Risky business: marginal switching and price volatility in PJM

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From coal to gas

Coal: traditional cheap, reliable base-load power source

- slowly going out of favor since about 2007 (fracking depressed natural gas prices, new emissions regulations)

A lot of new natural gas generation capacity has been built across the U.S. since then.

Some hypothesize that continued switch from coal to natural gas may raise volatility of wholesale power prices

- Brown and Kodaka (2014): gas price volatility, future fuel cost uncertainty
- Linn, Muehlenbachs, and Wang (2014): inframarginal supplier

The arguments

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So what? As wholesale prices become more volatile, either utilities or consumers face greater price risk, depending on the retail price structure (i.e., fixed or variable).

What do we ask?

Is there evidence in favor of these arguments?

A priori, unclear:

- bulk of new natural gas capacity built at the same time as new wind capacity, so can't separate effect of wind from effect of gas

Wind power can't be scheduled ahead of time or predicted with certainty, so more wind may mean more price volatility.

What do we contribute?

We develop and test a counter-argument:

Marginal generator sets energy component of LMP, so

- to affect prices we need to not only change shape of the *dispatched* supply curve, but also affect who is *on the margin*
  - wind enters at the bottom of the supply curve $\rightarrow$ affects dispatched supply, but not who is on the margin (unless A LOT of wind and low demand)
  - gas doesn't enter at the bottom, so doesn't obviously affect dispatched supply, but when it does, likely also affects who is on the margin

What do we contribute?

So to test whether natural gas affects price volatility, need exogenous shock that changes shape of supply curve, feeding more gas into dispatched segment, and affects who's on the margin

(1) shock should directly affect amount of gas generation on the margin

(2) should have no direct effect on amount of wind dispatched

(3) should have no direct effect on price of gas or coal

If (1)-(3) hold, then we will be able to pick up isolated effect of rising gas generation

Exogenous shock

emergency outages of coal generators

- uncorrelated with wind availability/dispatch
- uncorrelated with fuel prices
- correlated with amount of coal generation available for dispatch, and therefore amount of gas (closest substitute) dispatched, and probability of gas ending up on the margin

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We use coal outages to instrument for fraction of time that natural gas is on the margin.

1) first stage: fraction of time natural gas is on the margin, as function of emergency coal outages
2) second stage: measures of wholesale price and volatility as a function of gas generation

Data

Two main data sources

- PJM market and operations data (2014-2016)
  - hourly prices
  - fraction of time each fuel is on the margin (per hour)
  - start and end date and time of each emergency coal generator outage
- EIA form 860 data (2014-2016)
  - annual generator characteristics (technology, fuel sources, age, capacity, etc.)

Summary statistics - outages

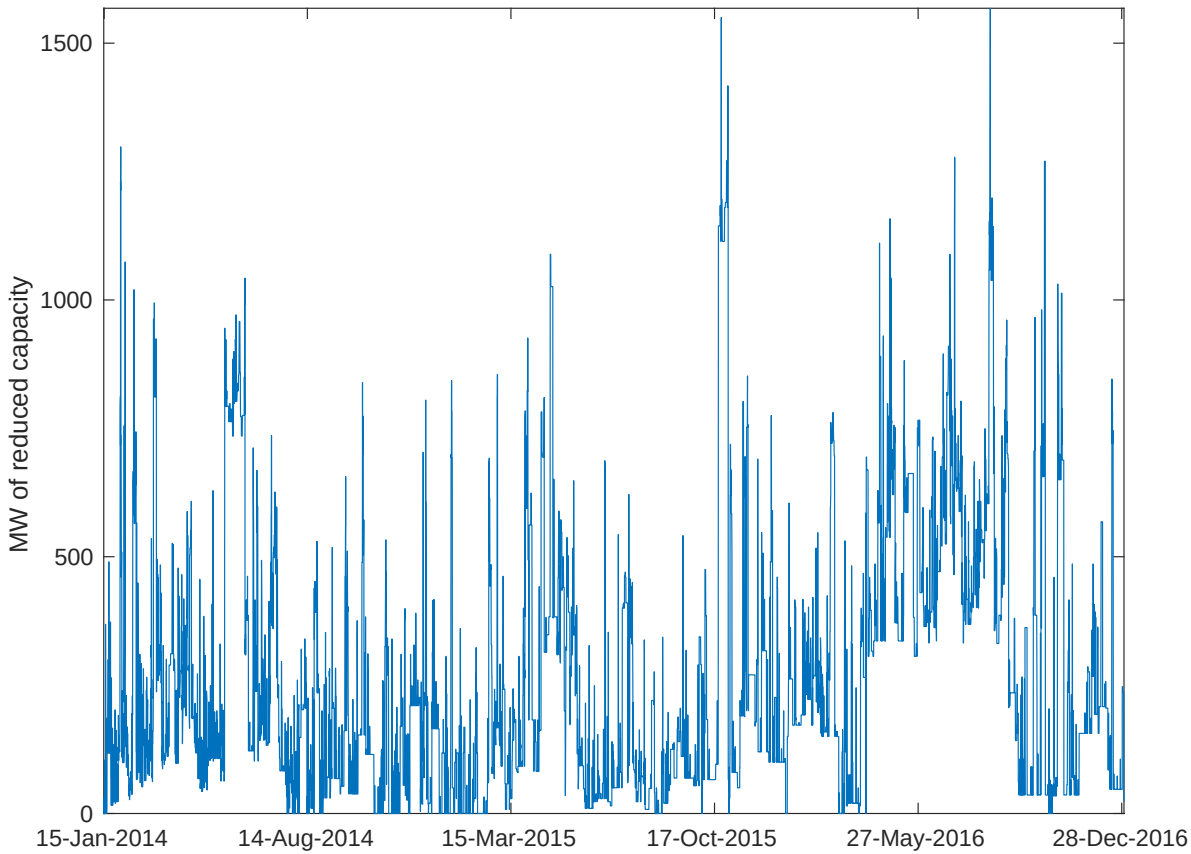
- Outages

	Instances	Operators	MW Reduction	% Reduction	Duration	Ramp Time
Coal	32169	177	125.4	0.28	2.25	209.7
Natural Gas	28915	423	59.7	0.38	2.24	76.6
Nuclear	1131	31	225.0	0.21	5.17	397.8
Oil Distillate	5459	179	43.8	0.37	4.06	74.8
Renewables	16964	113	7.6	0.30	2.65	2.5

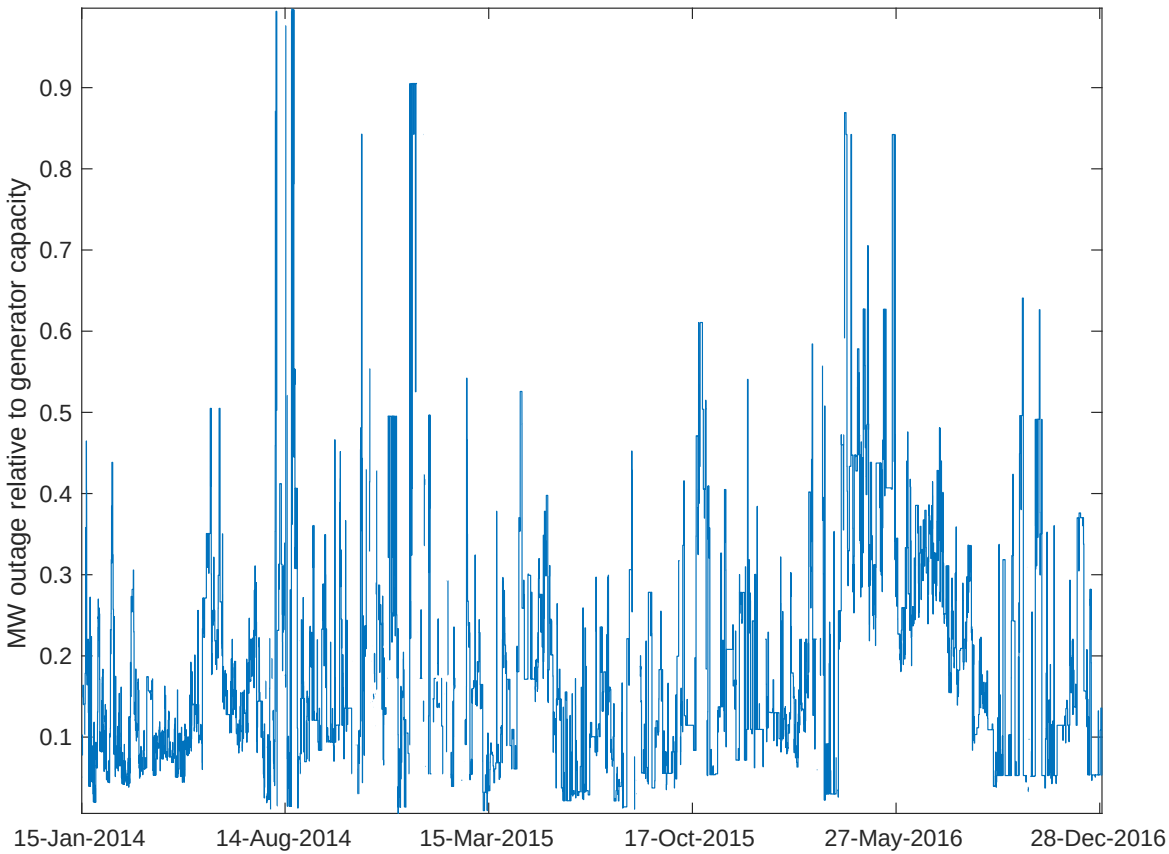
- Emergency Outages

	Instances	Operators	MW Reduction	% Reduction	Duration	Ramp Time
Coal	1884	101	82.7	0.19	1.89	251.2
Natural Gas	119	44	99.9	0.42	2.82	90.1
Nuclear	36	13	191.6	0.17	2.21	402.0
Oil Distillate	27	14	169.5	0.51	2.13	88.8
Renewables	7	5	13.7	0.61	0.56	8.1

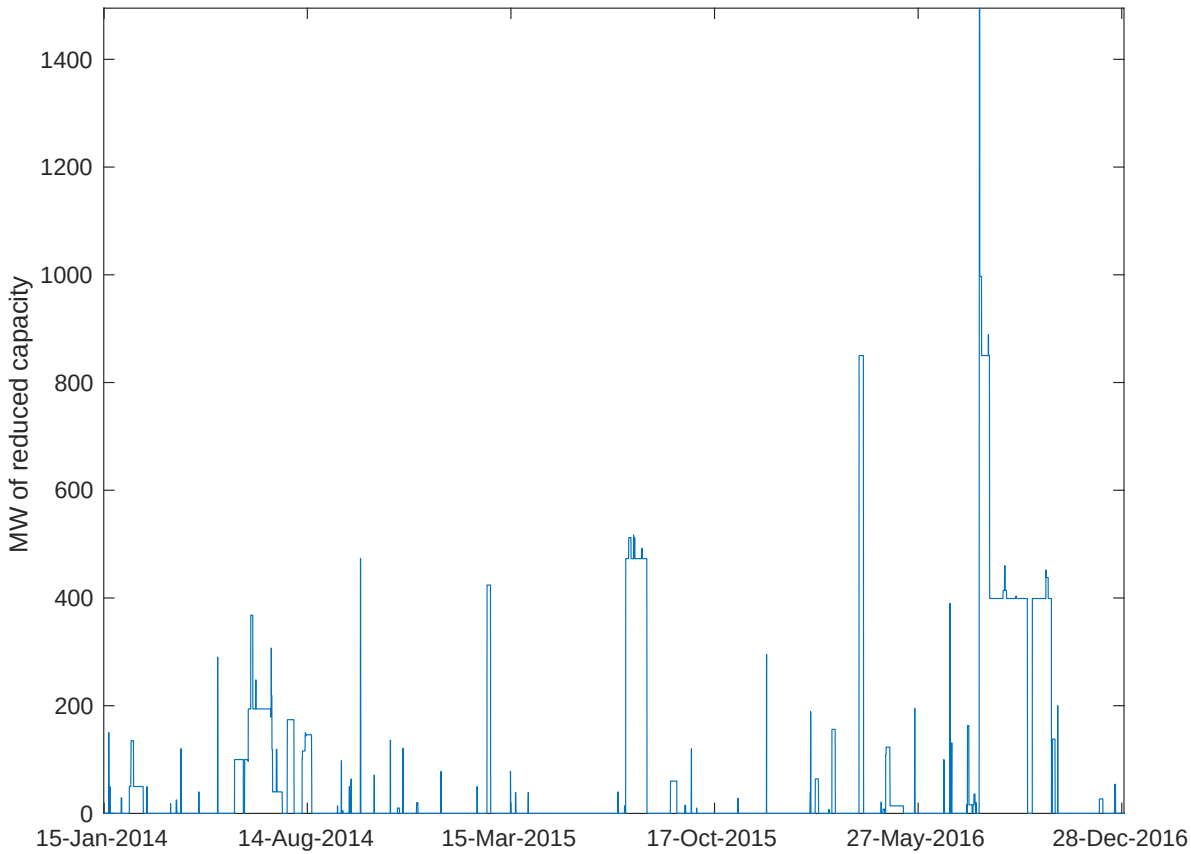
Emergency outages of coal generation over time, MWs



Emergency outages of coal generation over time, % of capacity



Emergency outages of natural gas generation over time, MWs



Changes in LMP over time

	All	2014	2015	2016
Coal				
Mean	30.06	34.05	27.47	26.23
Median	27.85	31.56	26.19	25.20
Natural Gas				
Mean	23.20	43.06	21.05	20.97
Median	21.93	27.35	22.05	20.63

The model: first stage

$$ng\ margin_t = \beta_0 + \beta_1 coal\ outages_t + \\ + \beta_2 load_t + \beta_3 real\ time\ supply_t + \beta_4 wind_t + \varepsilon_t \quad (1)$$

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Table 1: Natural gas margin percentage

	(1)	(2)
Coal outage (MW)	0.007	
	(2.40)	
Coal outage (%)		0.055
		(2.78)
Load	-0.164	-0.159
	(-5.64)	(-5.47)
Real time generation	-0.073	-0.066
	(-0.86)	(-0.78)
Wind generation	0.019	0.019
	(5.53)	(5.46)
R-squared	0.118	0.119

The model: second stage

$$price_t = \gamma_0 + \gamma_1 \widehat{ng\ margin}_t + \\ + \gamma_2 load_t + \gamma_3 real\ \ time\ \ supply_t + \gamma_4 wind_t + \eta_t \quad (2)$$

The model: second stage

$$price_t = \gamma_0 + \gamma_1 \widehat{ng\ margin_t} + \\ + \gamma_2 load_t + \gamma_3 real\ \ time\ supply_t + \gamma_4 wind_t + \eta_t \quad (2)$$

Table 2: Impact of natural gas on prices

	Price		Volatility	
	OLS	IV(1)	OLS	IV(1)
Gas on margin	3.565	-3.949	3.132	-0.504
	(4.32)	(-0.11)	(4.73)	(-0.02)
Load	42.632	41.422	16.608	16.023
	(17.25)	(6.99)	(9.29)	(3.40)
Real time generation	30.647	30.118	23.684	23.428
	(4.01)	(3.60)	(3.62)	(3.28)
Wind generation	-0.910	-0.768	-0.467	-0.398
	(-4.83)	(-1.05)	(-2.22)	(-0.69)
R-squared	0.352	0.350	0.095	0.093

Second stage results, cont.

Table 3: Impact of natural gas on prices

	Price		Volatility	
	OLS	IV(2)	OLS	IV(2)
Gas on margin	3.565	-39.730	3.132	-25.912
	(4.32)	(-1.77)	(4.73)	(-1.27)
Load	42.632	35.660	16.608	11.932
	(17.25)	(8.96)	(9.29)	(3.42)
Real time generation	30.647	27.598	23.684	21.639
	(4.01)	(3.45)	(3.62)	(3.10)
Wind generation	-0.910	-0.093	-0.467	0.081
	(-4.83)	(-0.19)	(-2.22)	(0.18)
R-squared	0.352	0.350	0.095	0.093

Next steps

So if natural gas doesn't drive price volatility, what does?

- fuel supply contracts
- policy (e.g., Mercury and Air Toxic Standards)

Thank you!
Questions? Comments?

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