A Regression Model of Natural Gas/Wholesale Electricity Price Relationship and Its Application for Detecting Potentially Anomalous Electricity Prices

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*The views set forth in this presentation are those of the authors and do not necessarily represent the views of the Federal Energy Regulatory Commission

Motivations

1. Estimate the effects of gas prices on wholesale electric prices in the Northeast region (New England, New York, PJM), and test whether the effect of gas prices on power prices has changed over time in the Northeast region.
2. Develop an initial screening tool (econometric model) for the detection of potentially anomalous electric pricing behavior/market outcomes.

Part I

Pricing Relationships between Natural Gas & Wholesale Electricity Price in the Northeast

As a starting point, we model electric price as follows:

Electric Price = f(Gas Price, Temperature, Seasonal Effects, Disturbances)

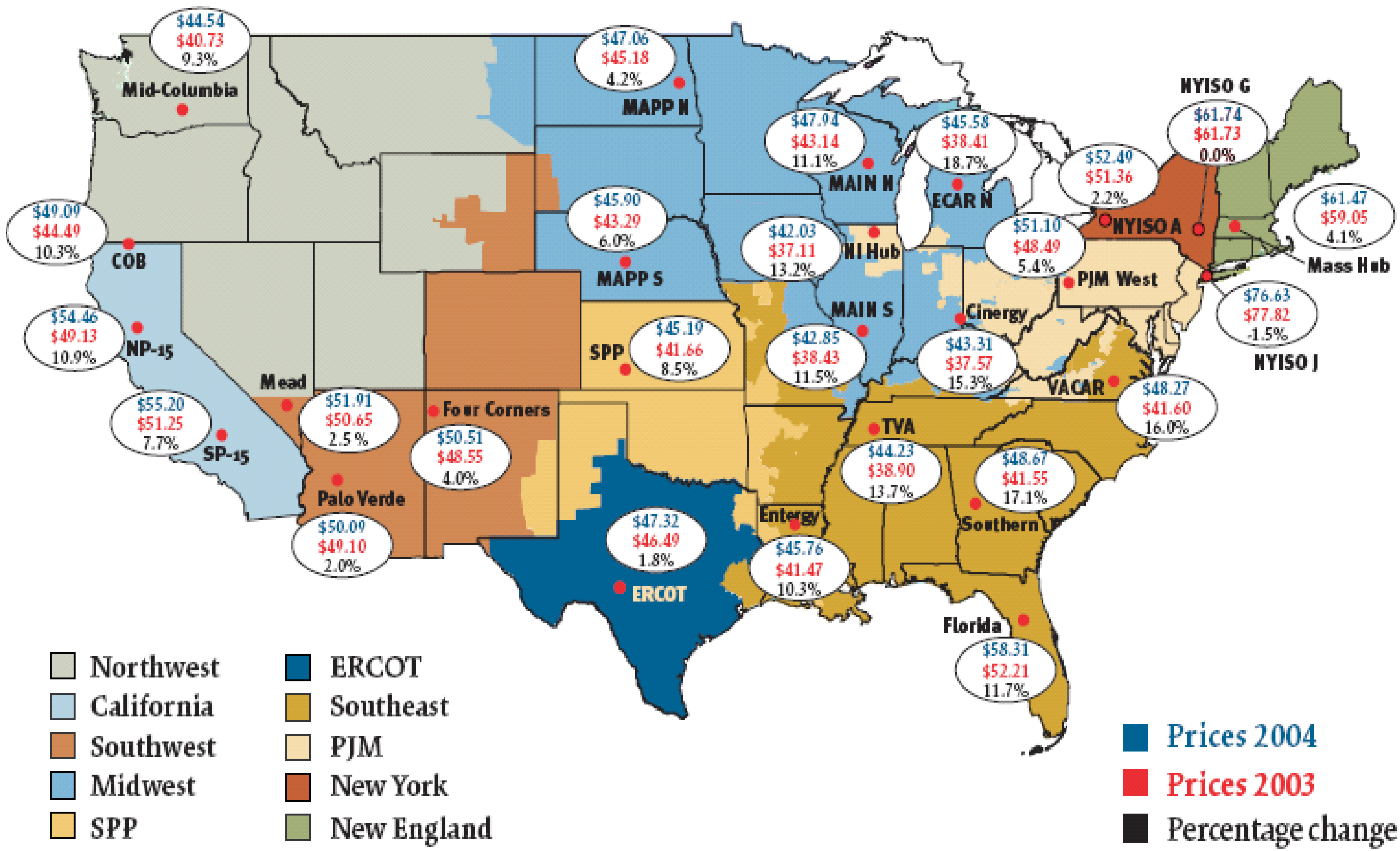
Data

- Sample period
  - New England, PJM: Year 2000 – 2003
  - New York: Year 2001 - 2003
- Electric price
  - Daily weekday bilateral spot peak price (source: Megawatt Daily)
- Natural gas price
  - Daily weekday bilateral spot price (source: Gas Daily)
- Average temperature
  - Daily average temperature (source: EarthSat)
- Electric/gas prices are inflation-adjusted using GDP deflator (base year: 1st quarter, 2004)

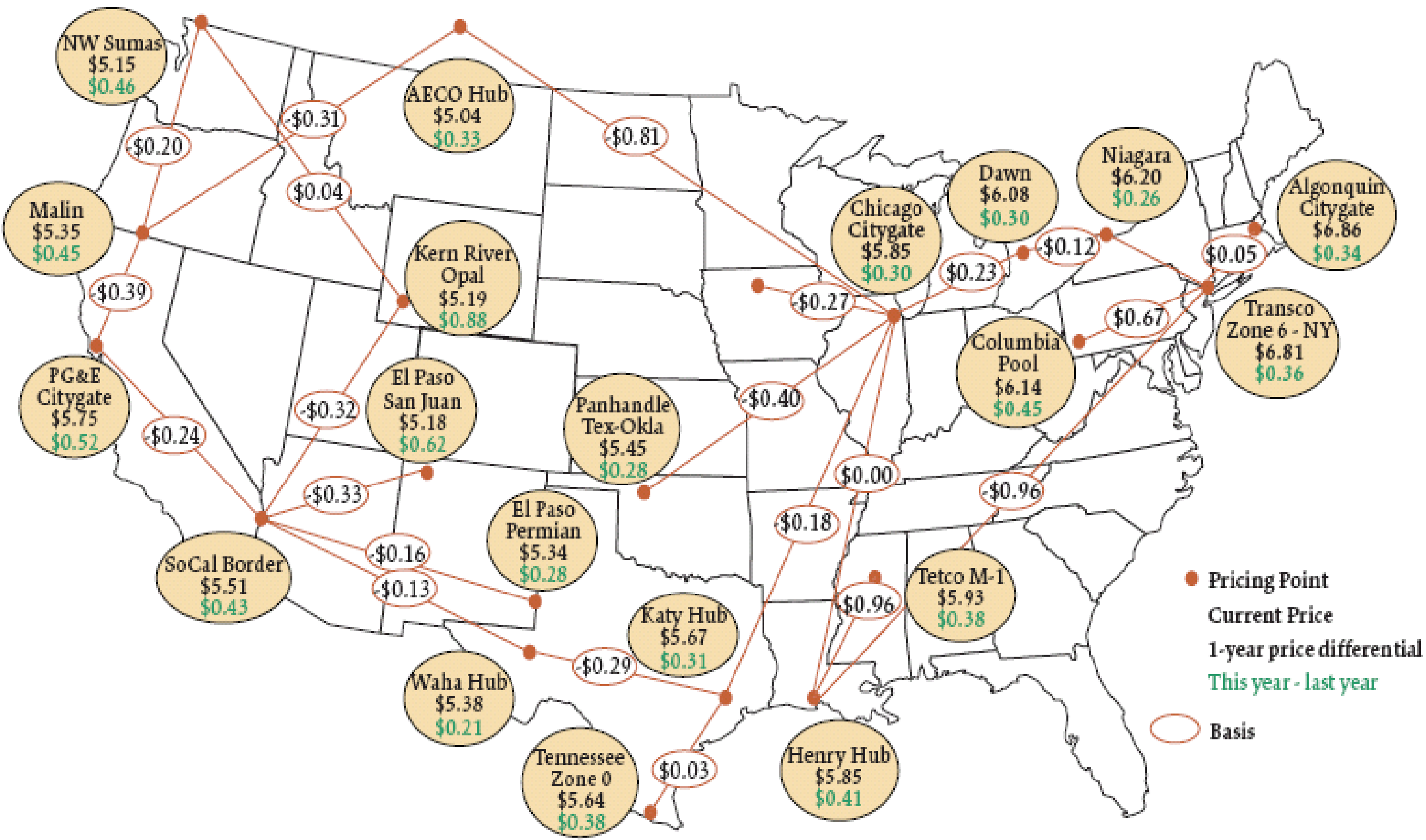
Electric price, gas price, & temperature pairs

Region	Electric Price	Gas Price	Temperature
New England	NEPOOL /Mass Hub	Algonquin City gate	Boston
New York	NYPP ZONE G	Transco Z6 NY	New York City
PJM	PJM-West	Transco Z6 Non-NY	Philadelphia

Electric Regions with Pricing Nodes On-Peak Prices ($/MWh)



2004 Locational Natural Gas Prices



Regression Model Specifications & Estimation Method

Electric Price

$= b_0$

$+ b_1$Gas price 2000 $+ b_2$Gas price 2001

$+ b_3$Gas price 2002 $+ b_4$Gas price 2003

$+ b_5$Tmean $+ b_6$Tmean^2 + Summer Dummy

$+ b_7$Year 2000 $+ b_8$Year 2001$+ b_9$Year 2002

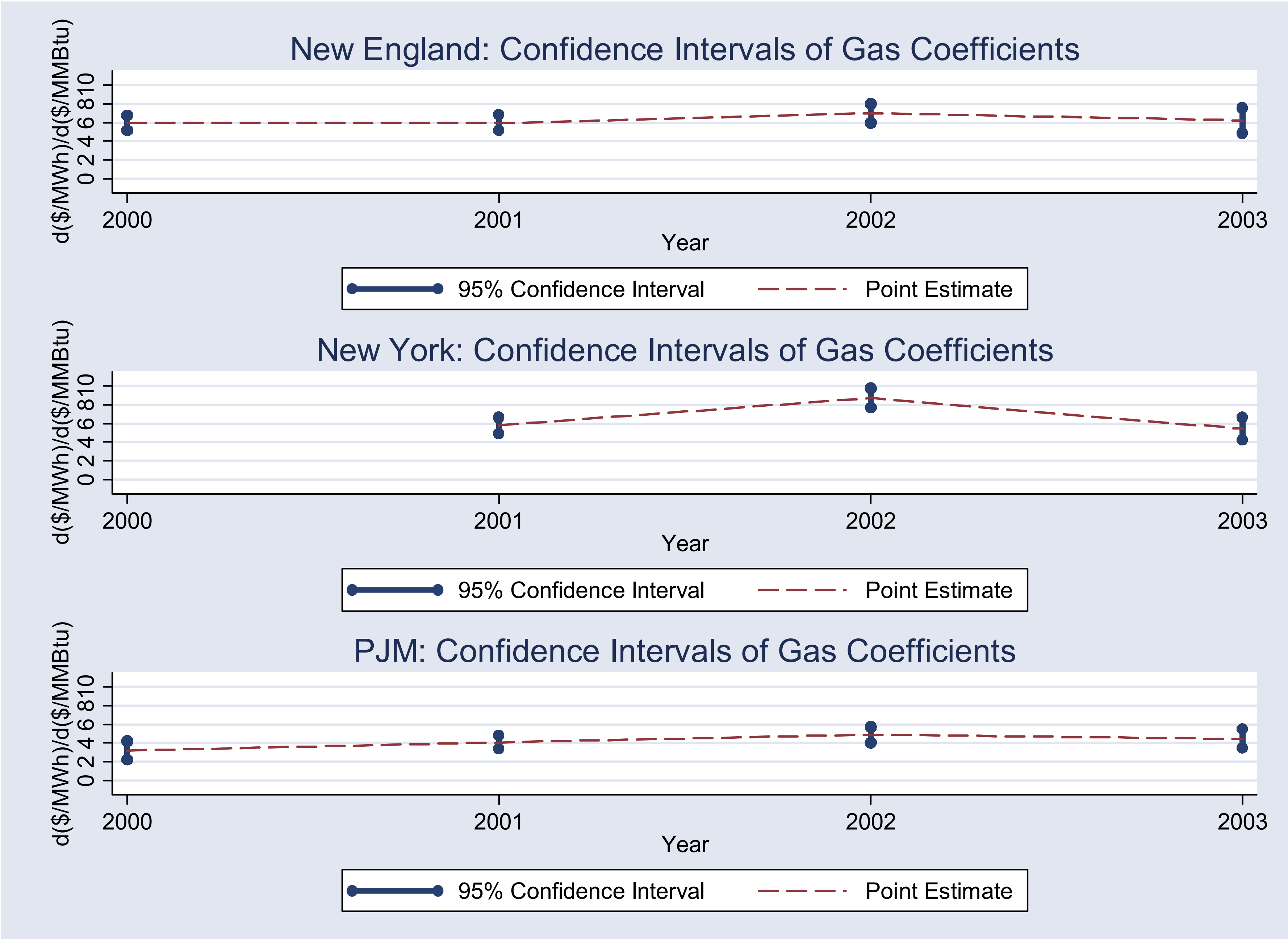
+ Disturbances

After removing significant outliers, the model is estimated applying an estimator that is robust to serial correlation & heteroskedasticity (Newey-West Estimator).

Regression Results

Variable	New_England	PJM	New_York
gas_2000	5.9354***	3.2080***	
gas_2001	5.9252***	4.0657***	5.7871***
gas_2002	6.9910***	4.8975***	8.7318***
gas_2003	6.2267***	4.4516***	5.4251***
tmean	-1.1859***	-1.4540***	-1.2317***
$tmean^2$	0.0162***	0.0167***	0.0149***
dsummer	-7.6257***	-6.2656***	-3.8133**
year2000	6.9817	4.8380	
year2001	3.9722	0.7598	-2.2457
year2002	-1.9715	-3.9747	-14.3497***
Constant	33.9725***	45.4450***	45.6413***
R^2	0.71	0.63	0.74
N	1020	1005	736

legend: * p<.1; ** p<.05; *** p<.01


New England: Confidence Intervals of Gas Coefficients
d($/MWh)/d($/MMBtu)
0 2 4 6 8 10
2000
2001
2002
2003
Year
95% Confidence Interval
Point Estimate
New York: Confidence Intervals of Gas Coefficients
d($/MWh)/d($/MMBtu)
0 2 4 6 8 10
2000
2001
2002
2003
Year
95% Confidence Interval
Point Estimate
PJM: Confidence Intervals of Gas Coefficients
d($/MWh)/d($/MMBtu)
0 2 4 6 8 10
2000
2001
2002
2003
Year
95% Confidence Interval
Point Estimate

Findings

- The regression results indicate that the marginal effect of gas prices on wholesale electric prices in the Northeast has remained roughly constant over the last several years, with an exception of New York in 2002.
- The lower marginal effect of gas prices in PJM is likely to reflect the differences in generation mix in the region.

Part II

Detection of Potentially Anomalous Wholesale Electricity Prices

- A Case for Western Electricity Prices in 2005 -

Approach

- Take into account time-varying volatility
- Model serial correlation explicitly
- Estimate the model using 2003 – 2004 data
- Compare actual electricity prices with ex-post predicted prices for out-of-sample period to detect potential anomalies in 2005

The Model (GARCH (1,1))

$$p_t^{Electric} = \beta_0 + \beta_1 P_t^{Gas} + \beta_2 T\max_t + \beta_3 T\max_t^2 + u_t$$

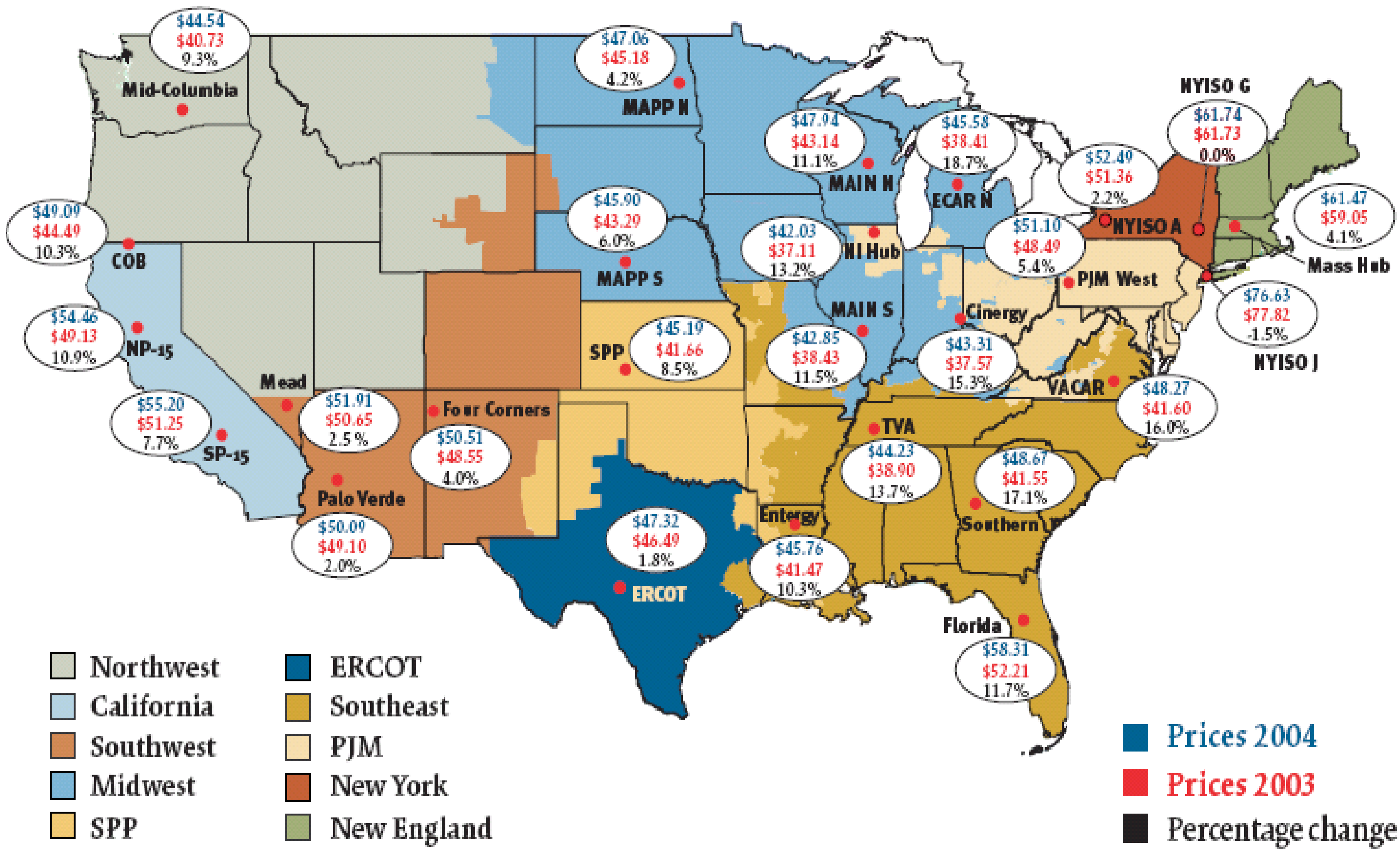
$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \rho_5 u_{t-5} + \epsilon_t$$

$$Variance\ (\sigma_t^2) = \omega + \theta\epsilon_{t-1}^2 + \lambda\sigma_{t-1}^2$$

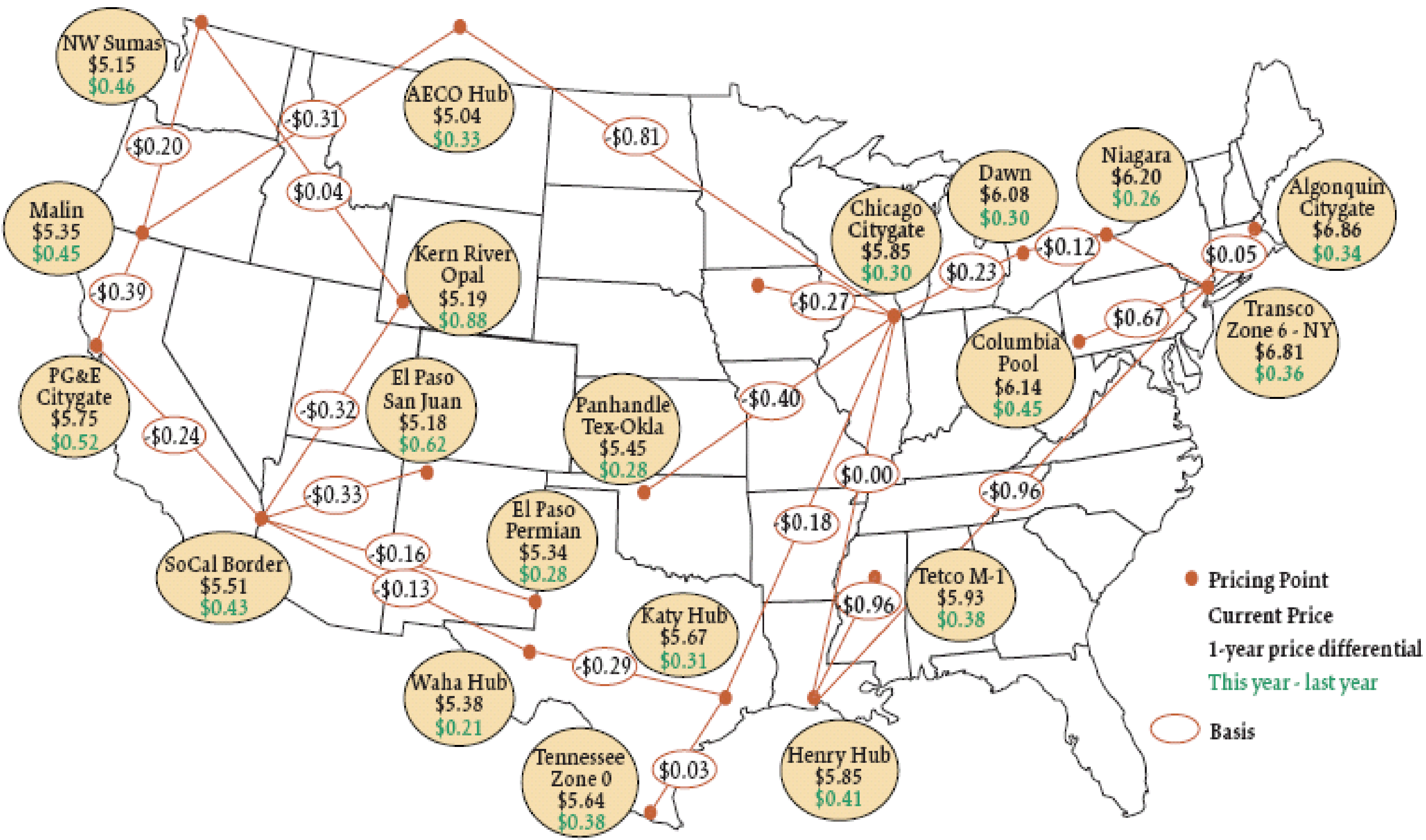
Electric price, gas price, & temperature pair

Electric Price ($/MWh)	Palo Verde
Gas Price ($/MMBtu)	SoCal Border
Temperature (degrees F)	Phoenix

Electric Regions with Pricing Nodes On-Peak Prices ($/MWh)



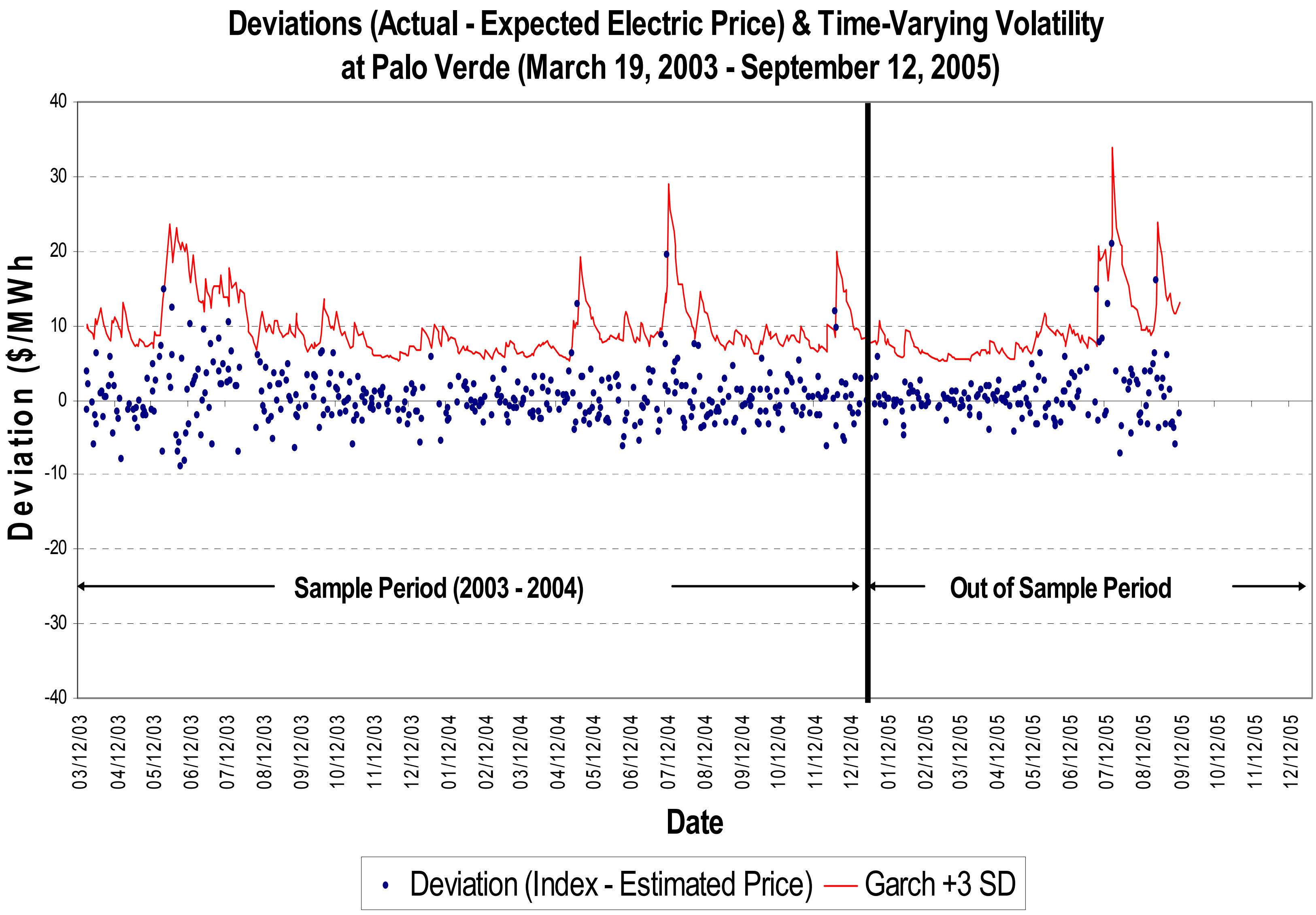
2004 Locational Natural Gas Prices



Dependent Variable: Palo Verde Electricity Price
Method: ML - ARCH (Marquardt) - Generalized error distribution (GED)
Sample (adjusted): 3/19/2003 12/30/2004
Included observations: 431 after adjustments
GARCH = C(8) + C(9)*RESID(-1)^2 + C(10)*GARCH(-1)

	Coefficient	Std. Error	z-Statistic	Prob.
C	35.44414	7.517003	4.715195	0.0000
SOCAL_GAS	7.634210	0.477091	16.00160	0.0000
PHOENIX_TEMP_MAX	-0.806452	0.152229	-5.297611	0.0000
PHOENIX_TEMP_MAX_SQ	0.005233	0.000897	5.836537	0.0000
AR(1)	0.532615	0.050129	10.62488	0.0000
AR(2)	0.150017	0.051938	2.888387	0.0039
AR(5)	0.180722	0.037386	4.833975	0.0000

Variance Equation				
C	0.625941	0.343346	1.823061	0.0683
RESID(-1)^2	0.191035	0.049480	3.860856	0.0001
GARCH(-1)	0.767920	0.059821	12.83686	0.0000
GED PARAMETER	1.465247	0.145364	10.07988	0.0000
R-squared	0.839905			
Adjusted R-squared	0.836093			
S.E. of regression	3.529652			
Durbin-Watson stat	1.775384			



Deviations (Actual - Expected Electric Price) & Time-Varying Volatility
at Palo Verde (March 19, 2003 - September 12, 2005)
40
30
20
10
0
-10
-20
-30
-40
Deviation ($/MWh)
Sample Period (2003 - 2004)
Out of Sample Period
03/12/03
04/12/03
05/12/03
06/12/03
07/12/03
08/12/03
09/12/03
10/12/03
11/12/03
12/12/03
01/12/04
02/12/04
03/12/04
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05/12/05
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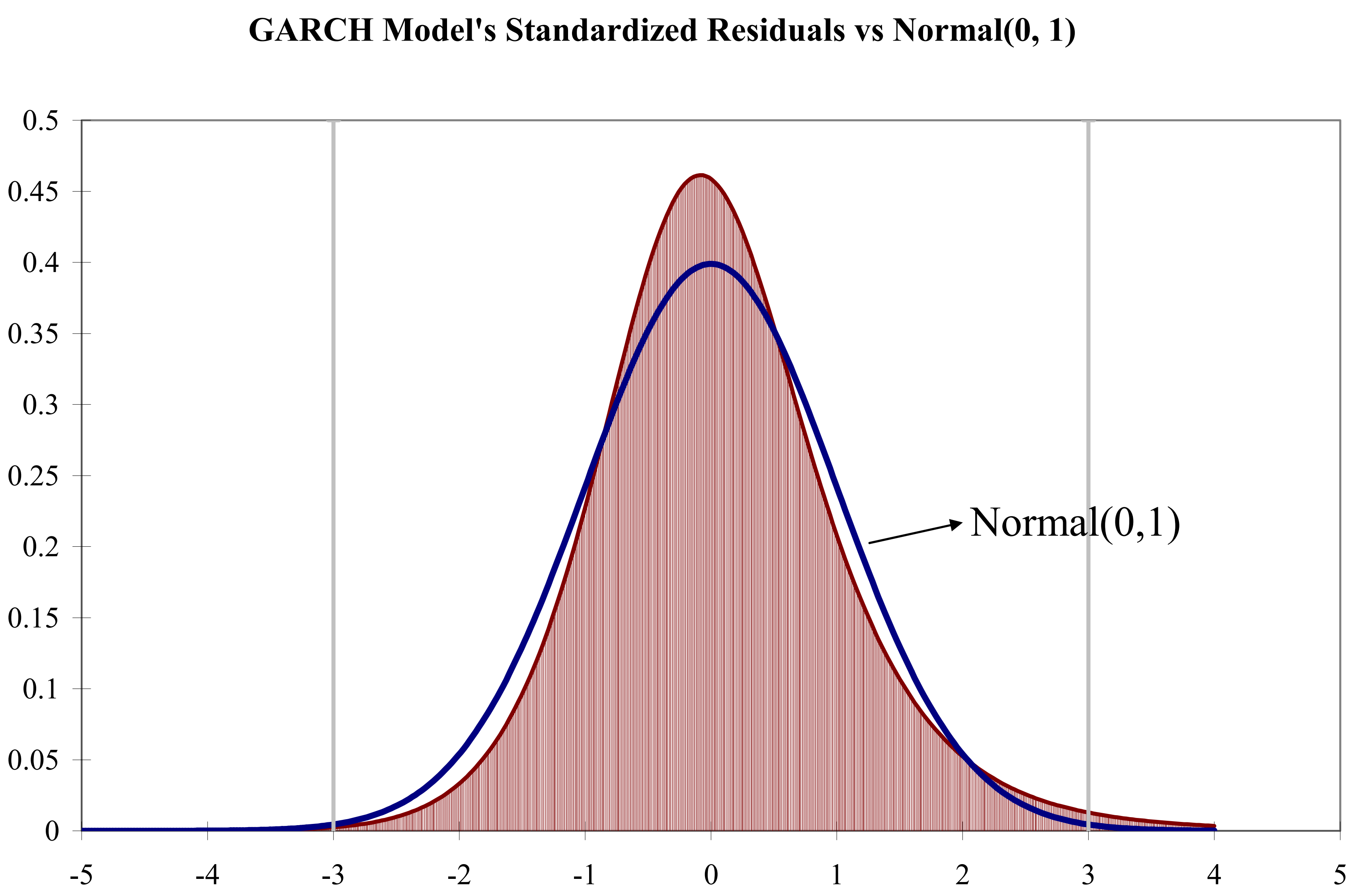
07/12/05
08/12/05
09/12/05
10/12/05
11/12/05
12/12/05
Date
Deviation (Index - Estimated Price)
Garch +3 SD

Detecting Outliers (Price at Risk)

- If disturbance is normally distributed, P(deviation>3*GARCH standard deviation) = 0.135% or less (0.35 day or less/250 days)
- If we use Standardized Residuals without normality assumption, P(deviation>3*GARCH standard deviation) = 0.908% or less (2.27 days or less/250 days)
- As of September 12, 2005, we observed 2 days during which deviation (actual – predicted price) exceeded 3*GARCH standard deviation (July 6, August 24)


GARCH Model's Standardized Residuals vs Normal(0, 1)
Normal(0,1)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-5
-4
-3
-2
-1
0
1
2
3
4
5

Next Steps

- Apply the GARCH model to the Northeast electric markets
- Explore and include other relevant explanatory variables to the model (e.g., oil price, generator availability, transmission constraints?)
- Model jump-diffusion behavior of electricity price?
- Any other suggestions for refining the model as a market-wide screening tool for the detection of potentially problematic electricity pricing behavior?