Price Volatility in the Electricity Market

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Motivation

- The unique nature of electricity markets by comparison of financial markets
  - Non-storable power
  - Non-stopped market operation
- Price volatility: How does it form?
  - inequilibrium of supply & demand
  - Negative Pricing (over-supply) & Peak Load Pricing (over-demand)
  - Forward premium: difference between forward and spot prices

Purpose of Study

- We conduct an empirical analysis in the PJM electricity market
- Using a High-Frequency dataset including 12,000 transmission lines
- Hourly day-ahead forward prices and spot prices

- We observe significant negative and peak load pricing as signals of high price volatility, and the spot price has significant calendar anomalies.
- We find the significant forward premia in the electricity prices across transmission lines. They are positively related to the congestion premium, and negatively related to the transmission loss premium. The forward premia have significance across hours.

Data

- the wholesale Pennsylvania, New Jersey and Maryland (PJM) electricity market
- Covers 13 states and Washington D.C. in USA
- 12,000 transmission lines (Pnodes) in areas served by PJM
- Market clearing price: for each Pnode, Hourly locational marginal price (LMP) between 2013-16

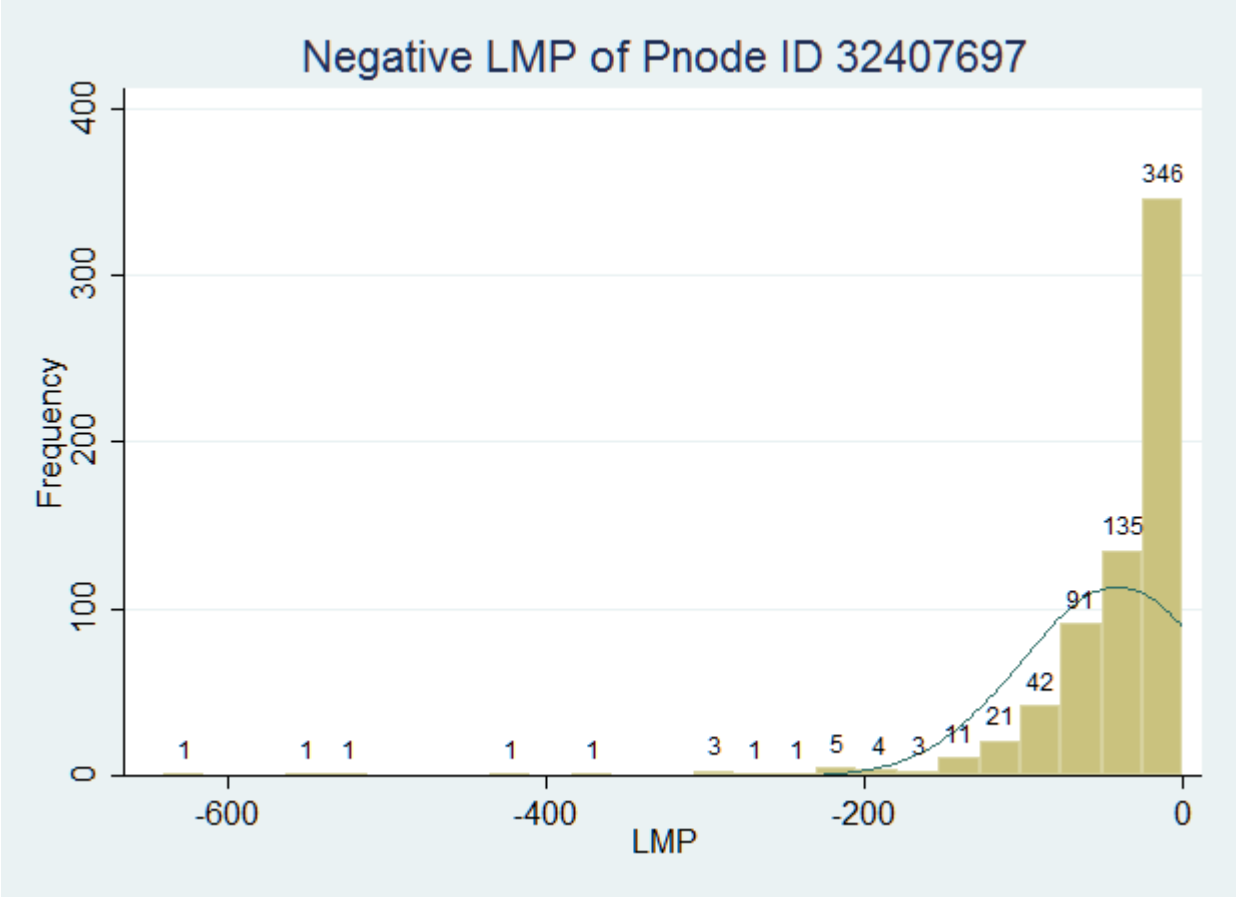
The Prevalence of Negative and Spike Price

The Prevalence of Negative Pricing across Pnodes

- 98% of Pnodes in PJM have negative LMP records

In Pnode 32407697

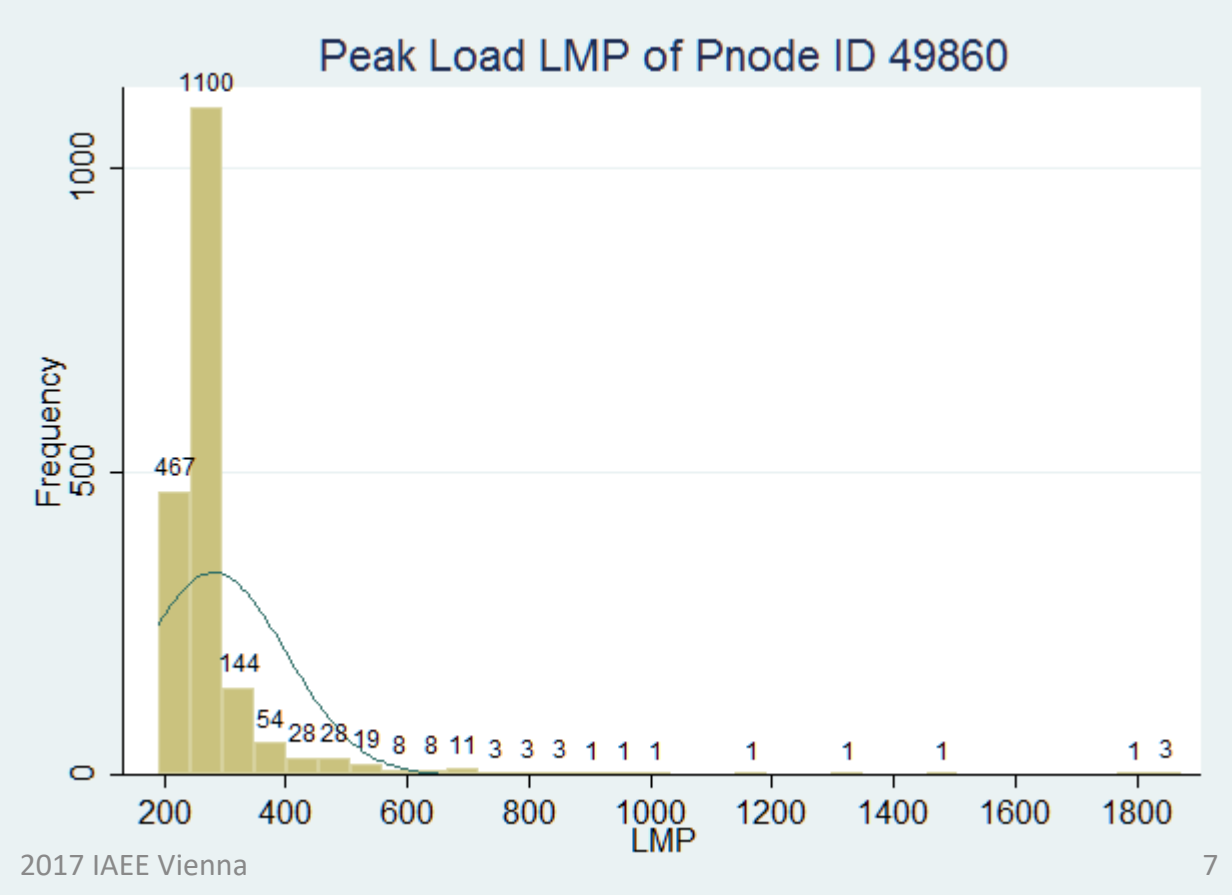
- 668 negative LMPs, 8% of the total hourly records in 2014
- Range between -$630 and 0



The Prevalence of Spike Pricing across Pnodes

In Pnode 49860

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



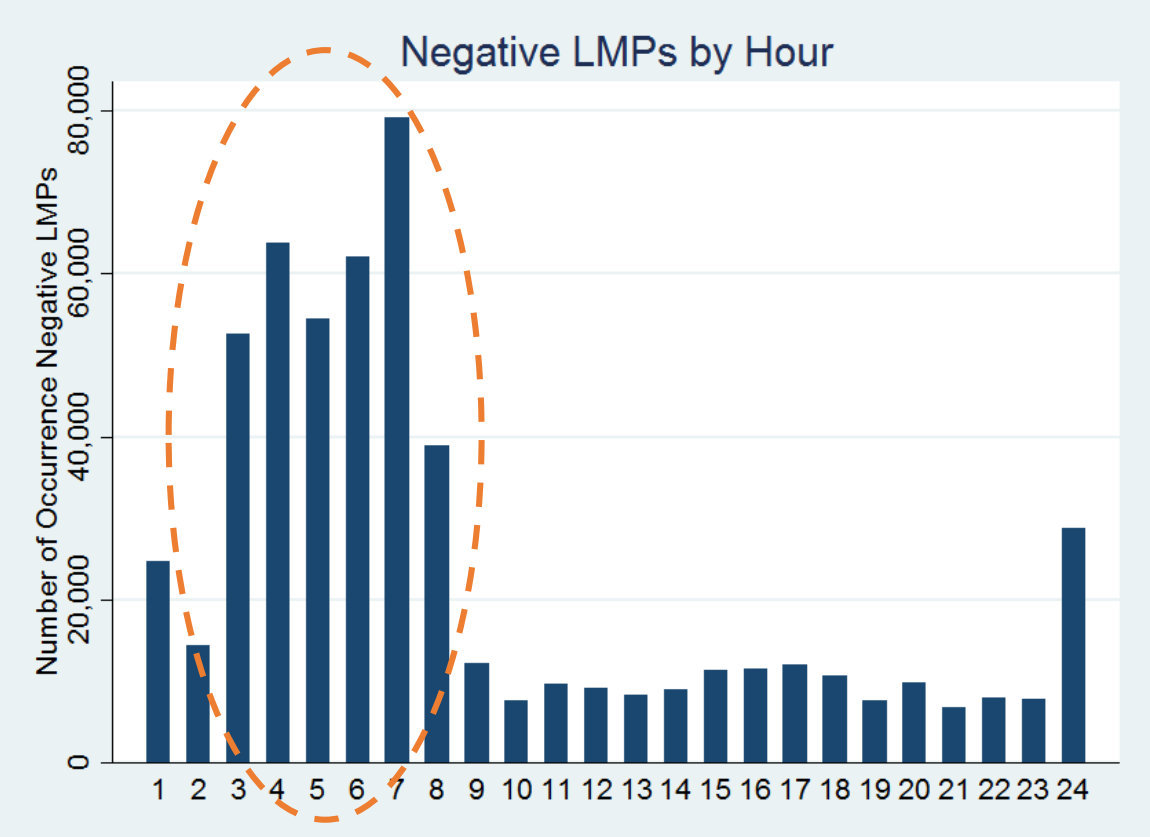
Pattern: Calendar Effects

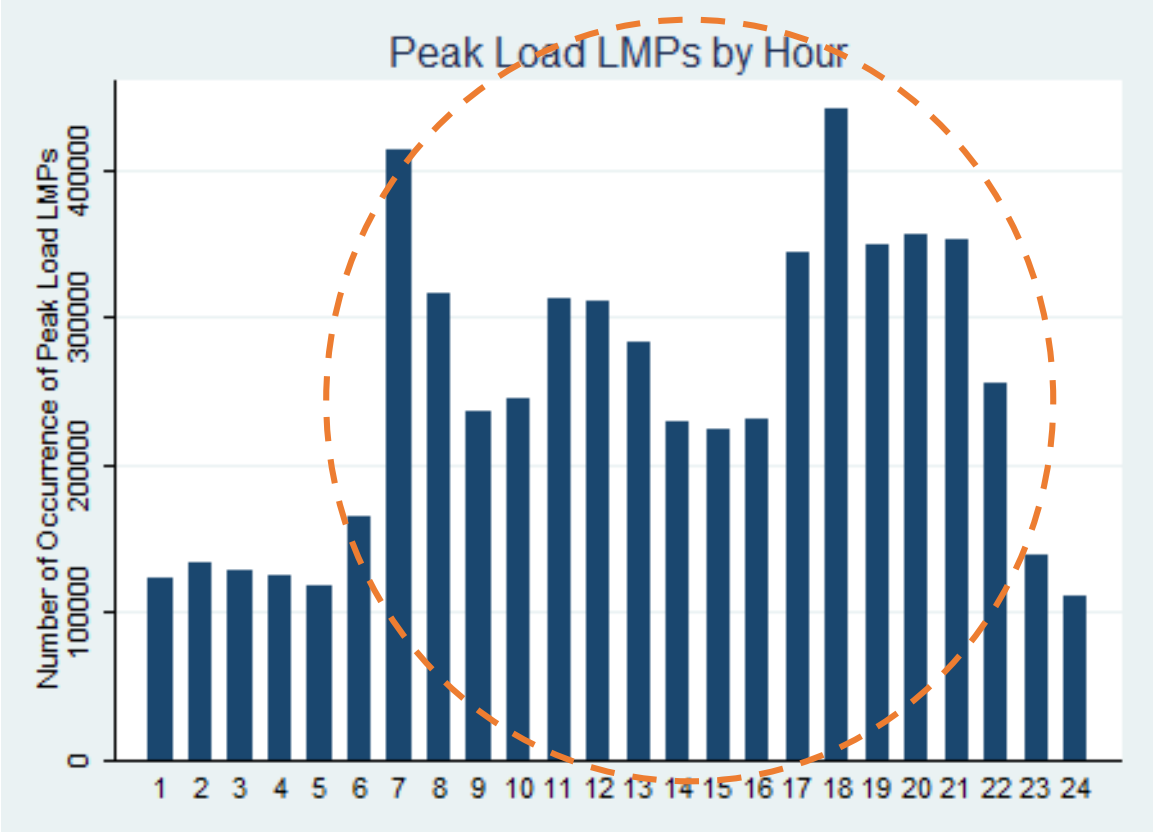
Anomalies in LMPs that relate to the calendar (e.g. hours of the day, Day-of-the-week, Day-of-the-month, Month-of-the-year)

LMPs by Hour

Negative Pricing is prevalent at night

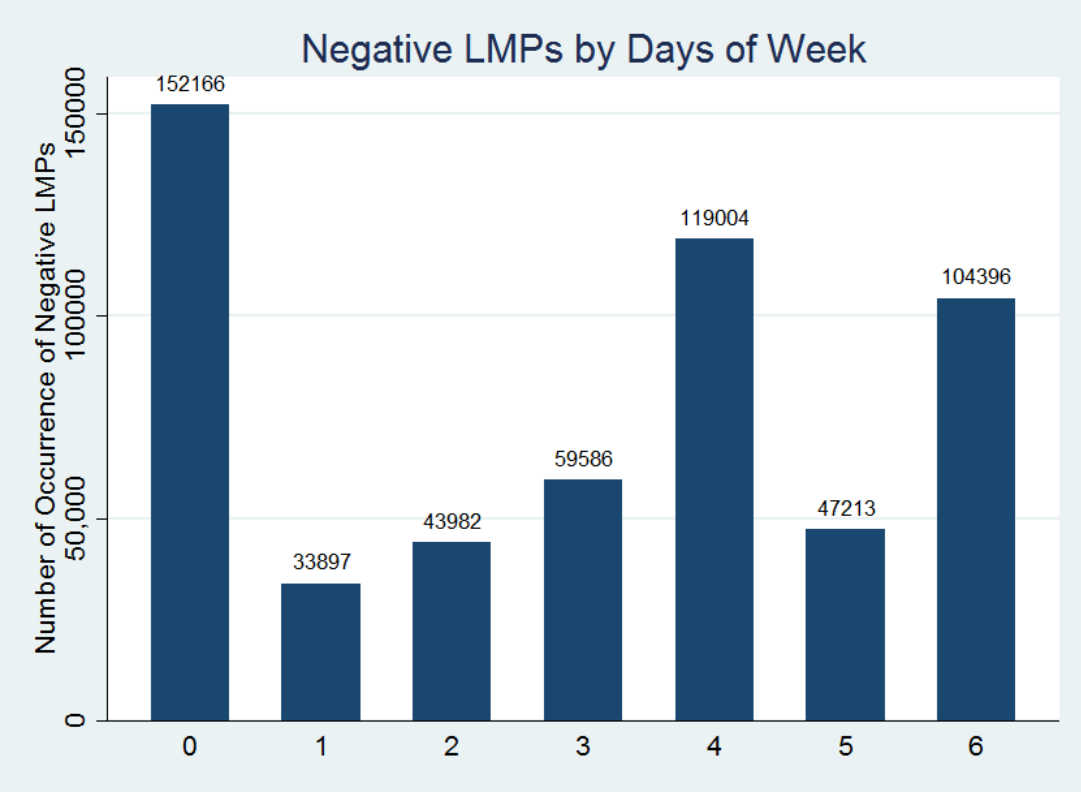
Peak Load Pricing is prevalent during the daytime

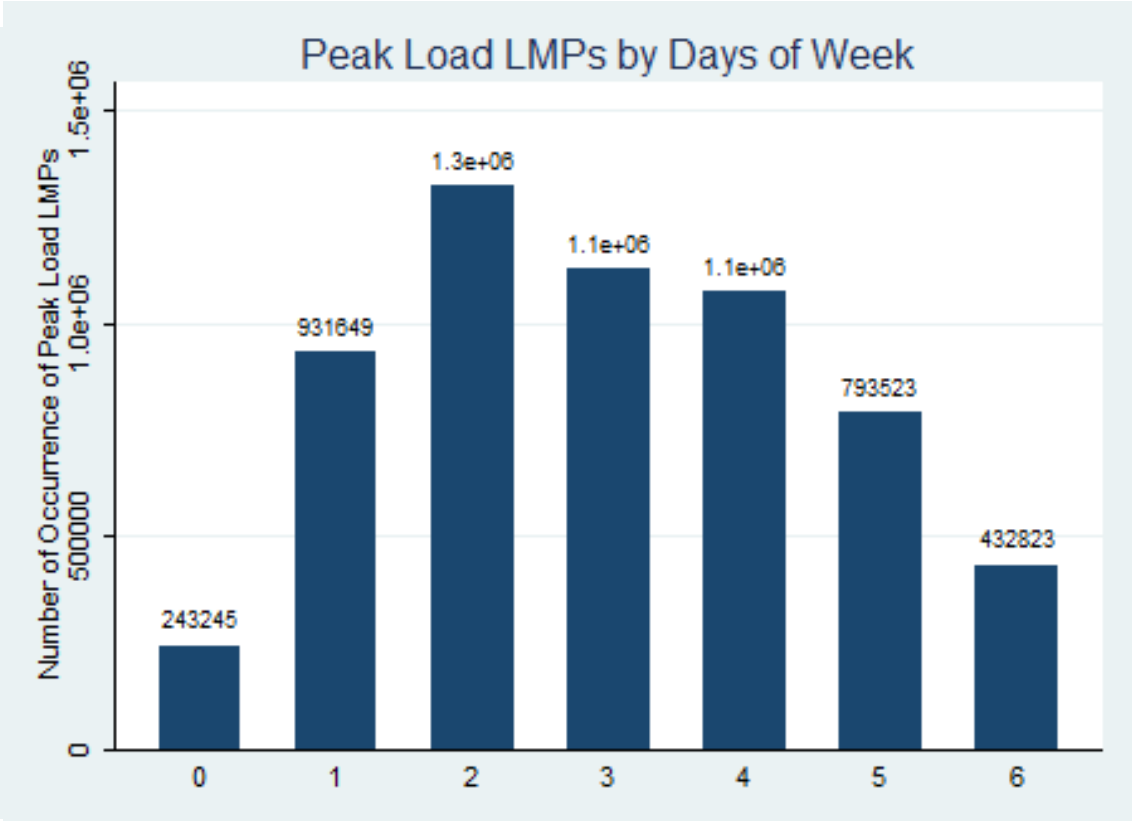




LMPs by Days of a Week

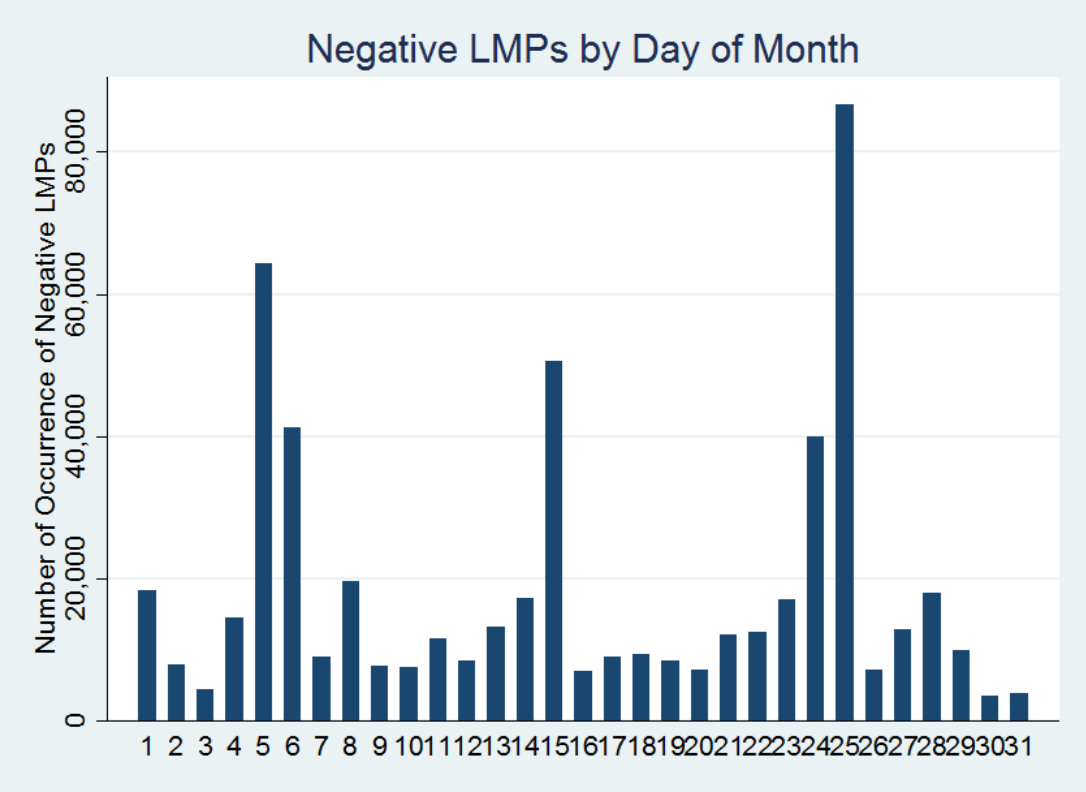
Negative Pricing: strong weekend effect
Peak Load Pricing: strong weekday effect

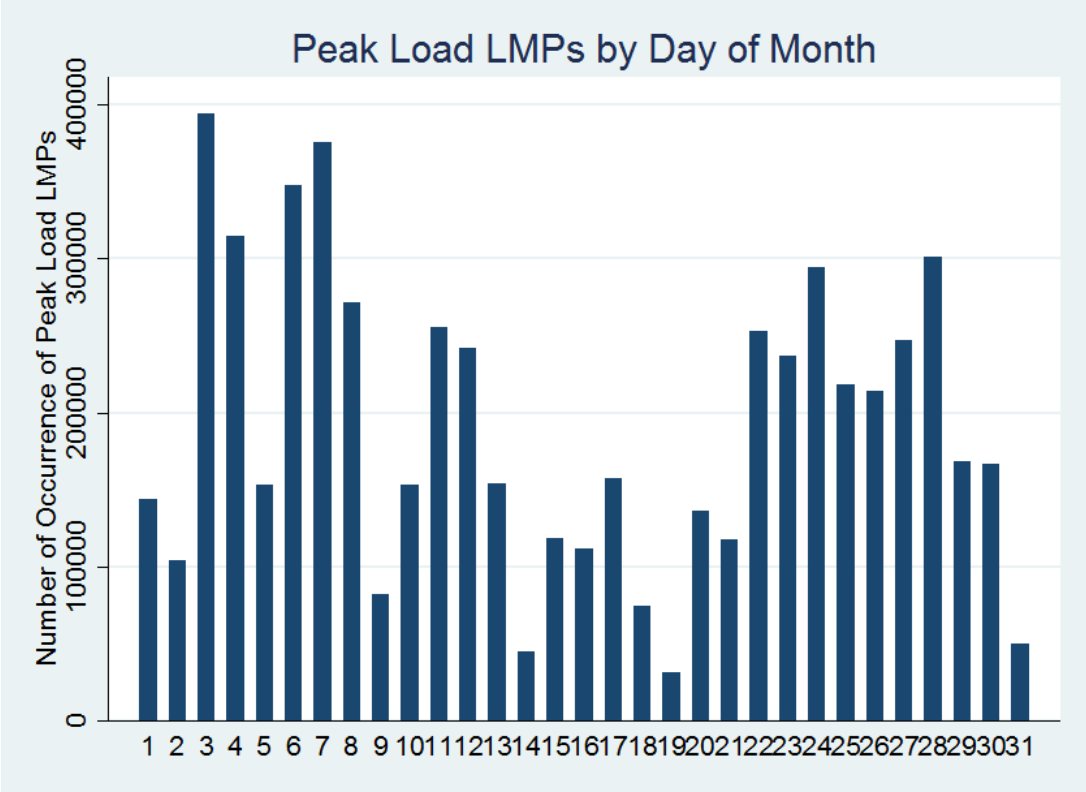




LMPs by Days of a Month

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

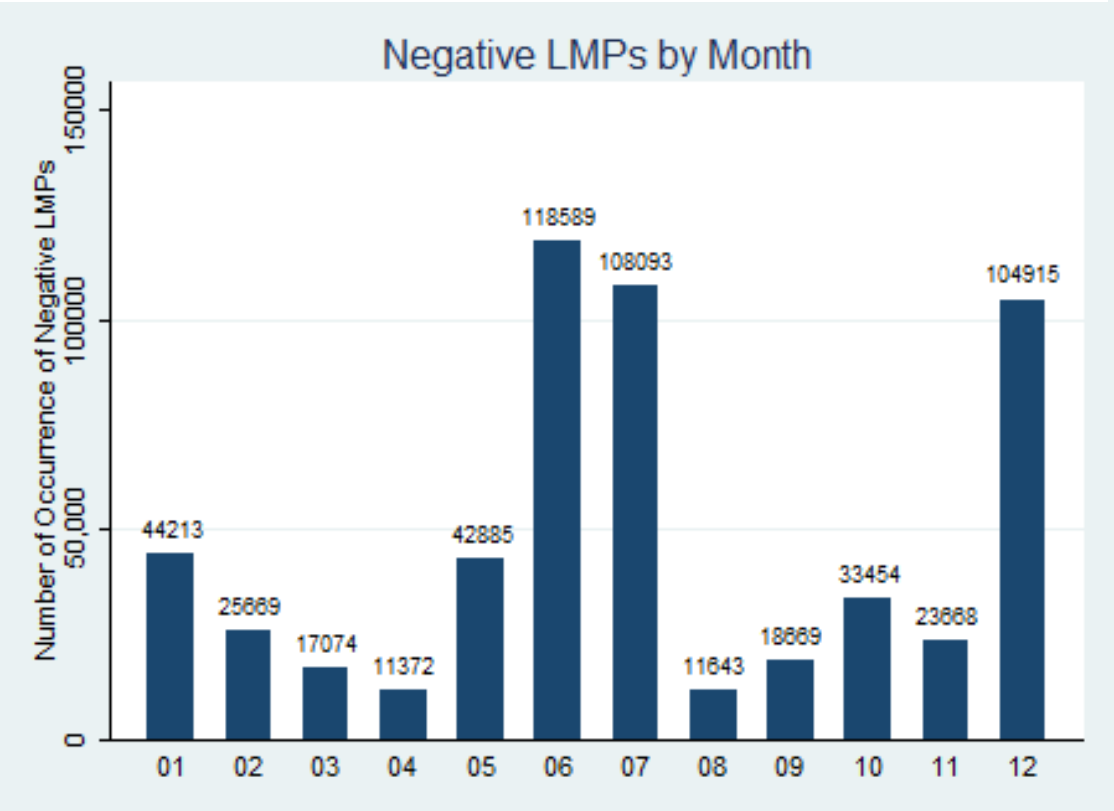


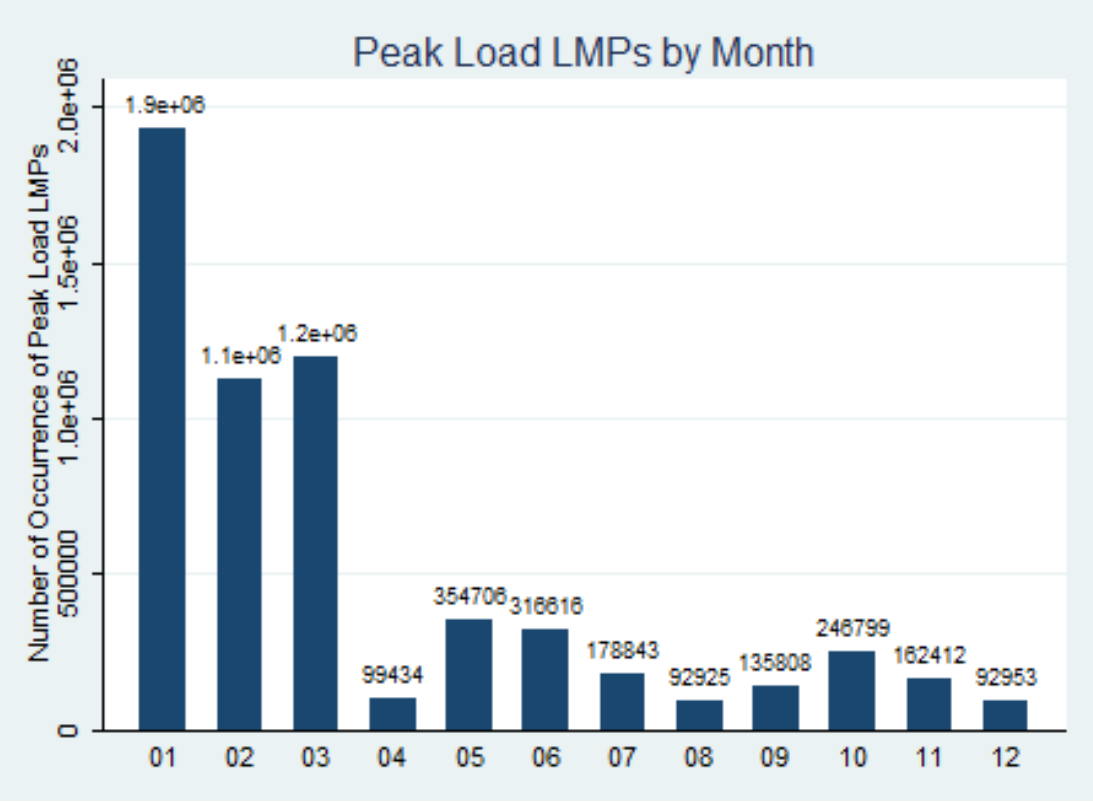


LMPs by Month

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

Peak Load: Winter Effect





Performance of Calendar Effects

We employ an upgraded Bonferroni bound type test by Hansen, et al (2007), to evaluate the significance of calendar specific anomalies.

Time Frequency	p-value	Most Significant Calendar Effects and Average LMPs		
Day-of-the-week	<0.0001	Tuesday	Wednesday	Monday
		44.15	40.99	40.61
Hour-of-the-day	<0.0001	6pm	7pm	8pm
		49.35	47.31	47.15
Month-of-the-year	<0.0001	January	February	March
		59.07	55.38	48.35
Season	<0.0001	Winter		
		47.93		
Day-of-the-month	<0.0001	7th	6th	3rd
		54.24	43.52	41.67

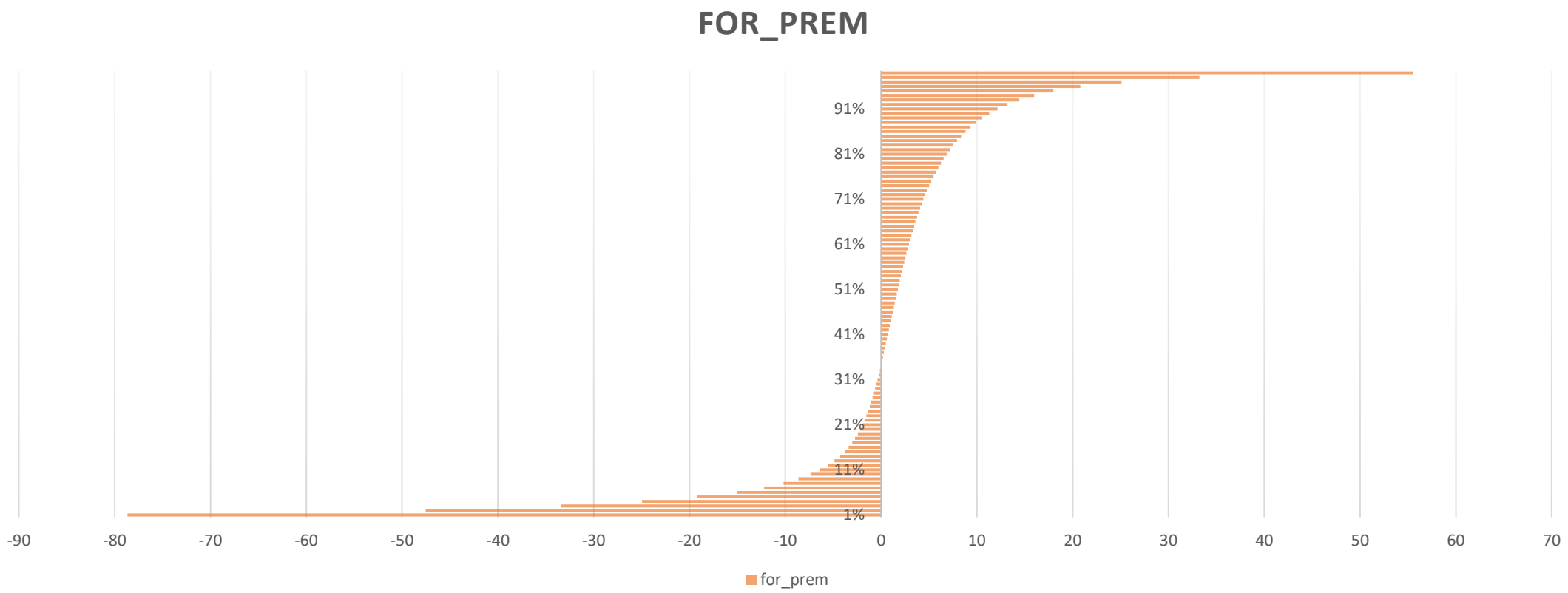
Forward Premium

Previous Studies on Forward Premium

- Forward Premium = $Forward_{i,t} - Spot_{i,t+1}$
- Bessembinder & Lemmon (2002, JF): forward premium increases when demand variance is high.
- Longstaff & Wang (2004, JF): significant forward premium exists in PJM and is related to economic risk factors
- Xiao et al (2015, JFM): forward premium is time-varying and state-dependent.

- As an extension to previous studies, we use a cross-line dataset instead of the overall market data.

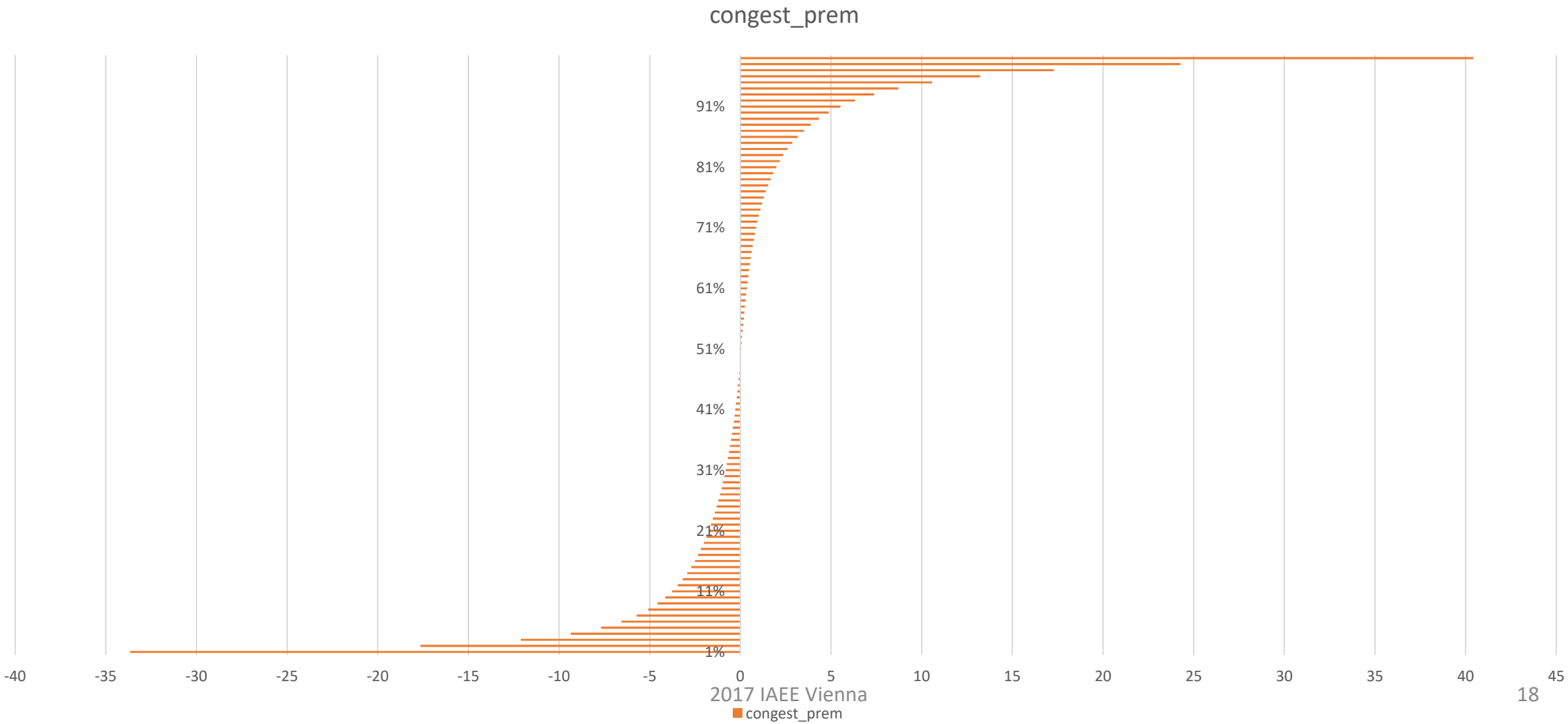
The percentile plot of forward premium



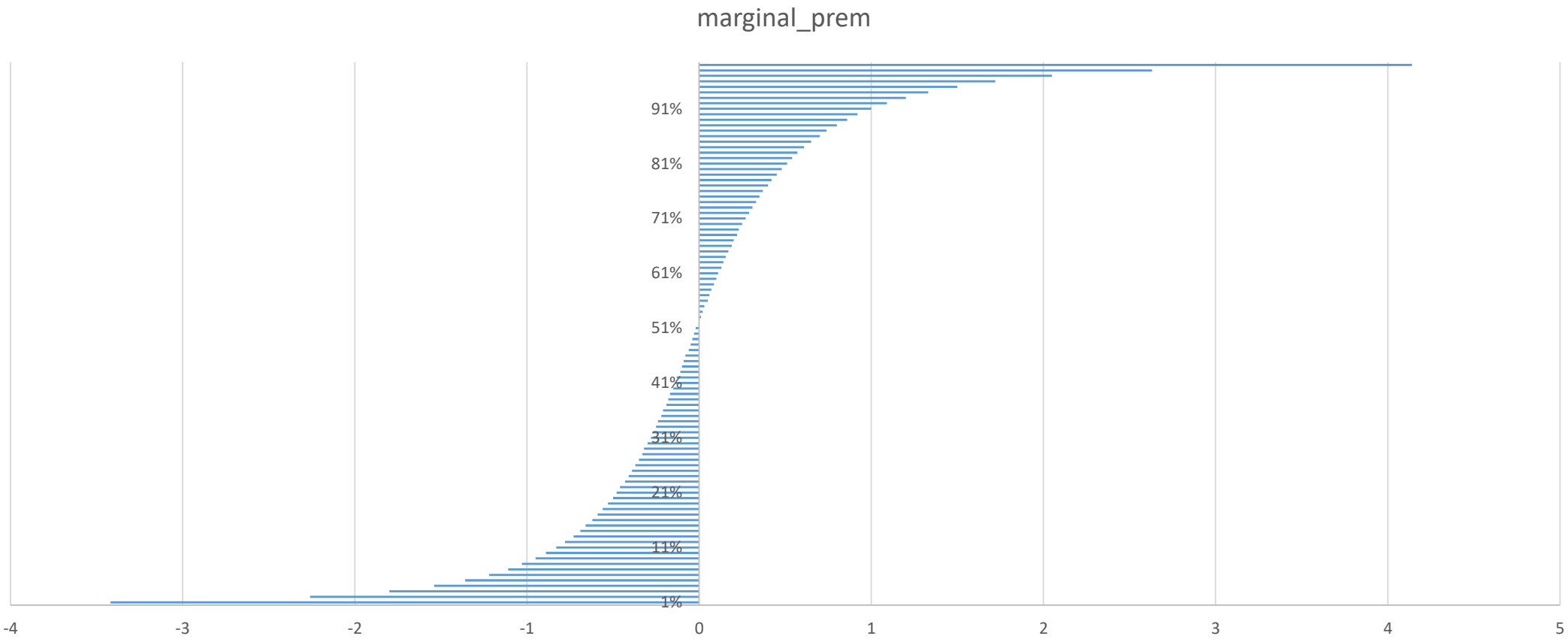
Composition of LMP

- Congestion Component—The congestion component of a nodal LMP reflects the marginal cost of congestion at a given node or external node relative to the load-weighted average of the system node prices.
- Marginal Loss Component— transmission loss, the loss component of an LMP at a given node or external node reflects the cost of losses at that location relative to the load-weighted average of the system node prices.
- Congestion_premium = Congestion_Forward – Congestion
- Marginal_premium = Marginal_Forward – Marginal

The percentile plot of congestion premium



The percentile plot of transmission loss premium



- Forward Premium = α_i + β_1 Congestion_premium + β_2 Marginal_premium + ϵ
- β_1= 0.50, β_2 = -0.06

- Controlling hour effects, forward premium is positively related to the congestion premium, and negatively related to the transmission loss premium.
- The impact of transmission loss is smaller than that of congestion.

Summary

- We observe significant negative and peak load pricing as signals of high price volatility, and the spot price has significant calendar anomalies.
- There are significant forward premia, and they are positively related to the congestion premium, and negatively related to the transmission loss premium. The forward premia have significance across hours.

About Me

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- **Thank you.**