The electricity market price: volatility, pattern and forecast analysis

Kun Li, Ph.D.

Assistant Professor of Finance, Beijing Normal University

kunli@bnu.edu.cn

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About the Presenter

- Kun Li, Ph.D.
- Assistant Professor of Finance, Beijing Normal University, China
- Research Fellow at the Smart Grid Cluster, Small Business Administration & Department of Energy, USA
- kunli@bnu.edu.cn

The objective of this study

- Introduce a powerful test for calendar specific anomalies, and assess the significance of the full universe of possible calendar effects.
- Implement this test to the PJM electricity market and assess the calendar effects

Calendar effects

- Calendar effects refer to cyclical anomalies that are related to the calendar and often classified as persistent cross-sectional and time series patterns in prices.
- Not predicted by extant theory, but popularly observed in financial market through analyses of price-related measures.
- Representative calendar effects: weekday/weekend effects, month effects, intra-month effects, intraday effects.

Statistical analysis of calendar effects

- Hansen, Lunde and Nason (H-L-N, 2005)

- $r_t \equiv \log P_t - P_{t-1}$: the log returns in which t represents one particular hour of a day, t-1 represents the previous hour.
- The sequence of returns are assumed to be uncorrelated: cov(r_s, r_t) = 0 for $s \neq t$.
- The expected return is denoted by $\mu_t \equiv E[r_t]$
- the variance is denoted by $\sigma^2 \equiv var(r_t)$.

Statistical analysis of calendar effects

- The periods of each calendar effect *k* is an element of a set $S_{(k)}$, where a subscript in parentheses refers to a calendar effect.
- n represent the total number of periods
- The full sample of all hours is represented by $S_{(0)}$, which has all n elements, in other words, $n_{(0)} = n$.
- The expected value and average return for calendar effect k are given by $\xi_{(k)} \equiv E\left[\bar{r}_{(k)}\right] = n_{(k)}^{-1} \sum_{t \in S_{(k)}} \mu_t$ and $\bar{r}_{(k)} \equiv n_{(k)}^{-1} \sum_{t \in S_{(k)}} r_t$ respectively.

Statistical analysis of calendar effects

Test two hypotheses

- The first type of hypothesis is that there are no calendar specific anomalies:
- $$H_0\colon \xi_{(0)} = \cdots = \xi_{(m)} \qquad (1)$$
- where $\xi_{(n)}$ represents the expected return for each calendar effect.
- The second type of hypothesis is that no calendar specific anomalies in standardized expected returns:
- $$H_0'\colon \rho_{(0)} = \cdots = \rho_{(m)} \qquad (2)$$
- where $\rho_{(n)}$ represents the expected standardized return for each calendar effect.

Statistical analysis of calendar effects

- The test of these hypotheses is in the form of a χ^2 test (3):
- $$T = X'\boldsymbol{B}_{\perp}(\boldsymbol{B}'_{\perp}\boldsymbol{\Omega}\boldsymbol{B}_{\perp})^{+}\boldsymbol{B}_{\perp}\boldsymbol{X} \qquad (3)$$
- **X** is a normally distributed vector with mean λ and covariance matrix **Ω**,
- **B** be a known matrix full column
- $\boldsymbol{B}_{\perp}$ is the orthogonal matrix to B and where $(\boldsymbol{B}'_{\perp}\boldsymbol{\Omega}\boldsymbol{B}_{\perp})^{+}$ is the Moore-Penrose inverse of $\boldsymbol{B}'_{\perp}\boldsymbol{\Omega}\boldsymbol{B}_{\perp}$.
- This χ^2 test is distributed with f = rank$(\boldsymbol{B}'_{\perp}\boldsymbol{\Omega}\boldsymbol{B}_{\perp})$ degrees of freedom.

Data

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

Candidate calendar effects to test

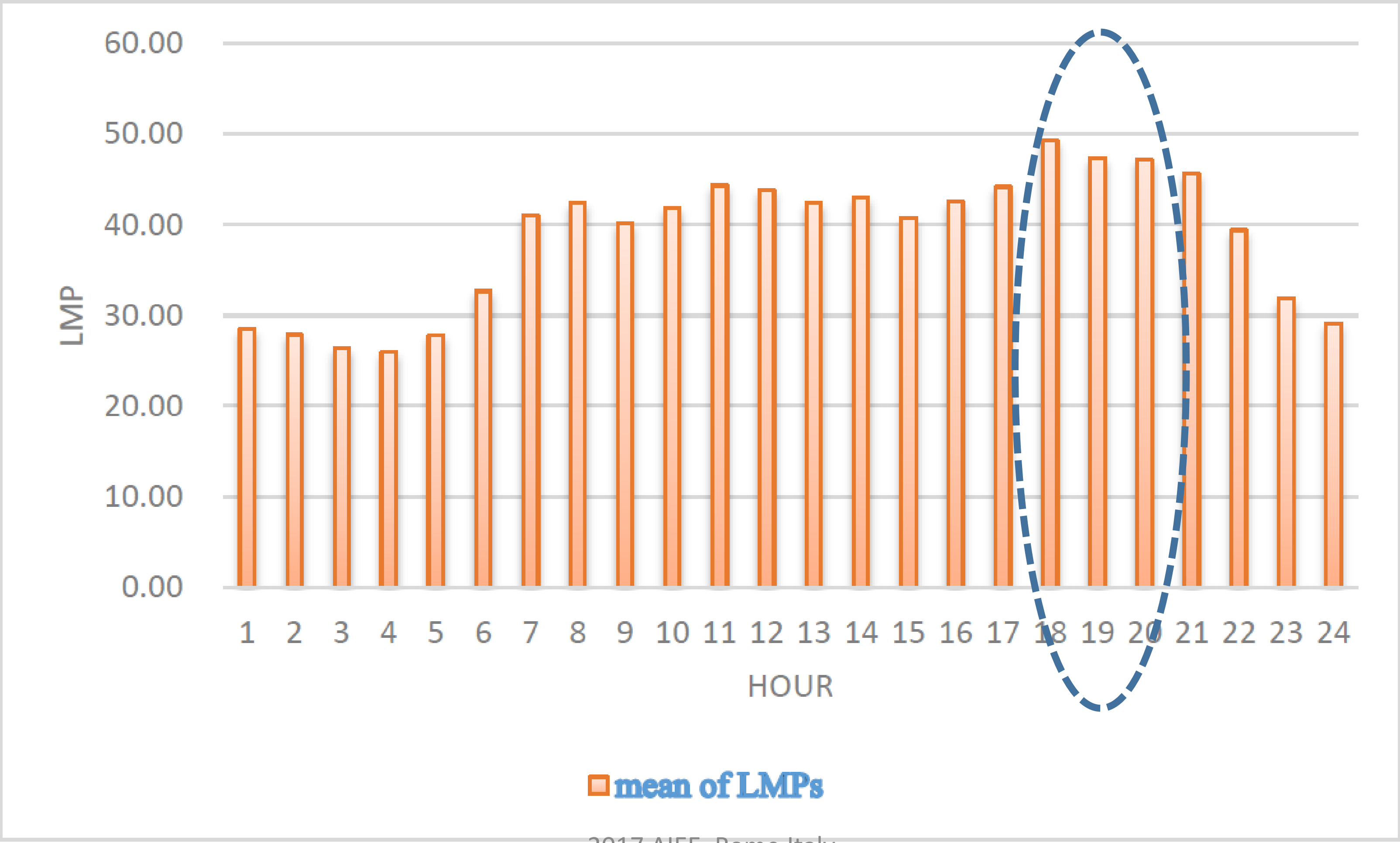
- Day-of-the-week: as we mentioned before, weekday/weekend effect is the most important and widely-discussed calendar effect among related studies
- Hour-of-the-day: the 24 hour-of-the-day effects. (Intra-day effect)
- Month-of-the-year: the difference of price movement across months.
- Season: winter (December, January and February), spring (March, April and May), summer (June, July and August) and fall (September, October and November).
- Day-of-the-month: 31 day-of-the-month effects.

Performance of Calendar Effects

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

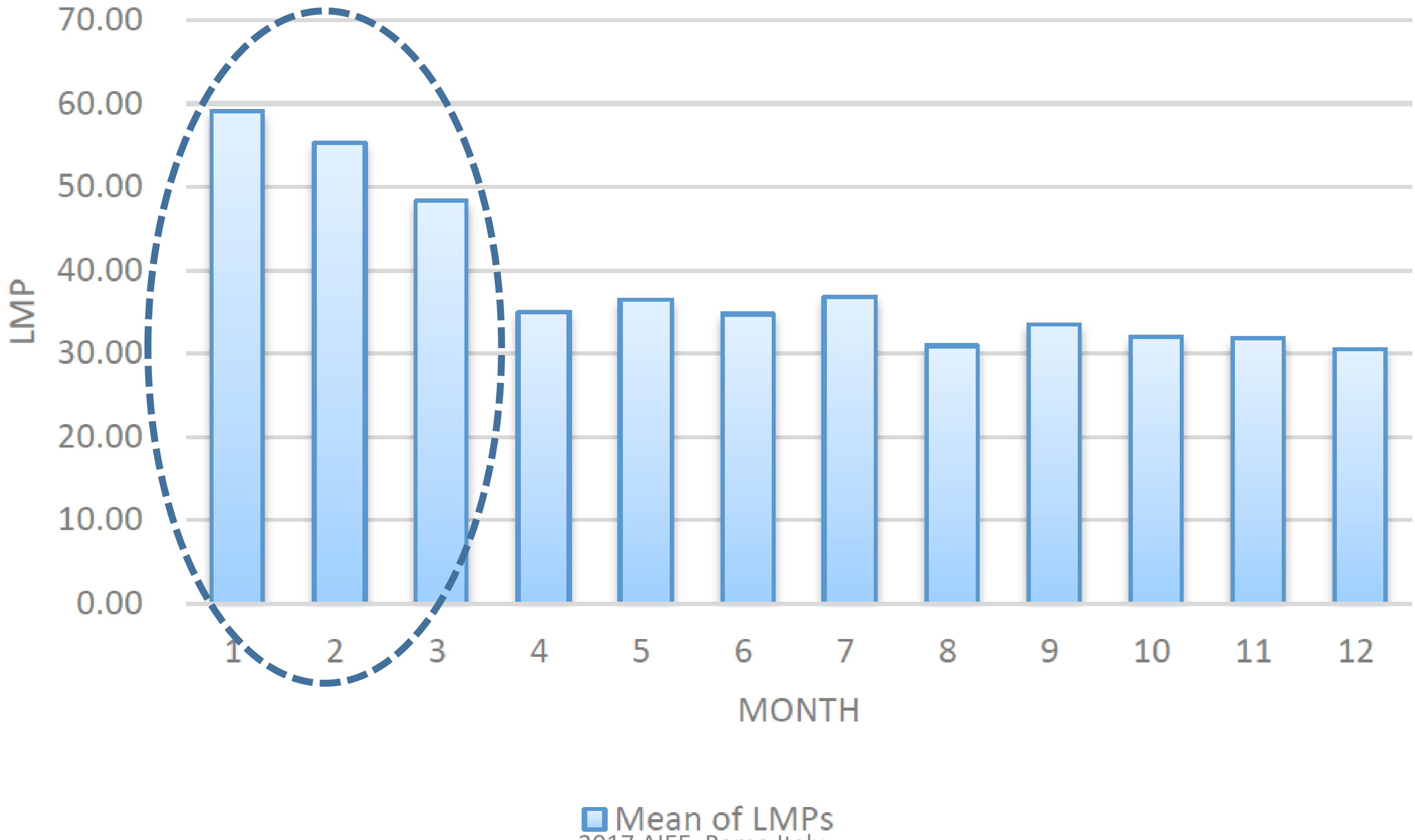
Performance of Calendar Effects

- Means of LMPs by Hour-of-the-day



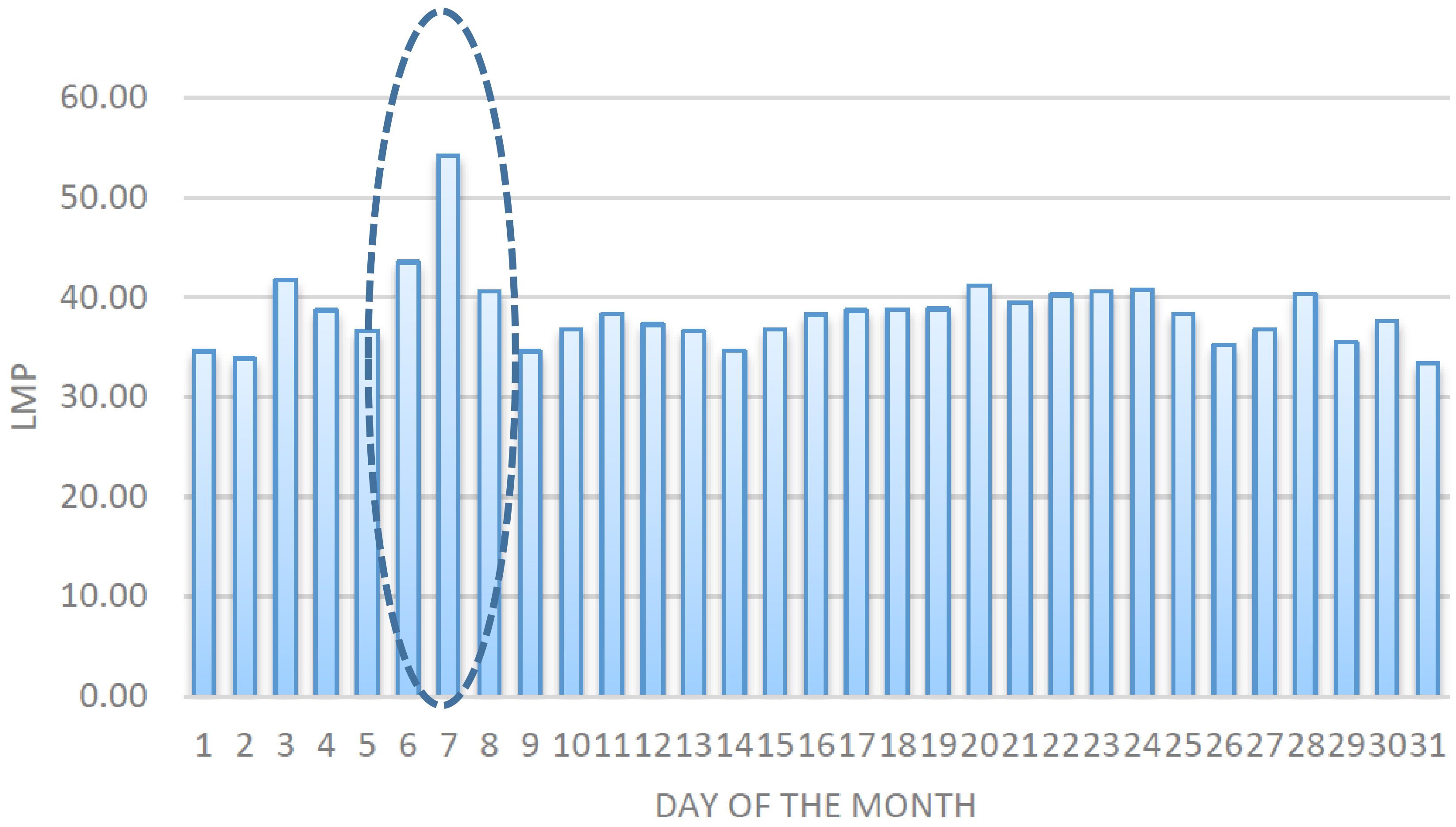
Performance of Calendar Effects

- Means of LMPs by months



Performance of Calendar Effects

- Means of LMPs by day-of-the-month



Implications

- Electricity is a kind of power with non-stopped consumption.
- The electricity market like PJM serves as a continuous market.
- In principle, the market with non-stopped actions should have less time-series anomalies.
- However, the significance of calendar effects in different time-frequency levels indicates the intrinsic imbalance of demand and supply.

Summary

- However, the significance of calendar effects in different time-frequency levels indicates the intrinsic imbalance of demand and supply.

- The observation of calendar effects from big data studies can help offset the imbalance between power supply and consumption.

- For example, a lot of countries launch the demand response (DR) program. DR is to adjust the demand of electricity by end-users in response to changes in the price of electricity overtime.