a tradeoff between withholding more to increase energy profits and producing more to get higher capacity compensation.

Data and Estimation Approach

The paper will provide empirical evidence for the predictions presented above. The primary data consist of generator-level daily offers in PJM and MISO wholesale market from 2013 to 2017, which I collected from PJM and MISO market reports. In daily energy auction, generators can offer up to 10 pairs of price and quantity, formalizing a step or piece-wise linear supply function.

I use difference-in-difference approach to estimate the effect of the new capacity design on generators' energy offers. Consistent unit ids allow me to track same generator's offers in PJM before and after the implementation of performance-based scheme, and compare them to generators in MISO, where the availability-based design remains. I also exploit the long borders between MISO and PJM and confine the comparison within the same state, so generators under different capacity designs are only compared when facing similar weather and demand conditions. Thus, the estimated effect on generators' offers is net of any time-invariant difference between the two markets and any contemporaneous changes such as fuel cost and demand.

Similar approach will be applied to capacity market analysis. As generator-level PJM capacity auction data is not publicly available, I am currently in active communication with PJM.

Initial Results

Using energy market auction bidding data, I first show the average price per mw that each generator offers in daily energy auction is significantly lower under performance-based capacity design. Figure 1 presents the trends of generators' monthly offer prices in PJM and MISO, after taking out natural gas price effects and generator fixed effects. Generators in PJM significantly lowered their offer price right after the implementation of new design in June 2016, while little change was observed for MISO during the same periods. This behavior change had direct impact

on energy prices. As shown in Figure 2, the policy change almost closed up a $10/MWh price difference between PJM and MISO market that consistently existed before June 2016.

I then use generator's offer price as dependent variable and apply the difference-in-difference approach on auction data from 2013 to 2017. As shown in Table 1, performance-based design contributes to $ 27.8/ MWh more drop in PJM generators' offer prices, compared to MISO generators. The treatment effect is even larger among peak-load situations. The effect is also much larger when not controlling for unit fixed effects. So besides the performance improvement from existing units, new commitments brought by new design further lower market generation costs.

Work in Progress

Besides capacity market data collection and analysis, future work also aims to answer the following questions: (1) As new capacity design induces both capacity price increase and energy price decrease, does it lower consumers total electricity payment? (2) Can consumer welfare and production efficiency be further improved under alternative capacity designs?

2 "Does Retail Deregulation Bring Strategic Wholesale Buyers? Evidence from Midwest Wholesale Electricity Market"

Many previous studies in US deregulated wholesale market record severe market power exercise from power producers. Generators withhold their production and drive up electricity price, especially during peak hours. One missing element in the market is demand-side response. Retail customers are mostly under fixed rate tariff and cannot see real time prices. Retail providers, traditionally regulated by state, also have no incentive to respond to high wholesale price. Under cost-of-service regulation, they can pass through all the costs to consumers. As a result, demand-side players in wholesale market are usually price-takers, rendering supply side more market power.

In this project, I examine whether retail deregulation can bring strategic buyers into wholesale electricity market. Intuitively, deregulated retailers are profit-maximizers and have incentives to minimize their wholesale procurement costs. In sequential wholesale markets, they can do that by strategically splitting their purchase between day-ahead market and spot market. Previous literature find producers with market power act similar to dynamic price discrimination, withholding more production in day-ahead market and creating higher day-ahead price than real-time price. Expecting such day-ahead price premium, competitive retailers can shift some purchase from day-ahead market to the real-time market, hence lower day-ahead price and their purchase costs.

I test this intuition using bidding data in US midwest wholesale market (MISO) from 2014 to 2015. Among 15 states covered by MISO, Illinois is retail deregulated with more than 50 competitive retailers. Exploiting the richness of hourly bidding data, I first find Illinois retailers buy significantly less load (compared to load forecasts) in day-ahead market than other states, consistent with a strategic response to systematic day-ahead price premium over $1.6/MWh in MISO. Second, I find every $1/MWh higher day-ahead price premium induces 13.3% more demand shifted to spot market in Illinois, while no such response is found in regulated regions. This shows deregulated buyers strategically split their purchase in response to changes in market prices.

I have signed a non-disclosure agreement with MISO to get detailed bidding data at individual buyer level to improve my analysis. I will also explore the welfare implications of strategic retailers in wholesale market, using structural models considering both buyers and sellers strategic biddings.

3 Graphs and Tables

Figure 1: Monthly Average Generator Offer Price in PJM and MISO

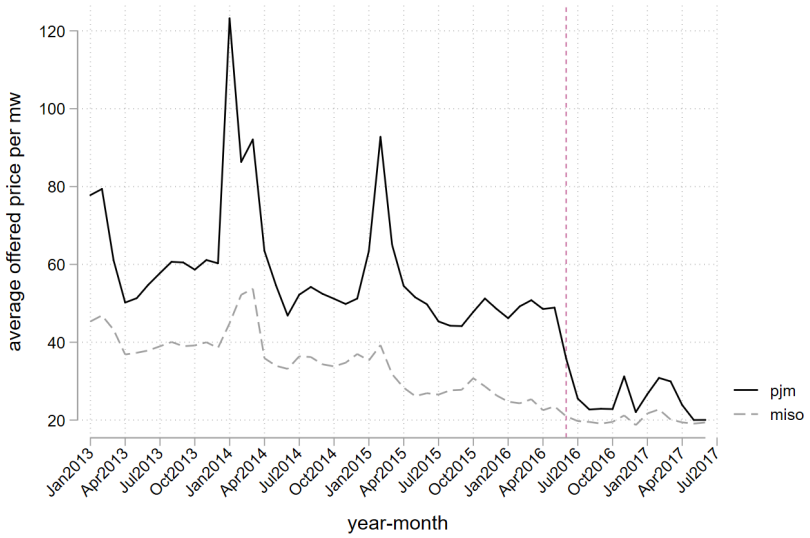


Figure 2: Monthly Average Spot Market Price in PJM and MISO

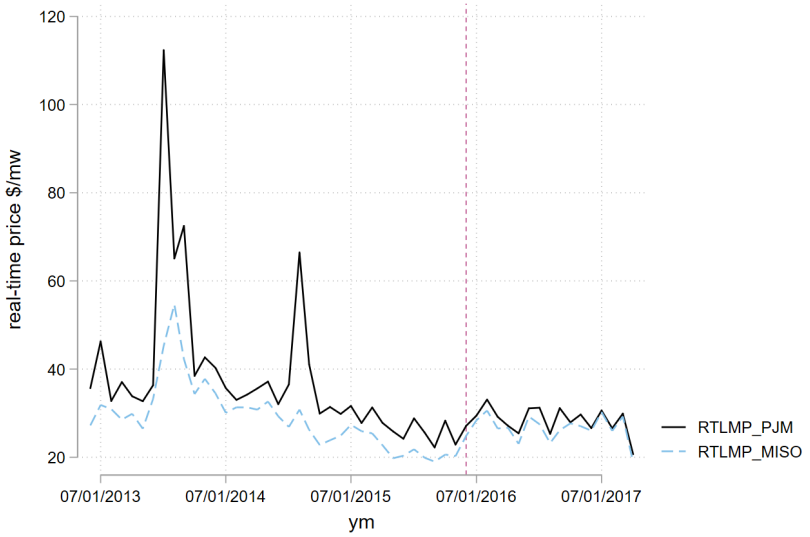


Table 1. Capacity Policy Change Effects on Generators Energy Market Offers

	All	All	Peak-load	Peak-load
	(1)	(2)	(3)	(4)
PJM	64.05***		73.50 ***	
	(5.36)		(5.60)	
After	-19.89 ***	-17.31 ***	-14.83***	-13.44 ***
	(1.84)	(1.81)	(1.81)	(1.79)
Treatment	-40.35 ***	-26.76***	-46.96***	-33.34 ***
	(6.42)	(6.73)	(3.94)	(3.65)
Month FE	✓	✓	✓	✓
Gen Unit FE		✓		✓
N	3,343,281	3,343,281	530,479	530,479

Notes: Dependent variable is each unit's average offer price in $/MWh. "After" is a dummy taking 1 for time after June 2016; "Treatment" is (PJM×After). Column (1) and (2) are DID results with full auction data from January 2013 to June 2017. Column (3) and (4) are results with peak-hour sample, which is the overlapped hours between PJM's and MISO's highest 25% load every year. Standard errors are clustered at generation unit level in parentheses. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

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FIELDS

Environmental and Energy Economics; Industrial Organization; Applied Microeconomics

EDUCATION

Ph.D. in Public Policy, University of Chicago (UChicago) 2014–2020 (Expected)
Master of Public Policy, UChicago 2012–2014
B.S. in Mathematics and Economics, Highest Honor, Southwestern University of Finance and Economics (SWUFE) 2008–2012

LANGUAGE AND COMPUTER SKILLS

English (Fluent), Mandarin Chinese (Native)
Matlab, R, Stata, Python

REFERENCES

Professor Ryan Kellogg
Harris School of Public Policy, UChicago
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RESEARCH PAPERS IN PROGRESS

Availability-Based versus Performance-Based Capacity Market Design in US Electricity Market

In US deregulated electricity market, capacity market payment is designed as additional compensation for keeping sufficient power supply in energy market during tight demand. However, such availability-based compensation has gameable loopholes, hence cannot ensure compensated generators to operate in times of greatest need. This project investigates a recent policy change to a new incentive scheme, which introduces performance assessment and extreme penalties for generators' under-performance. Using generator-level panel data, I show that this policy change improves capacity payment allocation by discouraging over-commitment. By exploiting policy variations in two neighboring markets, I also find the new scheme significantly lowered generators average offer price, leading to lower electricity costs for consumers.

Does Retail Deregulation Bring Strategic Wholesale Buyers? Evidence from Midwest Wholesale Electricity Market

Using auction data on midwest electricity market, this paper tests whether retail deregulation brought strategic buyers into wholesale electricity market. Under sequential market settings, I find retail competitive buyers strategically split their purchase between day-ahead market and spot market in order to minimize their procurement cost. Specifically, they tend to underbid more in the day-ahead market when the day-ahead price premium is higher. In contrast, no such strategic behaviors are found for the buyers in retail regulated regions. By exploiting a retail policy change which greatly increased the competitive retail consumption in Illinois, I find buyers strategic underbid indeed lower the wholesale price. This paper suggests the potential benefits from retail deregulation in improving wholesale market efficiency.

WORKING PAPER

Authoritarian Environmentalism and Public Attitudes toward the Environment in China
with Dali Yang

HONORS AND AWARDS

James Bartlett Research Fellowship, Energy Policy Institute at UChicago (EPIC) 2015–2016
Full Scholarship for Ph.D. Students, Harris School of UChicago 2014–
Excellent Graduation Thesis, SWUFE 2012
National Scholarship, Ministry of Education, China 2011–2012
National 2^{nd} Prize, China Undergraduate Mathematical Contest in Modeling (CUMCM) 2010

RESEARCH EXPERIENCE

Research Assistant to Prof. Ali Hortaçsu, Department of Economics, UChicago 2016–2017
Project: Pollution Mitigation and Productivity: Evidence from Chinese Manufacturing Firms
Project: Underwriting Competition in Indian Treasury Bond Market

Research Assistant to Prof. Koichiro Ito and Prof. James Sallee, EPIC, UChicago 2015–2016
Project: The Economics of Attribute-Based Regulation: Evidence from Fuel-Economy Standards
Project: Willingness to Pay for Clean Air: Evidence from Air Purifier Markets in China

NORC Graduate Research Fellow, National Opinion Research Center (NORC) 2013–2015
Project: Speech and Wages (RA to Prof. Jeffery Grogger)
Project: Local Labor Markets and the Evolution of Inequality (RA to Prof. Dan Black)

Project Leader, Energy Policy Lab Project, UChicago Booth School of Business 2015
White paper with two MBA students: The Potential for Adopting Hydrogen Vehicles in California

Graduate Supervisor, China Environmental Governance Research Group, UChicago Beijing Center 2014
- Supervised and guided UChicago undergraduates for their research
- Organized group trips to typical regions in China for environmental governance field studies

Survey Team Leader, China Household Finance Survey, SWUFE 2011
- Led a 8-undergraduate team in a 40-day survey covering 1 city, 5 counties, and 11 villages in Anhui Province; Interviewed respondents in their homes

PRESENTATIONS AND SEMINARS

EPIC Lunch Series, Midwest Energy Fest, Harris PhD Workshop (UChicago) 2017
Harris PhD Workshop 2016
UChicago East Asia Workshop, Harris PhD Workshop 2015

TEACHING EXPERIENCE

Advanced Microeconomics (Harris MPP core), TA to Prof. Dan Black, UChicago 2017
Environmental and Energy Economics III (Econ PhD field), TA to Prof. Koichiro Ito, UChicago 2017
Analysis of Microeconomic Data (Econ PhD field), TA to Prof. Dan Black, UChicago 2017
Statistical Methods and Applications II (Harris MPP core), TA to Prof. Bruce Meyer, UChicago 2016