The Significance of Calendar Effects in the Electricity Market

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AIEE 2016, Milan, Italy

About Me

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Purpose of Study

- What accounts for the large price swing in the electricity market
- 2 opposite cases coexisted: Negative Pricing & Peak Load Pricing
- Negative Pricing (over-supply): certain types of generators (e.g. nuclear, hydroelectric, and wind energy) pay demanders to take power instead of lowering their output due to technical and economic factors (e.g. subsidy by government)
- Peak Load Pricing (Over-demand): generate high marginal costs for the excess demand

Data

- the wholesale Pennsylvania, New Jersey and Maryland (PJM) electricity market
- Covers 13 states and Washington D.C.
- 11,574 transmission lines (Pnodes) in areas served by PJM
- Market clearing price: for each Pnode, Hourly locational marginal price (LMP) for Year 2014

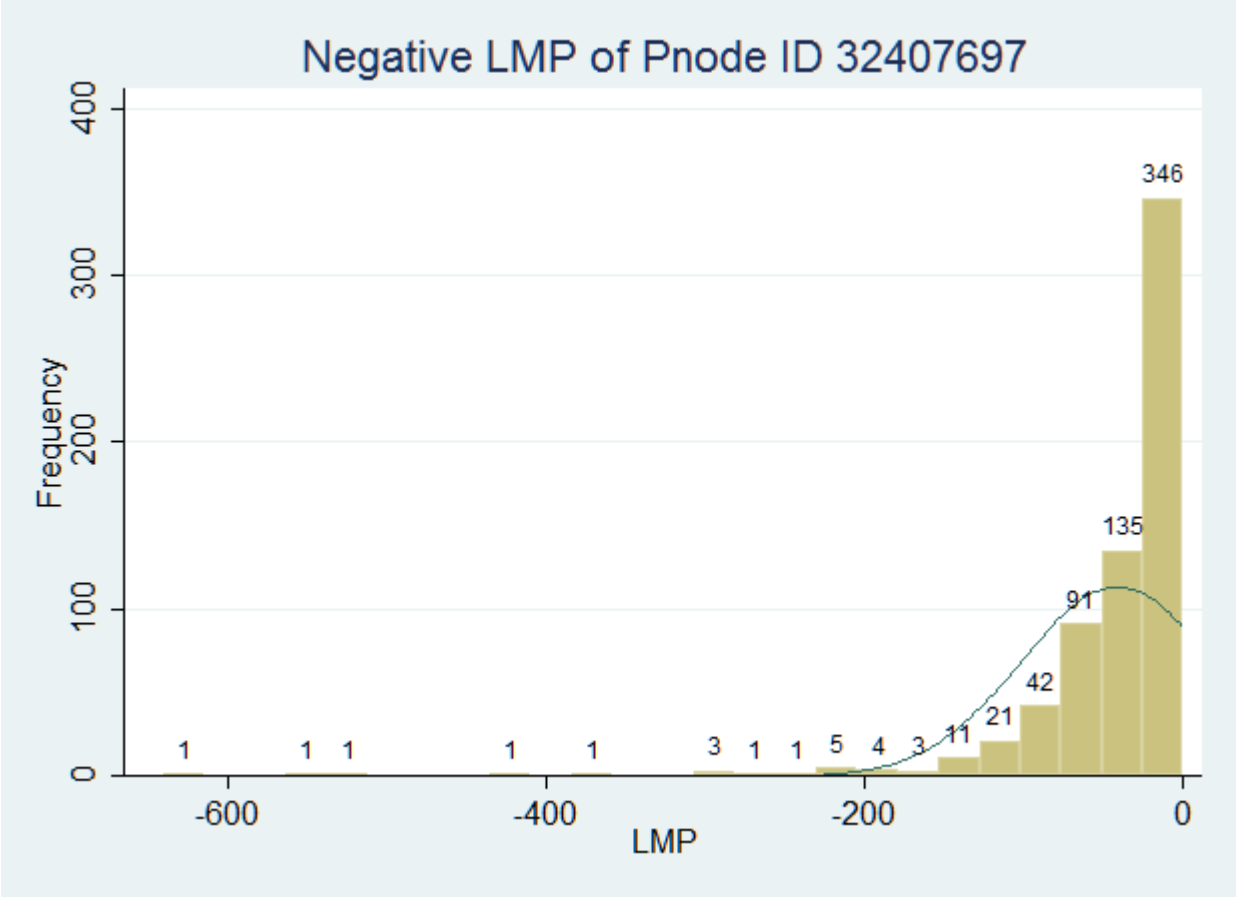
variable	Negative LMP	Peak Load LMP
Number of Occurrence	560,244	5,923,637
mean	-23.58	216.38
Std. Dev.	53.42	209.12
skewness	-11.04	4.48
kurtosis	249.01	29.88
min	-2240.30	43.02
max	0	4643.74

The Prevalence of Negative Pricing across Pnodes

- 98% of Pnodes in PJM have negative LMP records

In Pnode 32407697

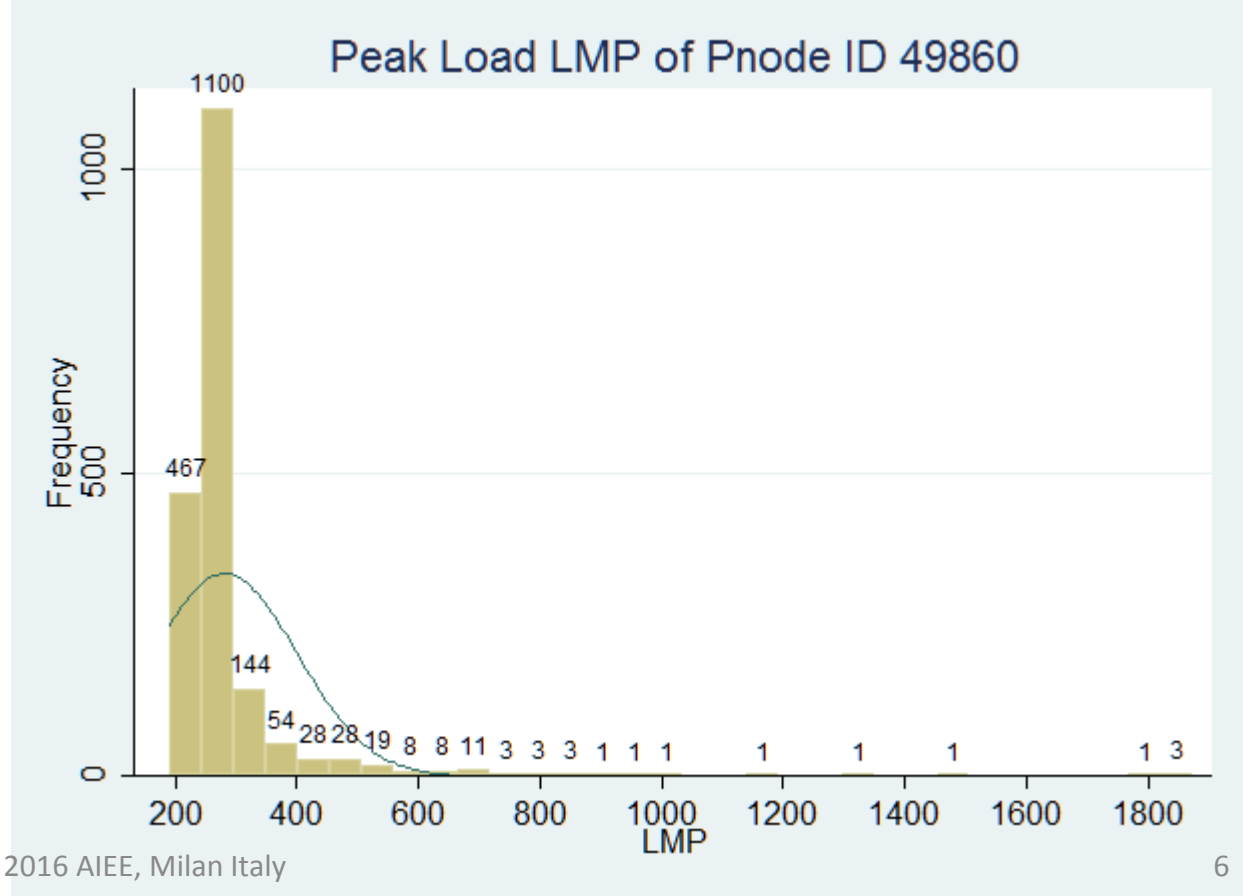
- 668 negative LMPs, 8% of the total hourly records in 2014
- Range between -$630 and 0



The Prevalence of Peak Load Pricing across Pnodes

In Pnode 49860

- 1887 Peak Load records
- Range between $190 and $1875



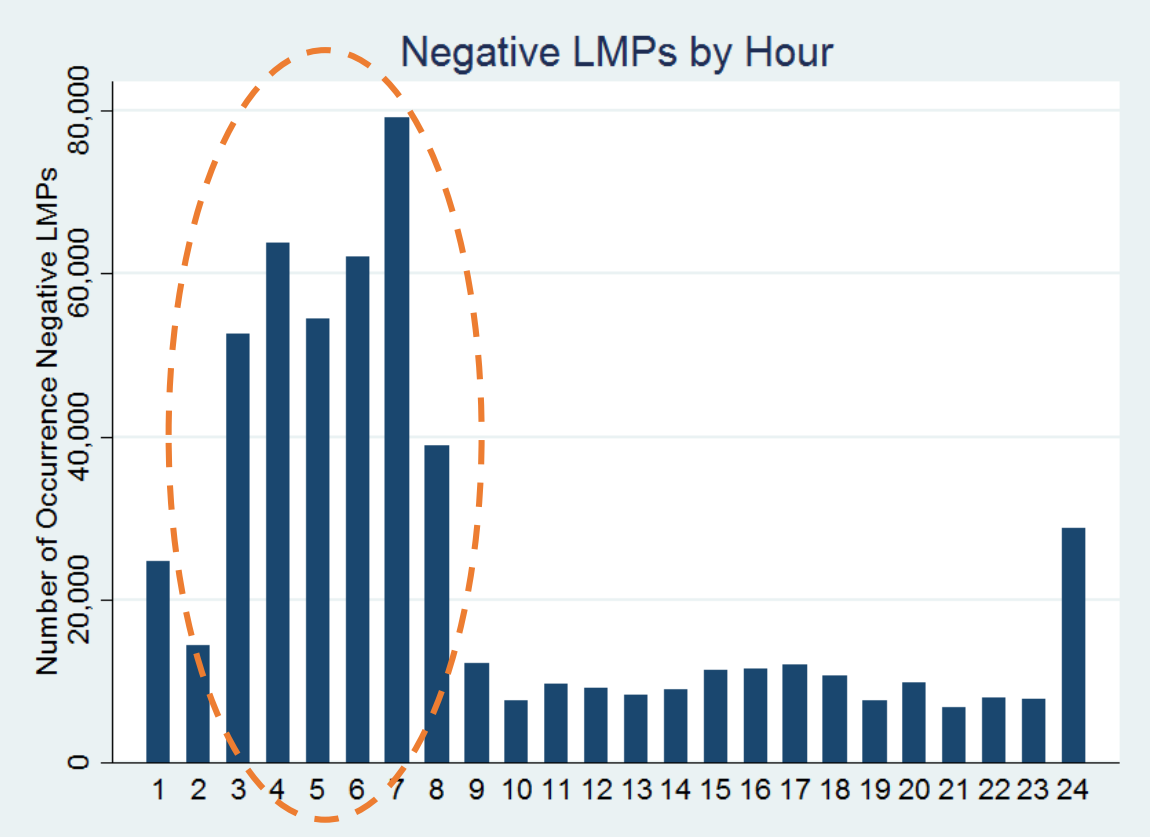
Pattern: Calendar Effects

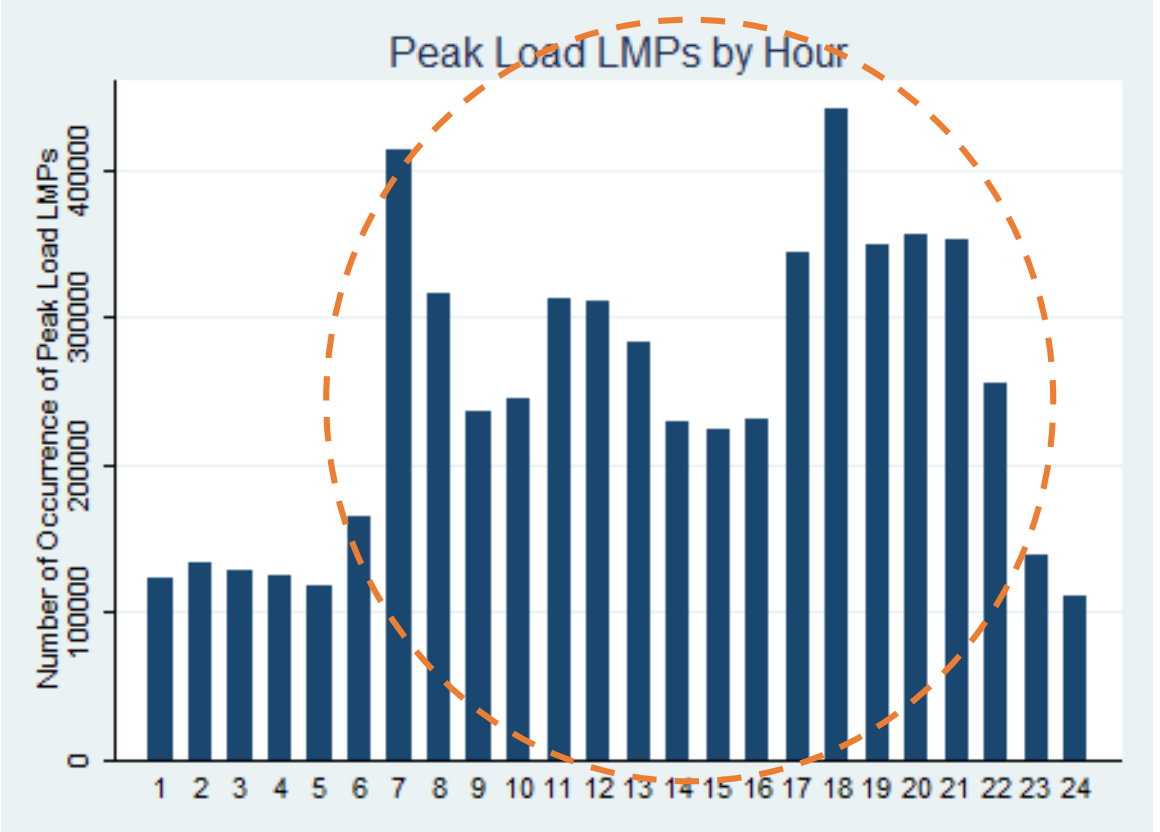
Anomalies in LMPs that relate to the calendar (e.g. hours of the day,

LMPs by Hour

Negative Pricing is prevalent at night

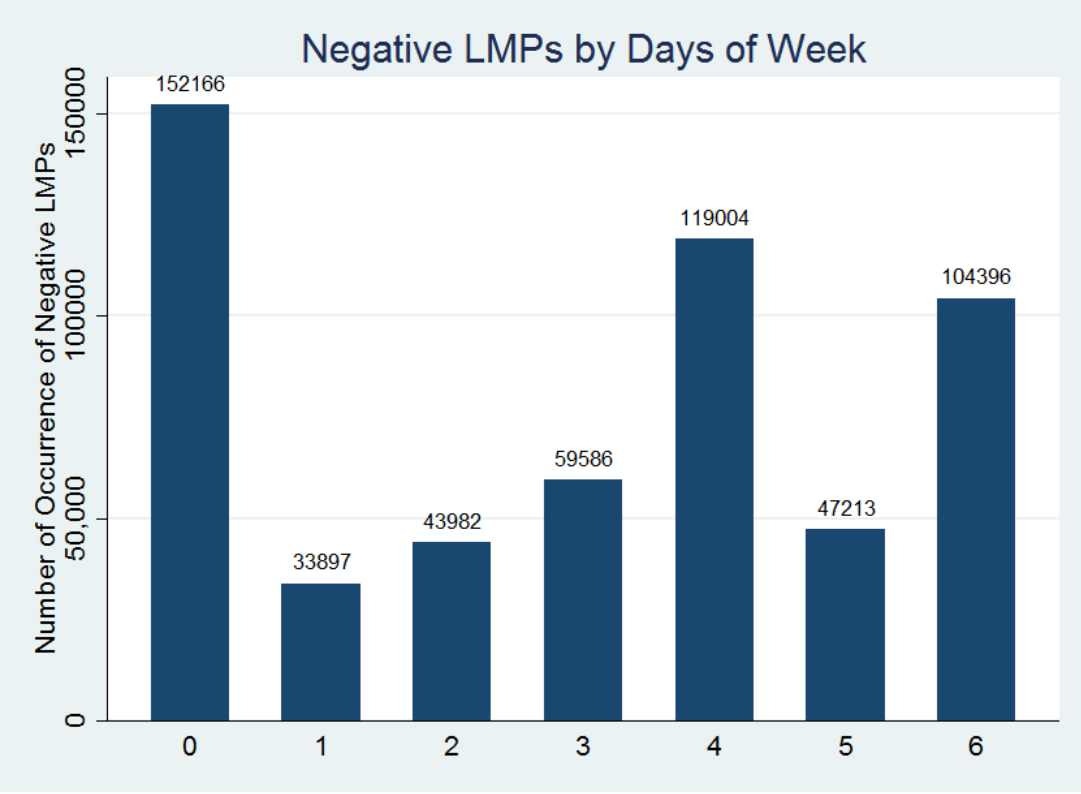
Peak Load Pricing is prevalent during the daytime

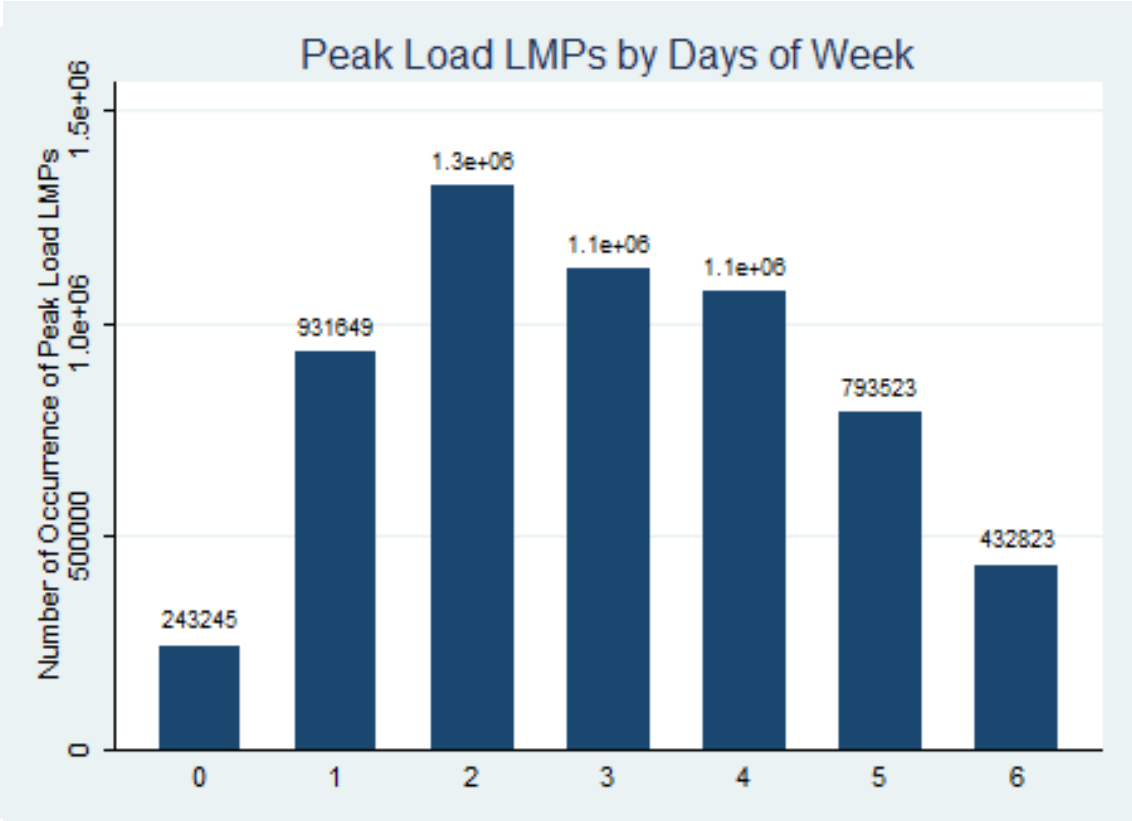




LMPs by Days of a Week

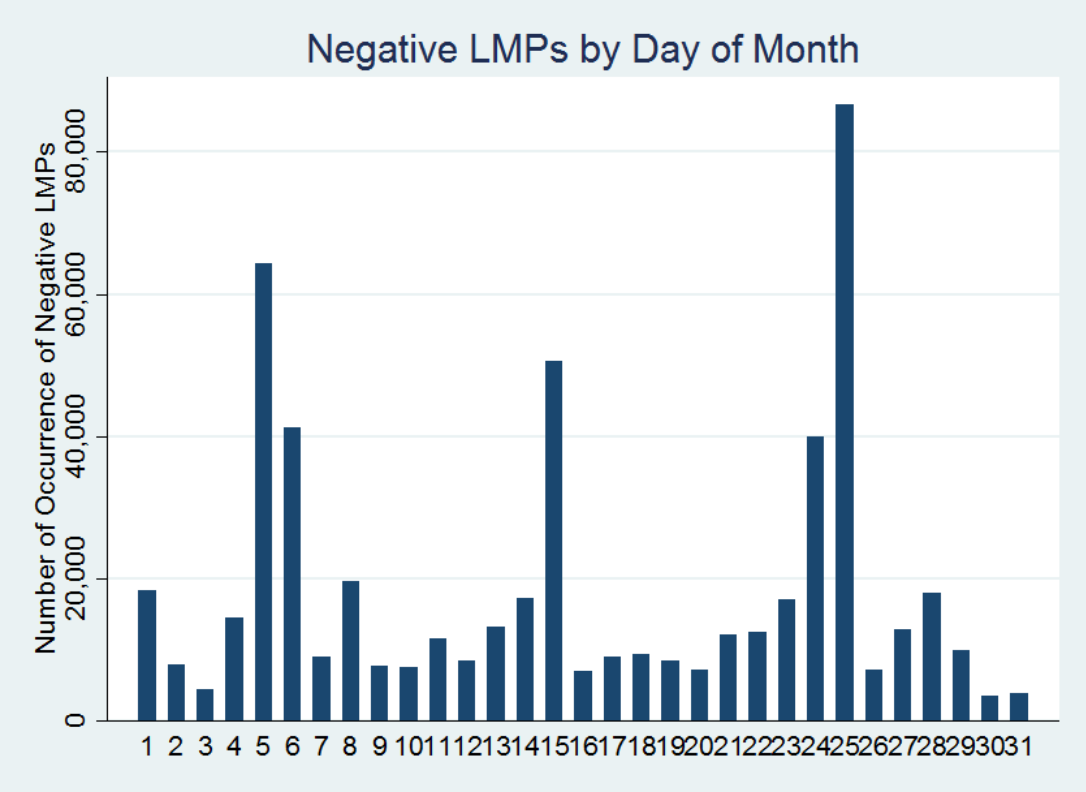
Negative Pricing: strong weekend effect
Peak Load Pricing: strong weekday effect

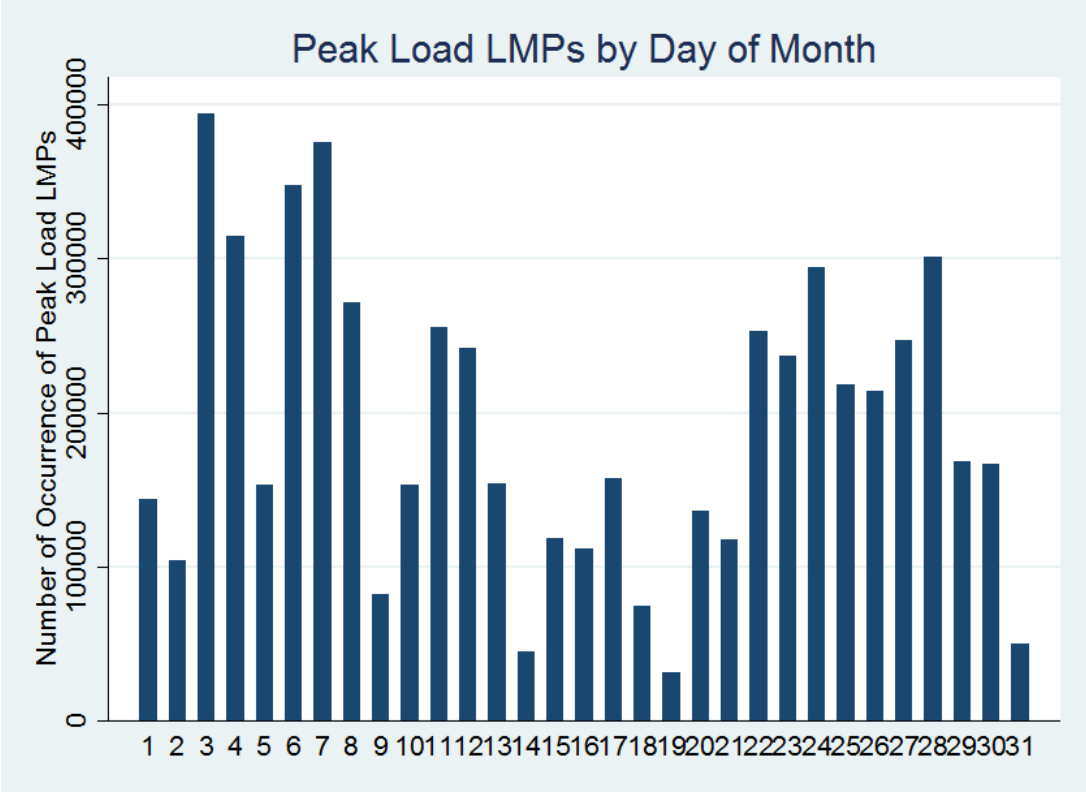




LMPs by Days of a Month

Peak Load Pricing: occurs more during the beginning and the end of a month

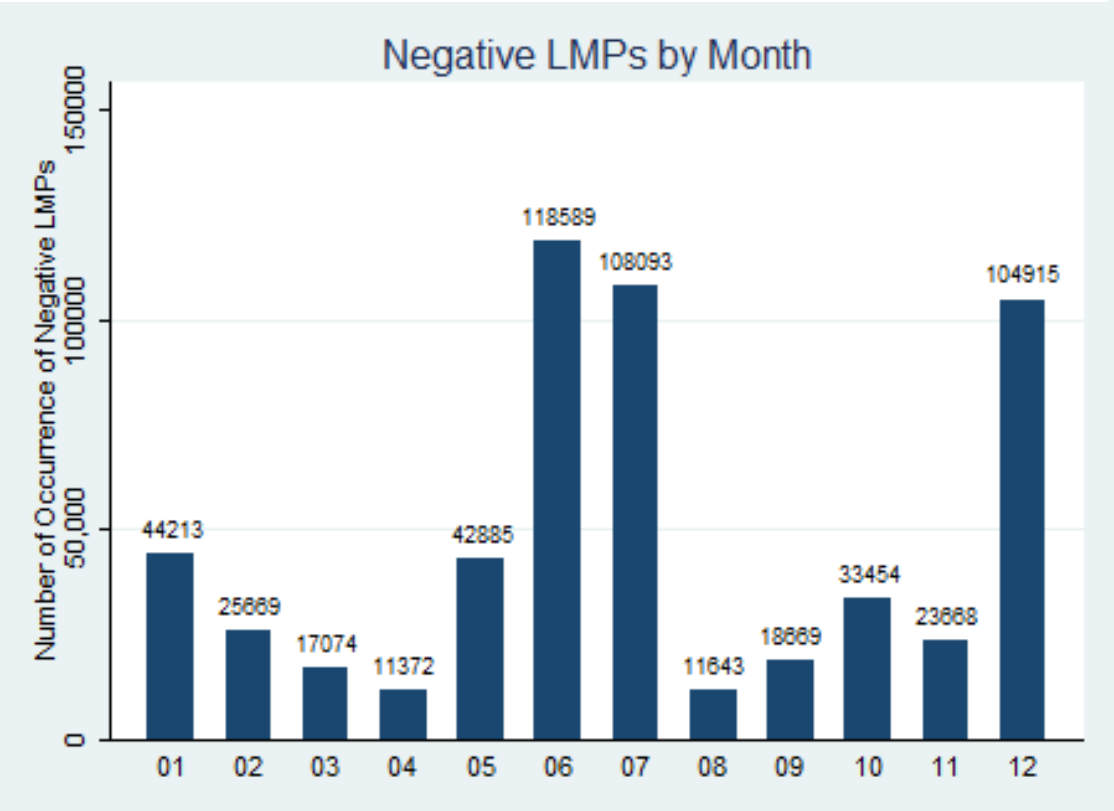


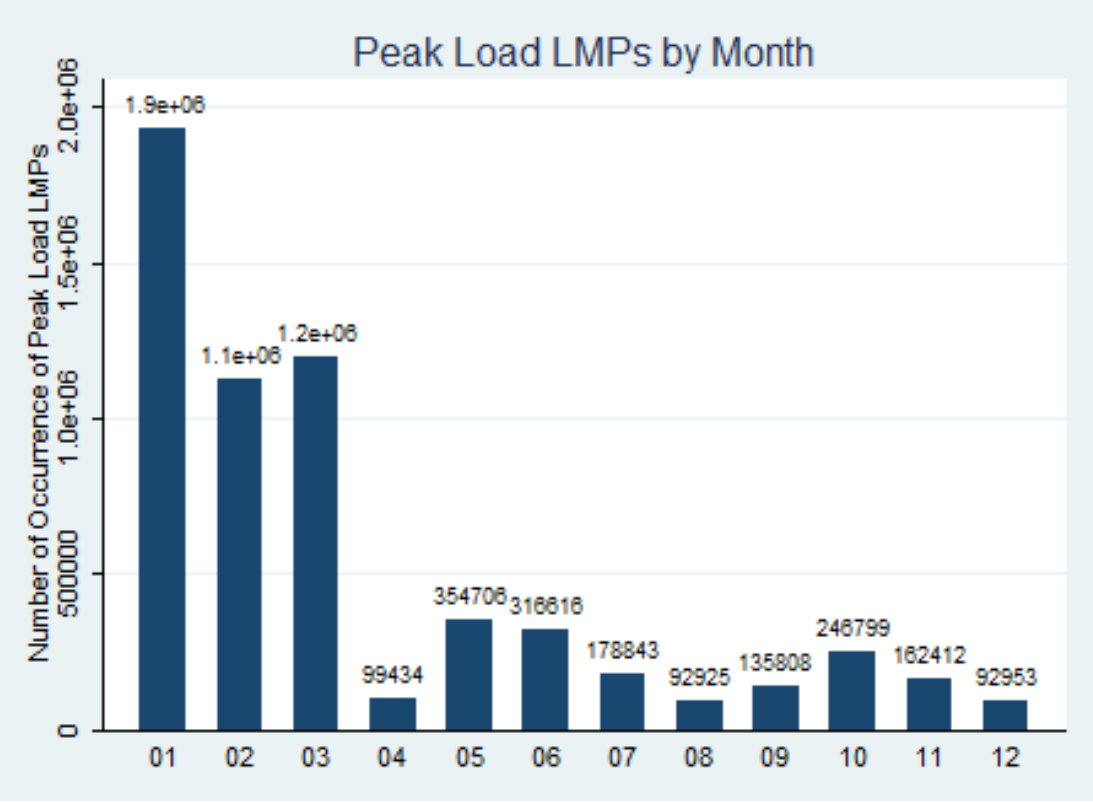


LMPs by Month

Negative Pricing: Seasonal Effect (wind, solar power energy)

Peak Load: Winter Effect





- Overlapped calendar effects between negative and peak load pricing are very few.
- Occurrence of Negative Pricing offsets the occurrence of peak load pricing.

Dominant Factor for High Volatility

Principal Component Analysis (PCA)

To construct latent common structure of factors (PC) and discover the structural meaning

For each Pnode, calculate the 13 covariates from the two groups below

Covariates	Negative LMPs	Peak Load LMPs
Percentage of Occurrence	Neg_Per	Peak_Per
mean	Neg_Mean	Peak_Mean
Std. Dev.	Neg_Std	Peak_Std
skewness	Neg_Sku	Peak_Sku
kurtosis	Neg_Kur	Peak_Kur
min	Neg_Min	Peak_Min
max		Peak_Max

Principal Component Analysis (PCA)

- We generate principal components (PCs) as linear combinations of covariates.
- The first component, PC1, explains the largest proportion (31%) of variation in the covariates. The second PC2 explains the second largest (19%) proportion…

Component	Eigenvalue	Difference	Proportion	Cumulative
PC1	4.00	1.53	31%	31%
PC2	2.47	0.34	19%	50%
PC3	2.13	0.49	16%	66%
PC4	1.64	0.63	13%	79%

Principal Component Analysis (PCA)

Different PCs will have different covariates dominated in the combination.

- In PC1, *Peak_Mean*, *Peak_Min* and *Peak_Std* are dominant covariates. PC1 represents the position and dispersion of ***peak load pricing***.
- PC2, explains the position and dispersion of ***negative LMPs***
- PC3, explains the extent of concentration of ***peak load pricing***
- PC4, explains the extent of concentration of ***negative LMPs***
- PCs related to peak load pricing have larger proportion of variation than PCs related to negative pricing.

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Principal Component Regression

- Test how the volatility across Pnodes are affected
- $STD_i = \beta_1 PC1_i + \beta_2 PC2_i + \beta_3 PC3_i + \beta_4 PC4_i + \beta_5 PC5_i + \beta_6 PC6_i$
- PC1 has the largest value (0.91).
- The **dispersion of peak load LMPs** is the foremost condition to affect the price volatility

STD_i	β	Std. Err.	t	P>t
PC1	0.91	0.02	630.83	0
PC2	0.36	0.02	251.69	0
PC3	0.03	0.03	24.05	0
PC4	0.00	0.03	-0.82	0.412
PC5	0.04	0.04	29.65	0
PC6	0.14	0.05	95.17	0

Summary

- Both negative and peak load pricing have significantly obvious calendar effects. And the occurrence of negative pricing helps offset the prevalence of peak load pricing
- For the Pnodes, peak load pricing attributes to high volatility with larger power than negative pricing.