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Estimating the Volatility of Electricity Prices: The Case of the England and Wales Wholesale Electricity Market

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Recent Advances in Changepoint Analysis
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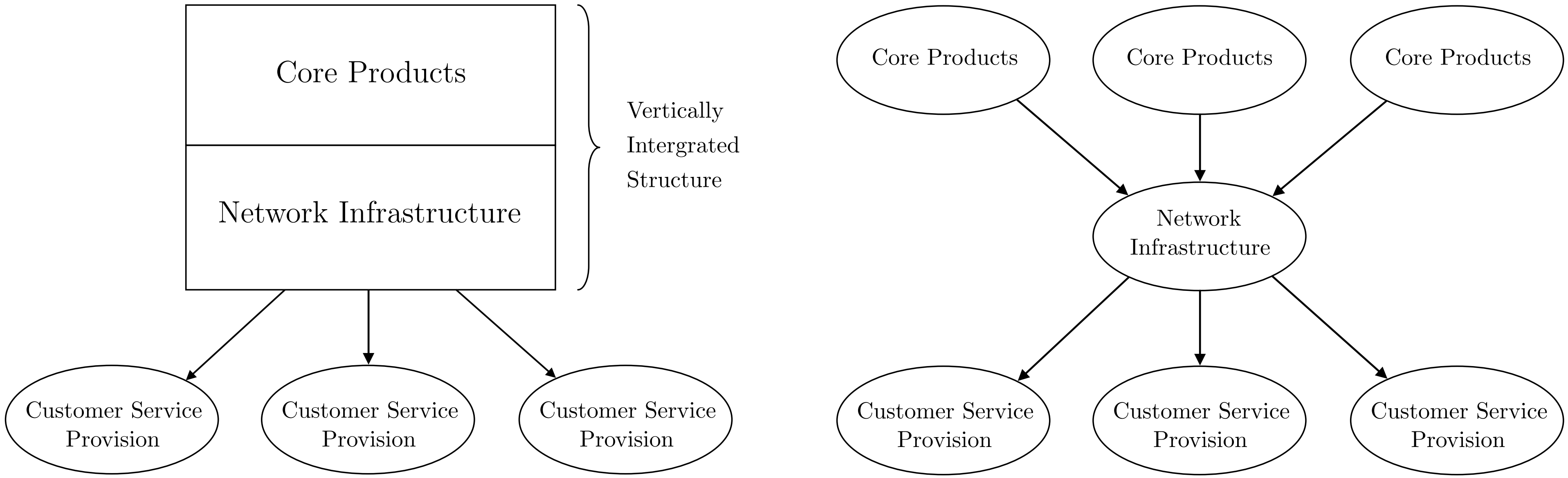
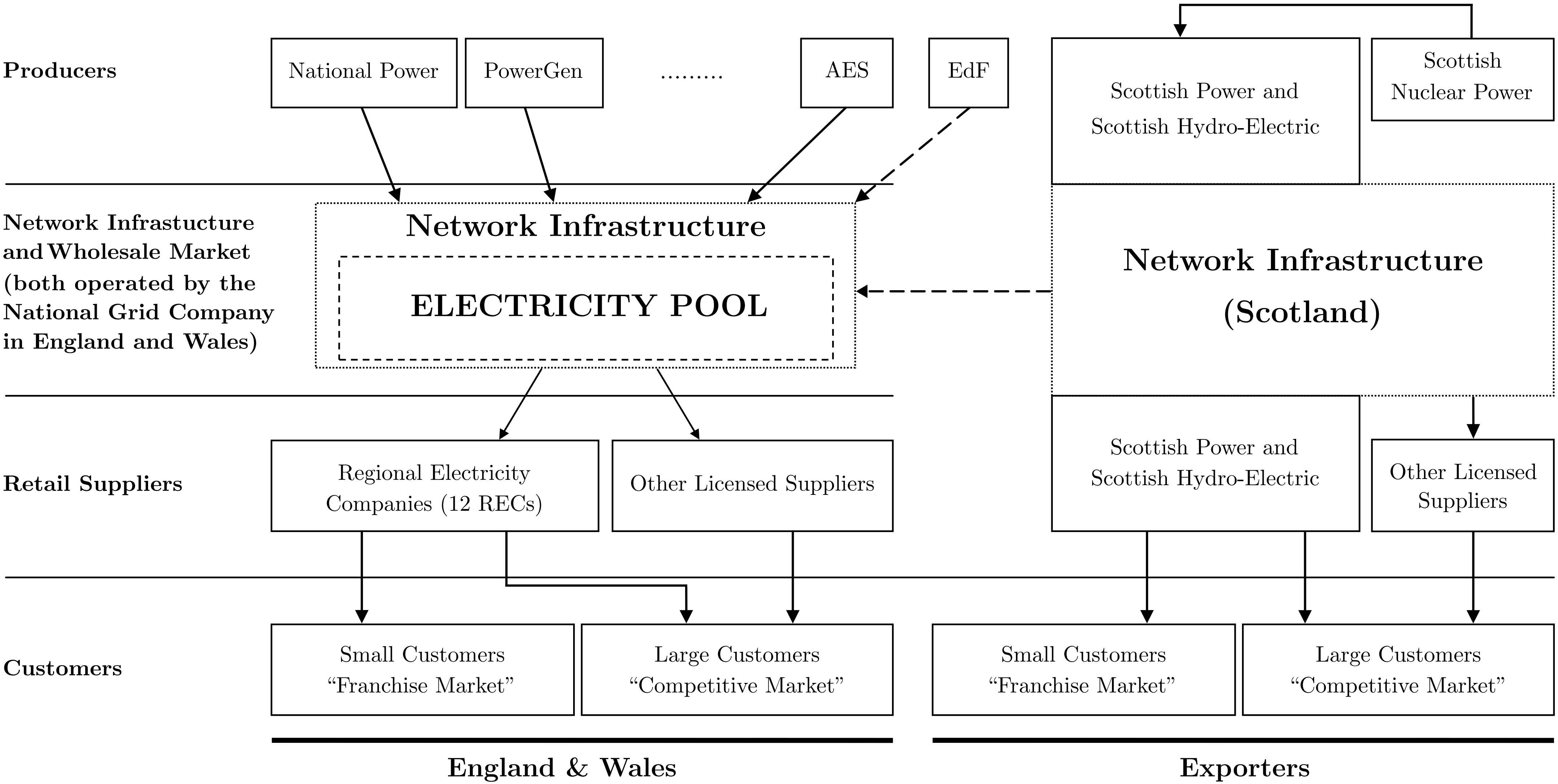
Fig. 1: *Structure of a Network Industry* **before** *and* **after** *Liberalization*



(a) Vertically Integrated Case

(b) Vertically Separated Case

Fig. 2: *Description of the Electricity Industry in Great Britain*

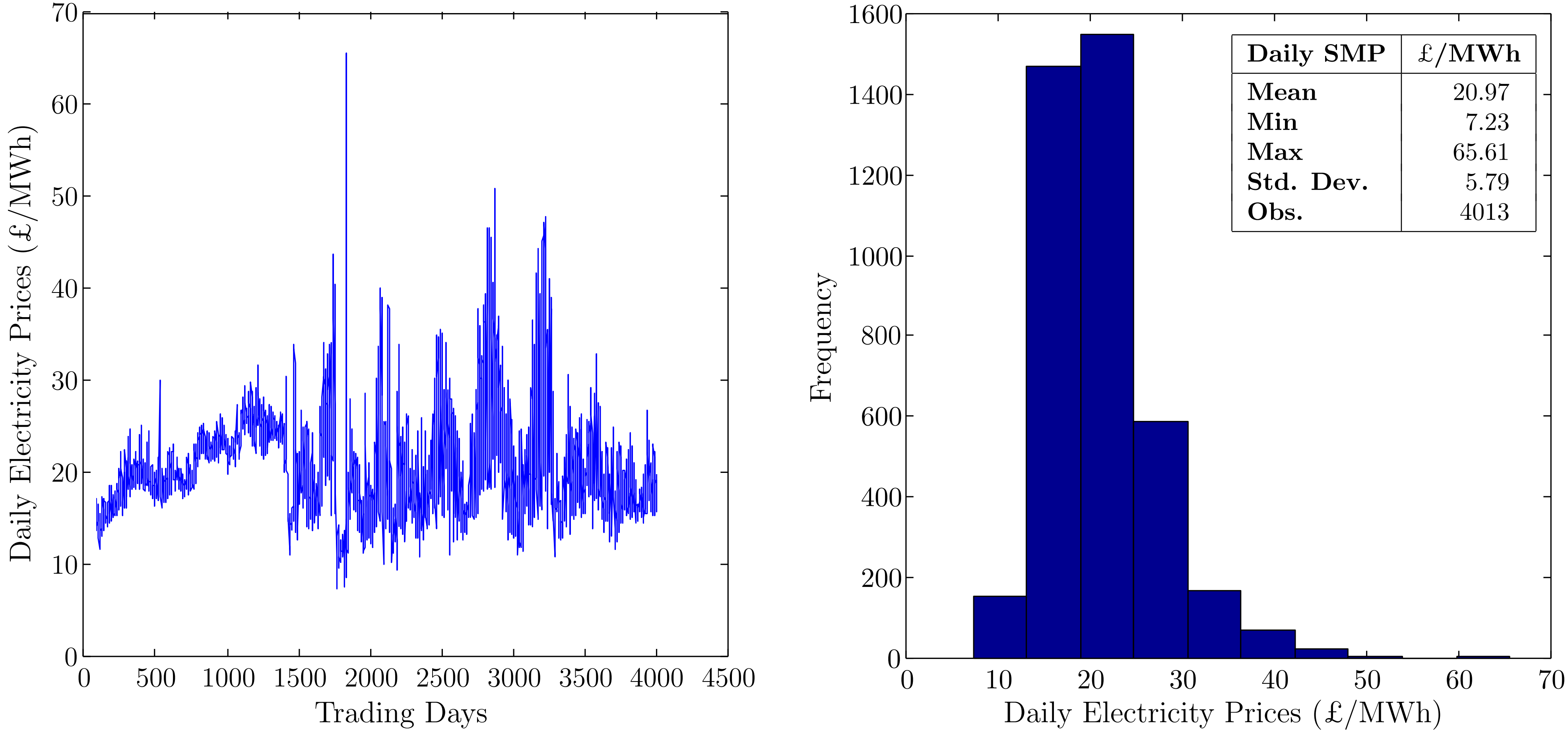


Liberalization of Electricity Industry

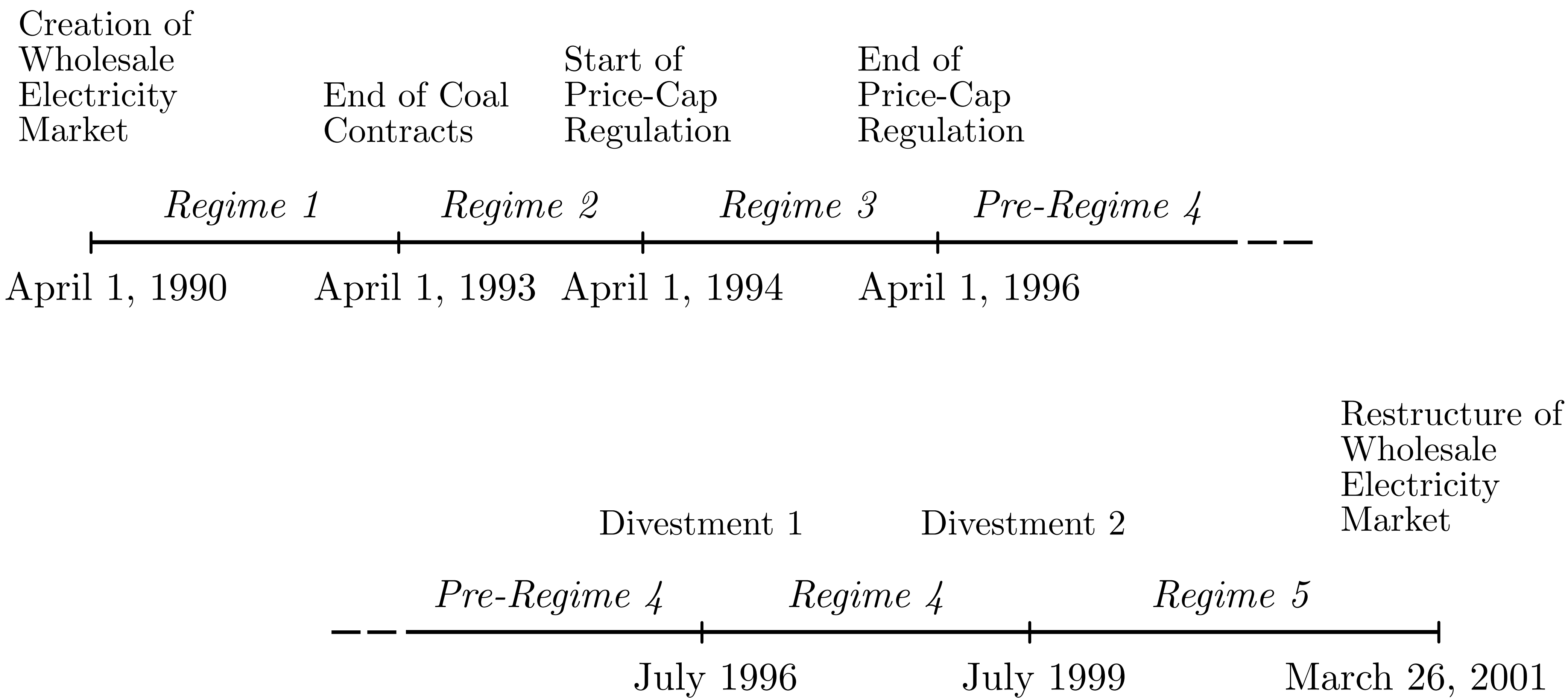
- The Key Question to Analyze Liberalization
  - Do liberalized markets drive price volatility?
- Case Study
  - Wholesale electricity market in England and Wales

- Motivation

Fig. 3: *Daily Electricity Prices (April 1, 1990 – March 26, 2001)*



Institutional Changes and Regulatory Reforms



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Paper Estimating the Volatility of Electricity Prices

- Motivation

Policy Importance

- Price fluctuations:
  - uncertainty about revenues and costs
  - higher electricity prices for consumers

Research Question

- How did the institutional changes and regulatory reforms affect the dynamics of electricity prices during the liberalization process?

Research Approach

- stationarity and seasonality
- AR-ARCH model with a smoothly time-varying intercept term

Paper Estimating the Volatility of Electricity Prices

- Literature Review

  - **Crespo *et al.* (2004)**
    Hourly prices from the Leipzig Power Exchange (Jun. 16, 2000 - Oct. 15, 2001)
    AR, ARMA models: separate studies of each hour yielded better forecasts

  - **Guthrie and Videbeck (2007)**
    30-min prices from the New Zealand Electricity Market (Nov. 1, 1996 – Apr. 30, 2005)
    Half-hourly trading periods naturally fall into 5 groups, which can be studied separately using a periodic AR model

  - **Huisman *et al.* (2007)**
    The Amsterdam Power Exchange (APX), the European Energy Exchange (EEX; Germany), and the Paris Power Exchange (PPX) for the year 2004
    Hourly electricity prices are treated as a panel in which hours represent cross-sectional units and days represent the time dimension. SUR is applied

Paper Estimating the Volatility of Electricity Prices

- Literature Review (*cont.*)

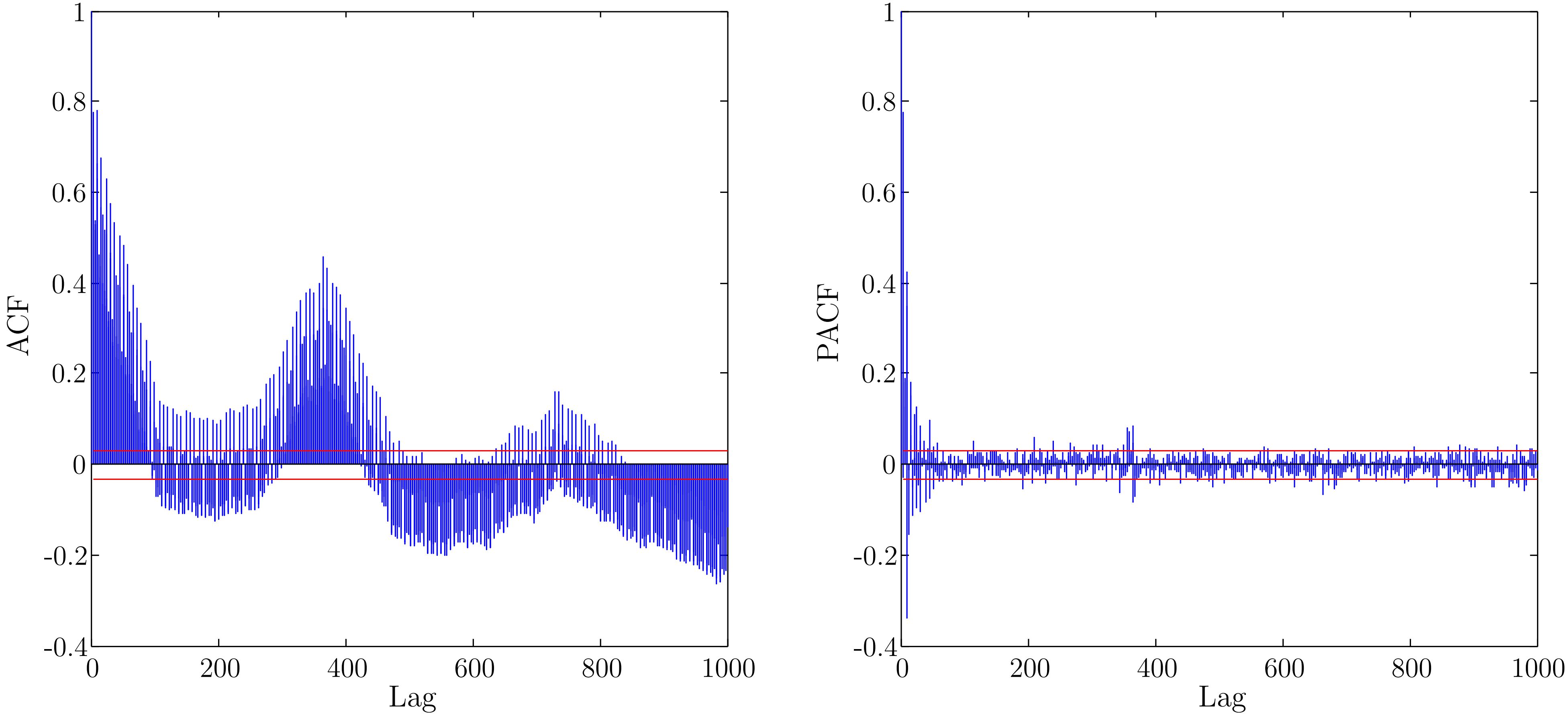
  - **Conejo *et al.* (2005)**
    PJM interconnection data for the year 2002
    Dynamic modeling is preferred to seasonal differencing

  - **Garcia *et al.* (2005)**
    Spanish and California electricity markets (Sept. 1, 1999 - Nov. 30, 2000; Jan. 1, 2000 - Dec. 31, 2000)
    GARCH model outperforms a general ARIMA model when volatility and price spikes are present

  - **Bosco *et al.* (2007)**
    Daily prices from the Italian wholesale electricity market
    Periodic AR-GARCH methodology

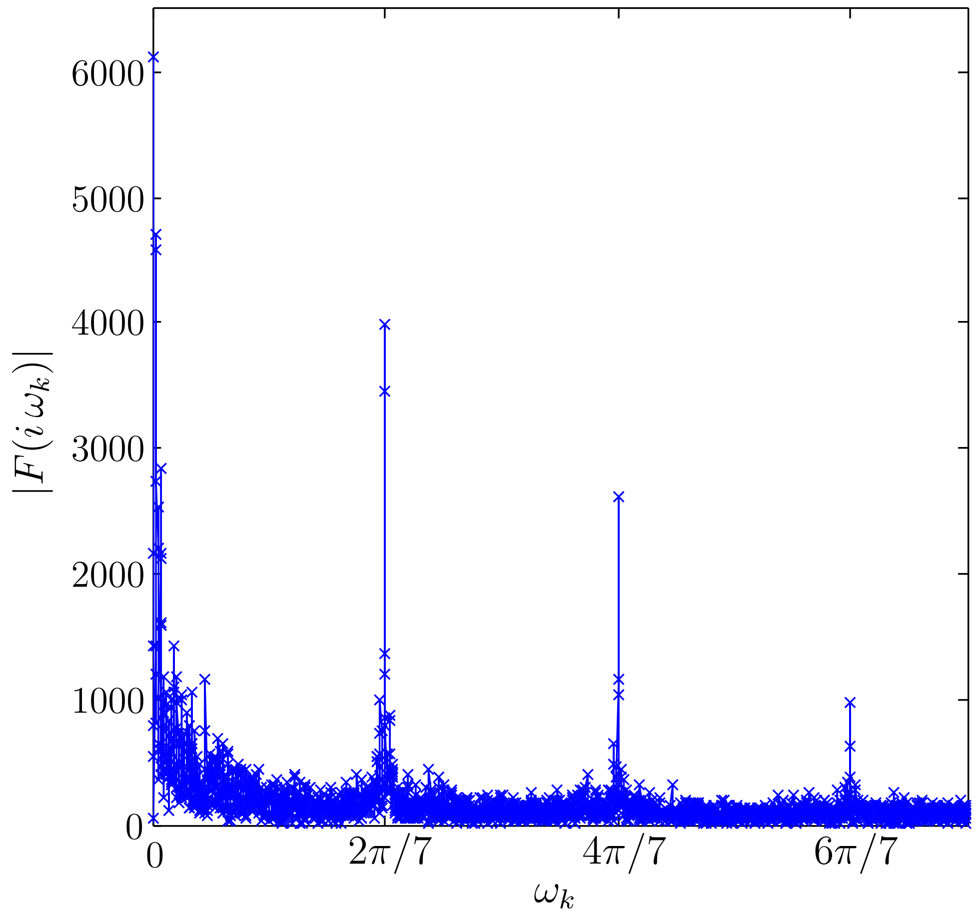
- Seasonality: Time Domain Analysis

Fig. 4: *Correlogram for Daily Electricity Prices*



- Seasonality: Frequency Domain Analysis

Fig. 5: *Periodogram for Daily Electricity Prices*



Paper **Estimating the Volatility of Electricity Prices**

- Regression Model

$$price_t = a_0 + \sum_{i=1}^{P} a_i \, price_{t-i} + z_t' \cdot \gamma + \varepsilon_t \qquad (1)$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, \varepsilon_{t-i}^2 + z_t' \cdot \delta \qquad (2)$$

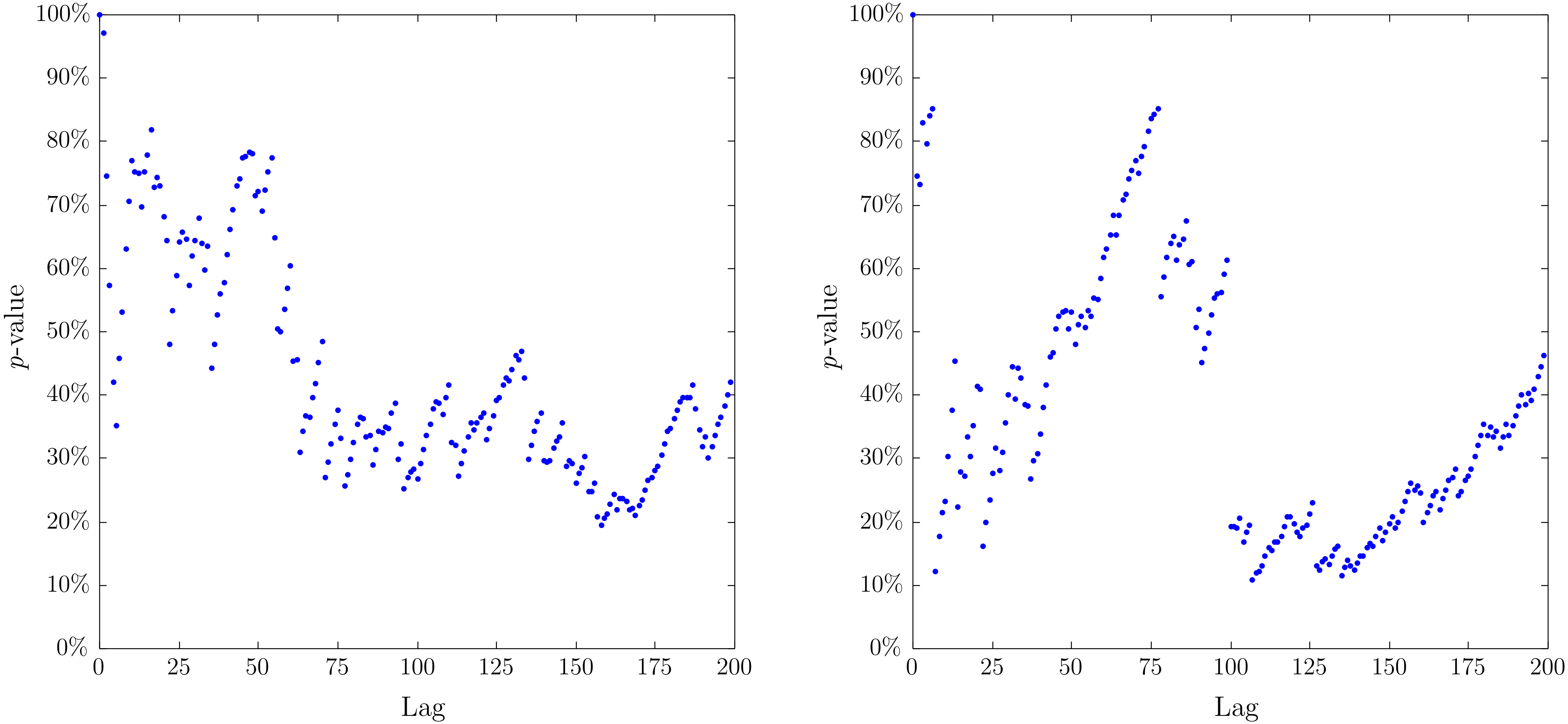
$$\nu_t = \frac{\varepsilon_t}{\sqrt{h_t}} \sim \text{GED}, \qquad (3)$$

where z_t is a vector of additional explanatory variables including the sine/cosine periodic functions and regime dummy variables.

- Methodological findings:
  - The sine/cosine periodic functions allow better modeling weekly seasonality
  - $+$ and $-$ shocks from the previous week are found to asymmetrically affect volatility

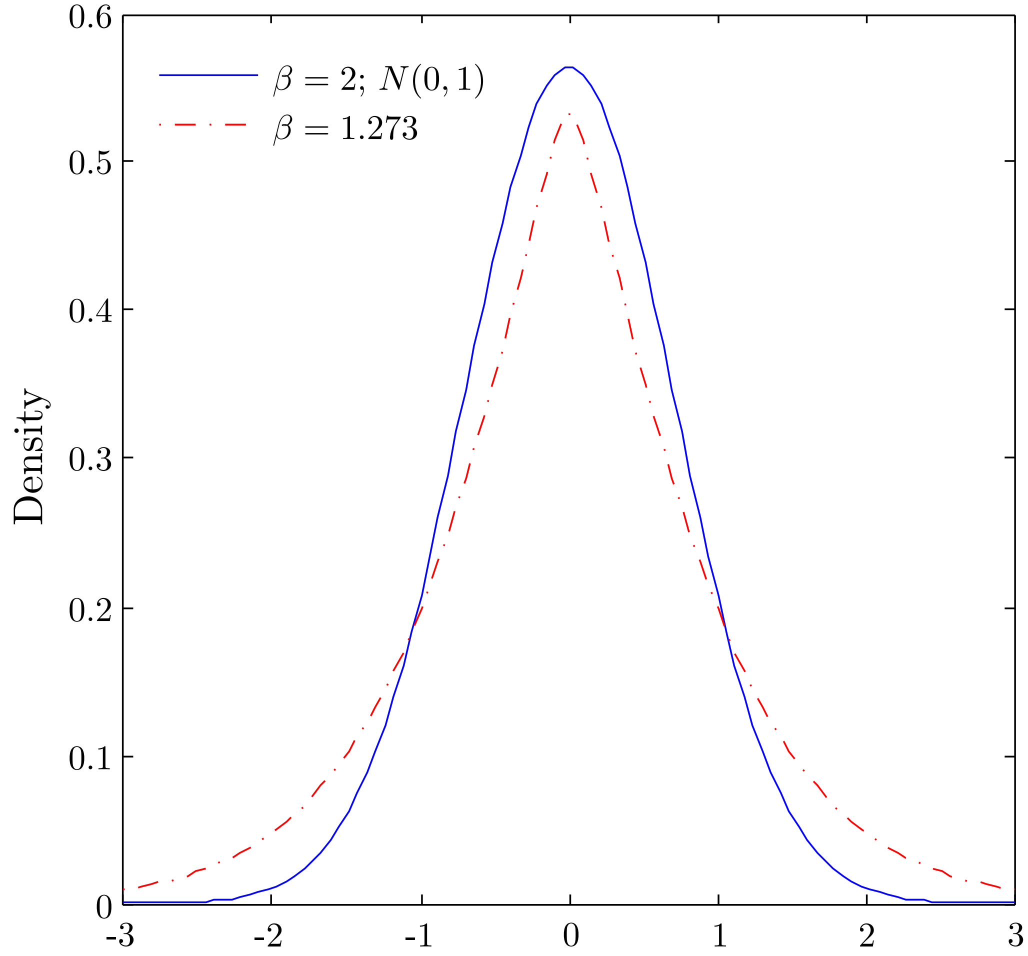
- Diagnostics of standardized residuals

Fig. 6: *Ljung-Box Q-Test for Standardized Residuals* $\hat{\nu}_t$ *and* $\hat{\nu_t^2}$



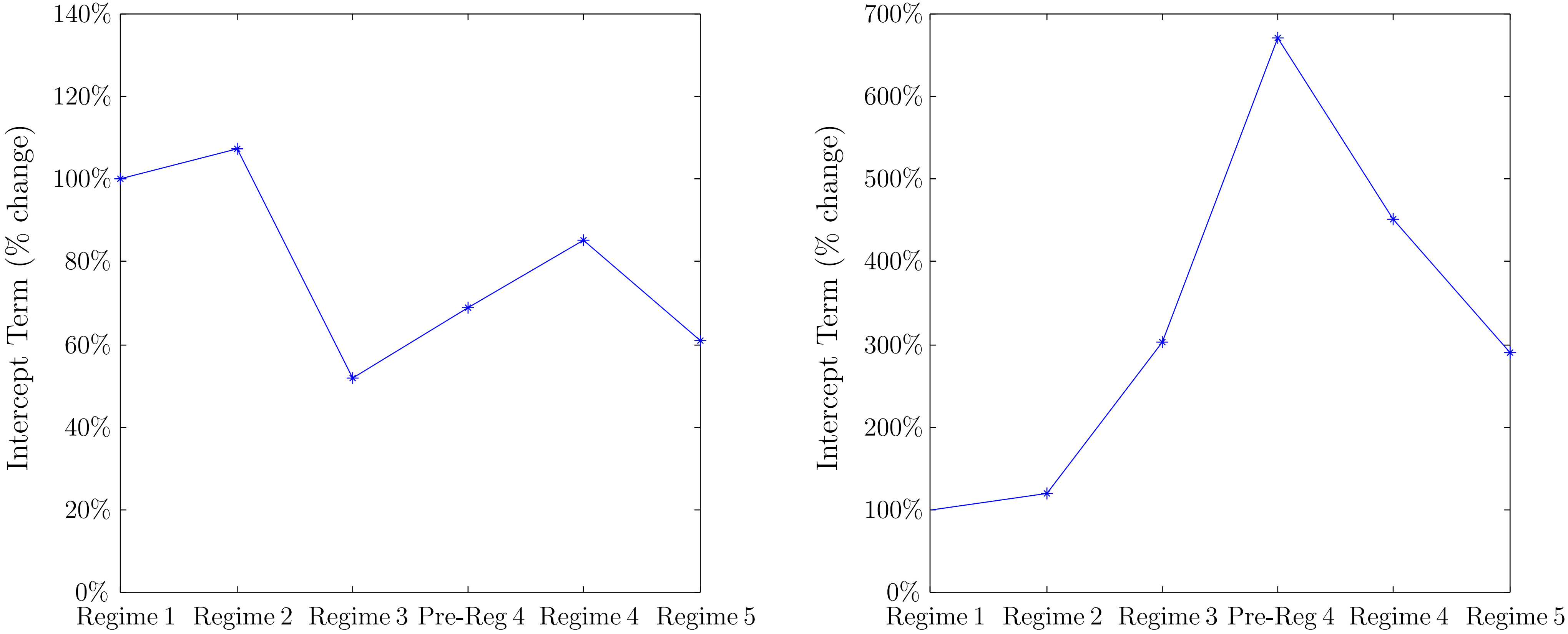
- Distribution of standardized residuals

Fig. 7: *Standard Normal Distribution and Distribution of Standardized Residuals* $\hat{\nu}_t$



- Results

Fig. 8: *Impact of the Institutional Changes and Regulatory Reforms on Price and Volatility Dynamics*



(a) Mean Equation (b) Conditional Volatility Equation

Paper **Estimating the Volatility of Electricity Prices**

- Contributions and conclusion

- Methodological contribution
  - Application of the sine and cosine periodic functions allow better modeling weekly seasonality
  - $+$ and $-$ shocks from the previous week are found to asymmetrically affect volatility

- Policy contribution
  - The price-cap regulation and first series of divestments are found to result in opposite directions for the movement in the price level and volatility
  - During the last regime period it was possible to simultaneously decrease prices and volatility

Thank You

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- Seasonality: Frequency Domain Analysis

The Fourier transform of a real-valued function $p(t)$ on the domain $[0, T]$ is defined as

$$F(i\,\omega) = \mathcal{F}\{p(t)\} = \int_0^T p(t) \cdot e^{-i\omega t}\, dt$$

$$|F(i\,\omega_k)| \approx \left| \sum_{t=0}^{T-1} p_t \cdot e^{-i\omega_k t} \right| = \left| \sum_{t=0}^{T-1} p_t \cdot (\cos \omega_k t - i \sin \omega_k t) \right| =$$

$$= \left| \sum_{t=0}^{T-1} p_t \cdot \cos \omega_k t - i \sum_{t=0}^{T-1} p_t \cdot \sin \omega_k t \right| =$$

$$= \left| (p_t, \cos \omega_k t) - i\,(p_t, \sin \omega_k t) \right| \longrightarrow \max_{\omega_k}$$

where $\omega_k = \frac{k}{N-1} \cdot 2\pi \quad \text{and} \quad k = 0, 1, 2, \ldots, N-1$