

# **Seasonal Factors and Outlier Effects in Returns on Electricity Spot Prices in Australia's National Electricity Market.**

**Stuart Thomas**

*School of Economics, Finance and Marketing,  
RMIT University, Melbourne, Australia*

11<sup>th</sup> FINSIA – MELBOURNE CENTRE  
BANKING AND FINANCE CONFERENCE

26/09/2006

# Acknowledgements

- Joint paper with Vikash Ramiah, Heather Mitchell and Richard Heaney
- Supported by Melbourne Centre for Financial Studies – Grant 18/2005
- Many thanks to Binesh Seetanah for tireless and invaluable research assistance.

# Electricity is Special

- Homogeneous commodity
  - Instantly produced and consumed
  - Unable to distinguish who produced or consumed a given unit
  - Perishable, unable to be stored
- “Non-storability” means no smoothing of demand and supply shocks
- Spot Markets clear instantly
- Market-clearing prices can be very volatile

# Brief Market History

- Historically the Australian electricity industry has been organised as state-controlled, vertically-integrated monopoly providers.
- Deregulation of Australian Electric Power markets in 1995
- “Pool” System in Wholesale Market, operated by NEMMCO
  - Originally Two Pools, VPX (Vic) and Transgrid (NSW)
  - VPX & Transgrid amalgamated with QLD, SA power systems to form NEM in 1998
  - Tas joined in May '05
  - Future plans for a WA pool (separate from NEM?)

# Electricity Value Chain

- Generation
  - Slow-start (Coal, oil & gas-fired), base load
  - Fast-start (Hydro, Geothermal), peak load
  - Generators obliged to sell into wholesale pool (over 30MW)
  - Variously under private or state ownership
- Transmission
  - “Poles & Wires”
  - each state has one state-controlled transmission business
- Distribution
  - Franchised – local grid operation & power delivery to end users
- Retail
  - Franchised - buy & sell power, read meters and issue bills

# Electricity Sales

- Proceeds from Sale determined by:
  - Spot Price
    - Wholesale pool price
  - Bilateral contracts
    - price and volume hedge contracts (futures and OTC forwards)
    - contracts for differences, (caps, floors and swaps)  
(a large component of Snowy Hydro's revenue)

# Spot price

- Spot price is a derived price, unlike spot prices in more “conventional” financial markets.
- Trading day is divided into 48 half-hourly “trading intervals”, each of which is further divided into five-minute “dispatch intervals”
- Generators submit “bids” to supply, for each dispatch interval. Bids typically made a day ahead.
- Spot price is determined based on dispatch solutions for each dispatch interval.

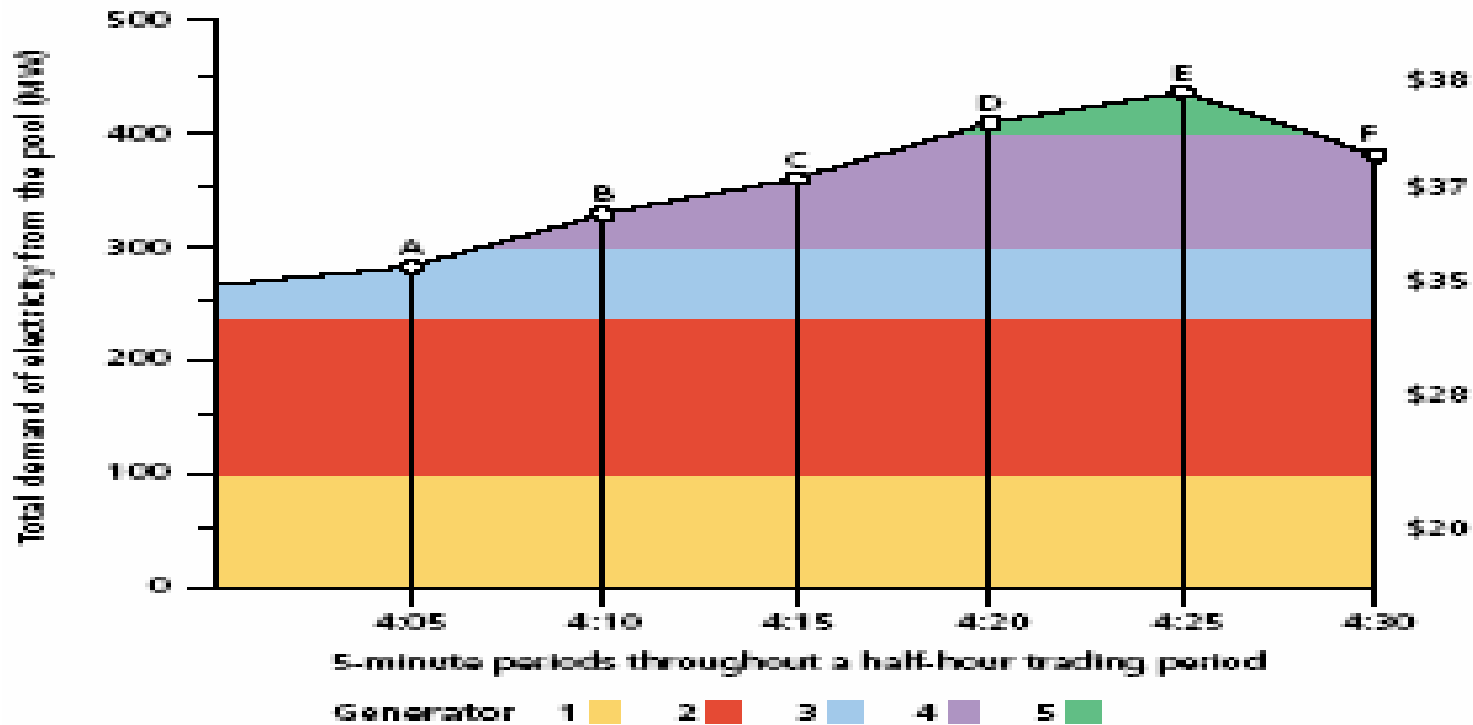
# Spot Price Determination

A two-step procedure:

- 1 A “**dispatch price**” is recorded as the marginal price of supply to meet demand for each five-minute dispatch within a given trading interval  
(marginal price is the offer price of the last generator brought into production to meet demand).
- 2 **Spot price** is calculated as the **arithmetic average of the six dispatch prices in a trading interval**. This price is paid to generators/by consumers at settlement.

# NEM Spot Price

Scheduling of NEM Generators



$$S = \frac{(\$35 + \$37 + \$37 + \$38 + \$38 + \$37)}{6} = \$37$$

# Key Literature

- Kaminsky (1997)
  - Identifies spiky characteristic, applies jump-diffusion model, adopted from Merton (1976), but ignores persistent mean-reversion in electricity prices
- Johnson and Barz (1997) and Clewlow and Strickland (2000)
  - Introduce mean-reversion to jump-diffusion. Problems with seasonalities and time-varying nature of jump size and diffusion rates
- Huisman and Mahieu (2001)
  - Regime switching - propose an isolation of two effects assuming three market regimes; a regular state with mean-reverting price, a jump regime that creates the spike and finally, a jump reversal regime back to previous normal level.

# Key Literature

- Knittel and Roberts (2001)
  - Apply mean mean-reversion, time-varying mean, jump-diffusion, time-dependent jump intensity, ARMAX and EGARCH - conclude that forecasting performance is relatively poor with standard financial models and suggest that seasonal and outlier factors should be incorporated
- Goto and Karolyi (2004)
  - Spikes in volatility
  - Volatility related to institutional features

# Key Literature

- Higgs and Worthington (2005) (NEM)
  - 5 different GARCH specs applied to half-hourly data
  - time-of-day, day-of-week and month-of-year effects significant
  - positive price spikes, early-morning, late-afternoon and early evening hours are associated with high volatility
  - negative price spikes, and other times of the day, week and year are associated with relatively lower volatility.

# Motivation for Paper

- Many studies recognise spikes and seasonalities and attempt to capture using standard financial markets techniques
- Most studies based on short samples or low-frequency data
- We attempt to identify and capture specific effects of seasonal factors, spikes and negatives over a longer term (7years) with HF (half-hourly) data.
- View to investigating causes of spikes and associated transmission mechanisms

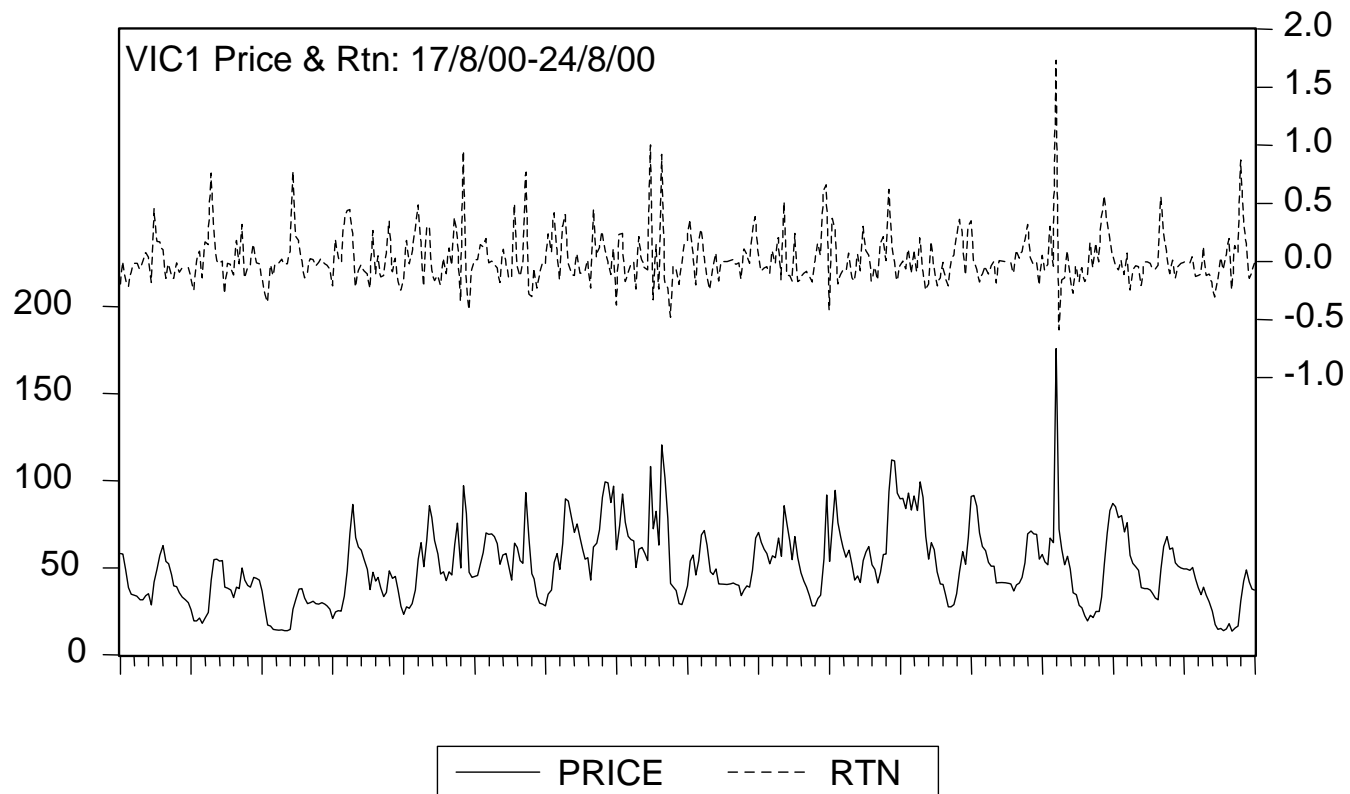
# Data Set

- Half-hourly pool price for 1/1/1999 to 31/1/2006 for 5 NEM regions:
  - VIC1,NSW1,QLD1,SA1,SNOWY1
  - 124,224 obs for each region
- Discrete returns generated as:

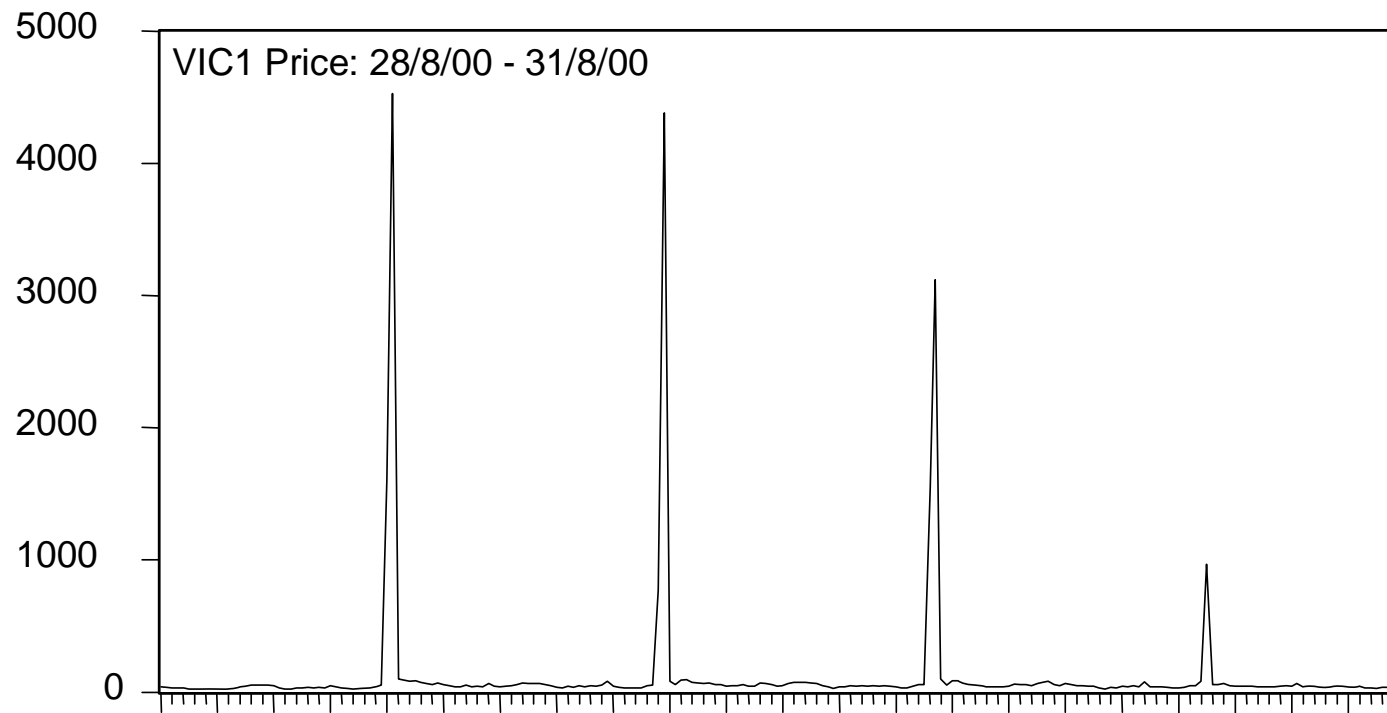
$$RET_t = \frac{(P_t - P_{t-1})}{|P_{t-1}|}$$

- Returns spikes defined as  $> \mu + 4\sigma$  or  $< \mu - 4\sigma$

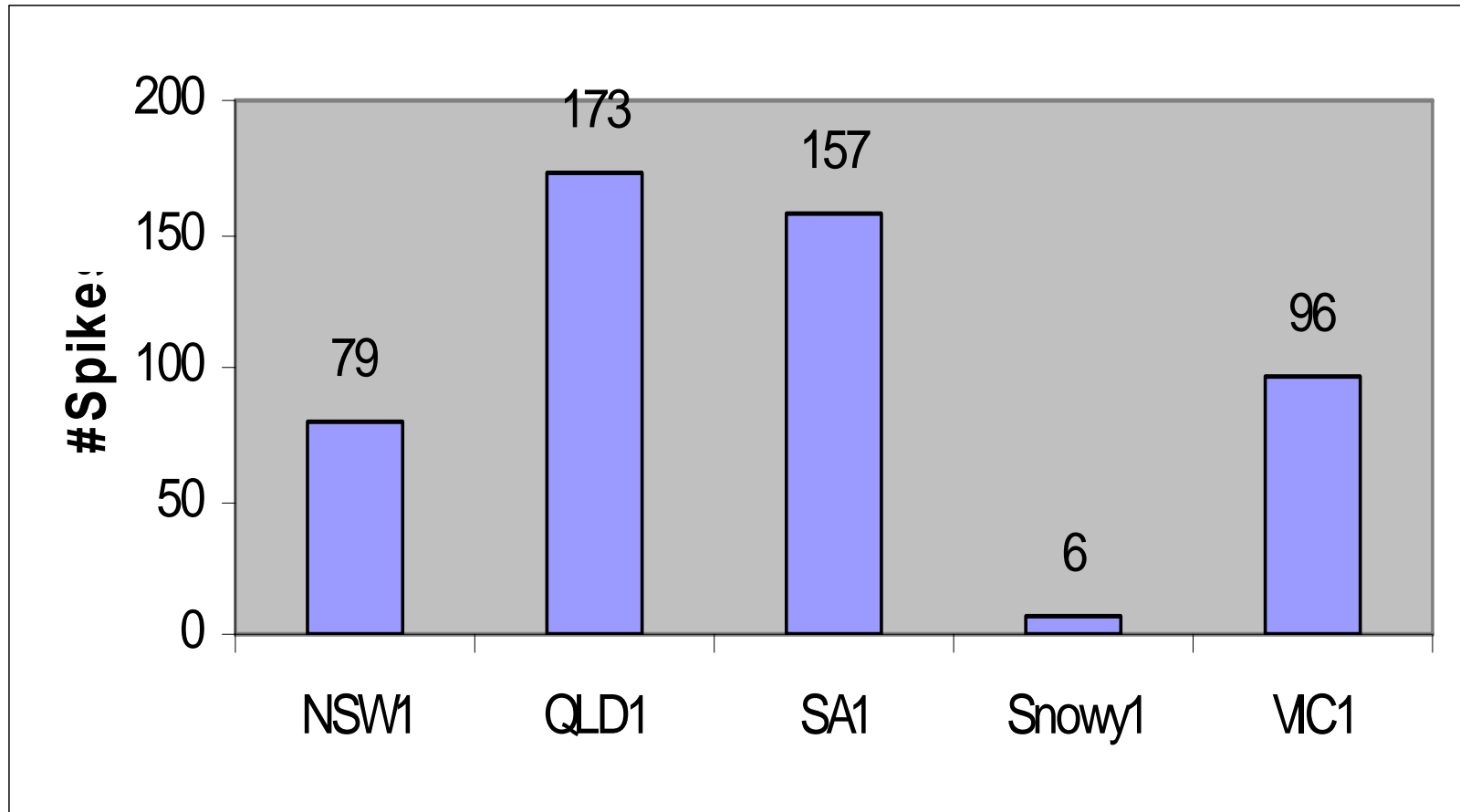
# VIC Price Series Snapshot



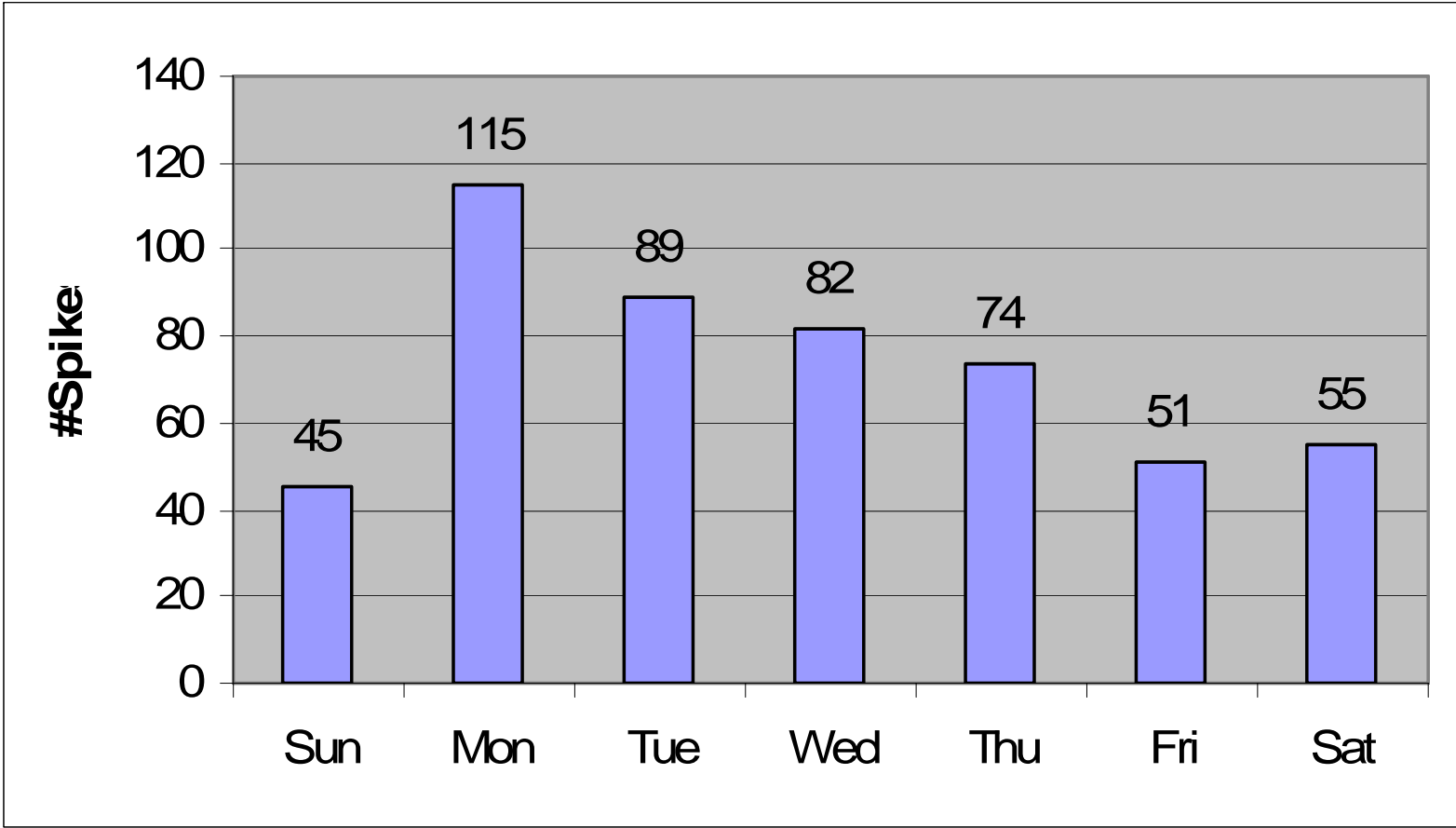
# Extreme spikes – VIC1



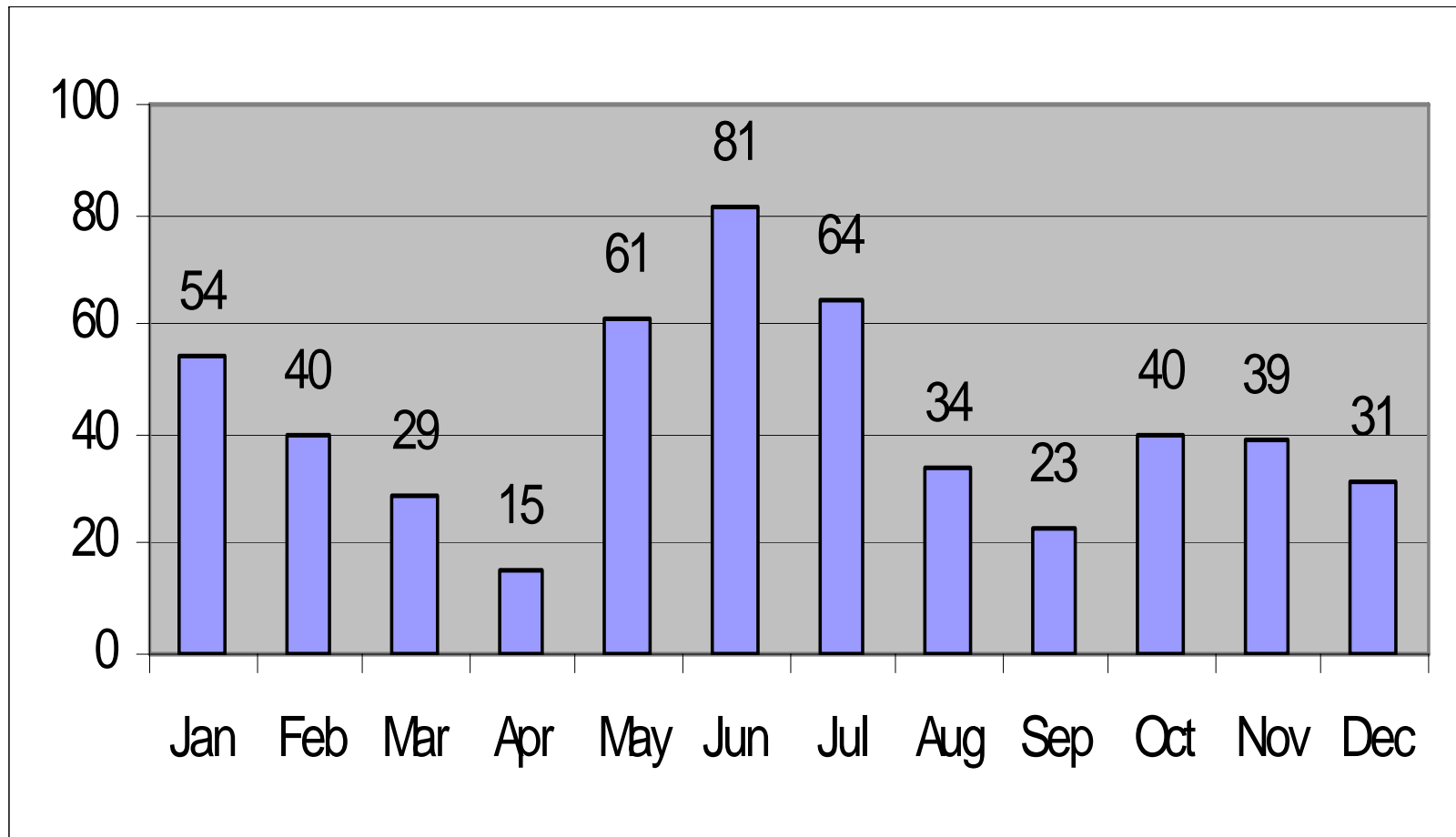
# Spike Occurrence – Region



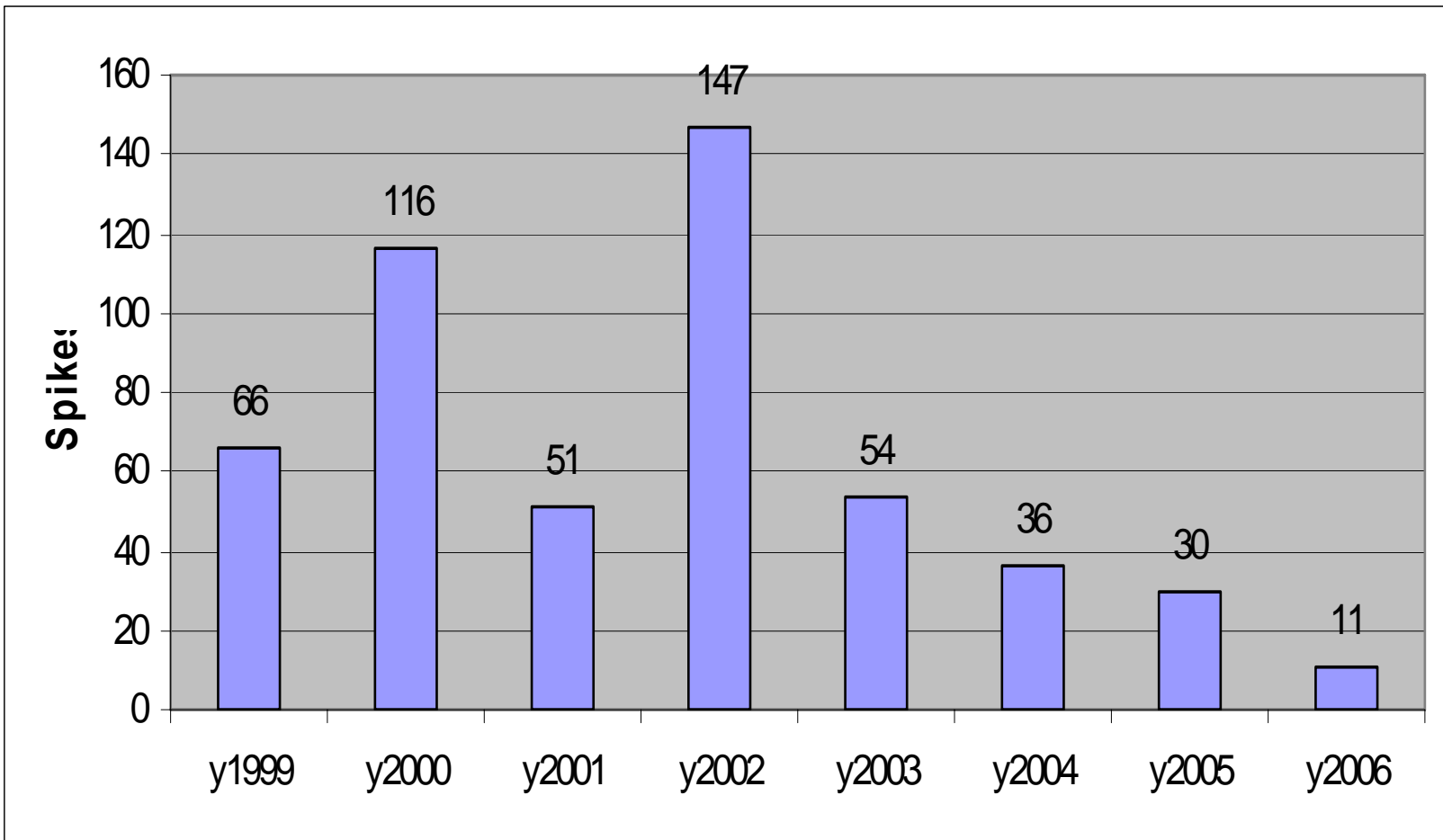
# Spike Occurrence – Day of Week



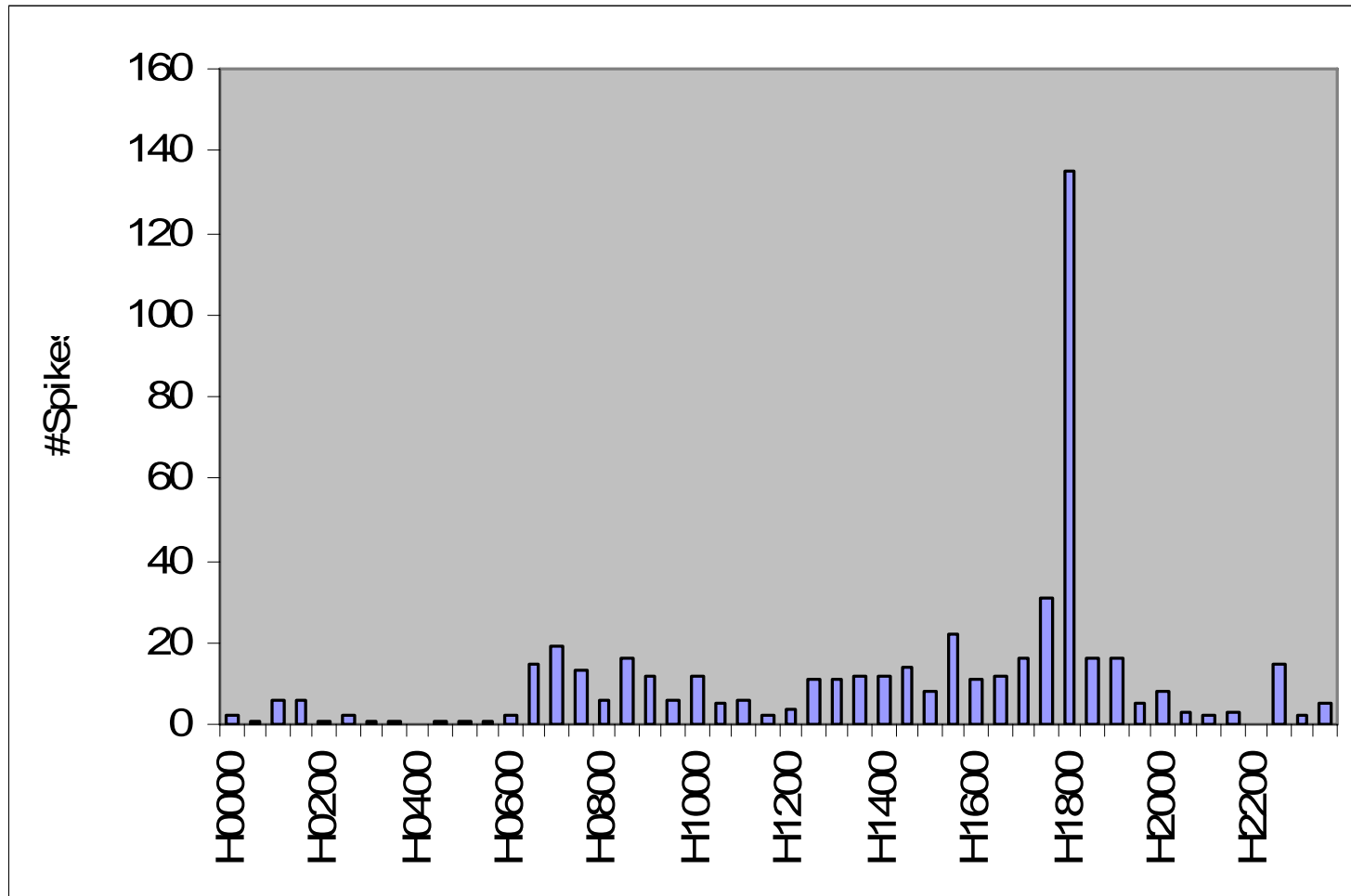
# Spike Occurrence – Month



# Spike Occurrence – Year

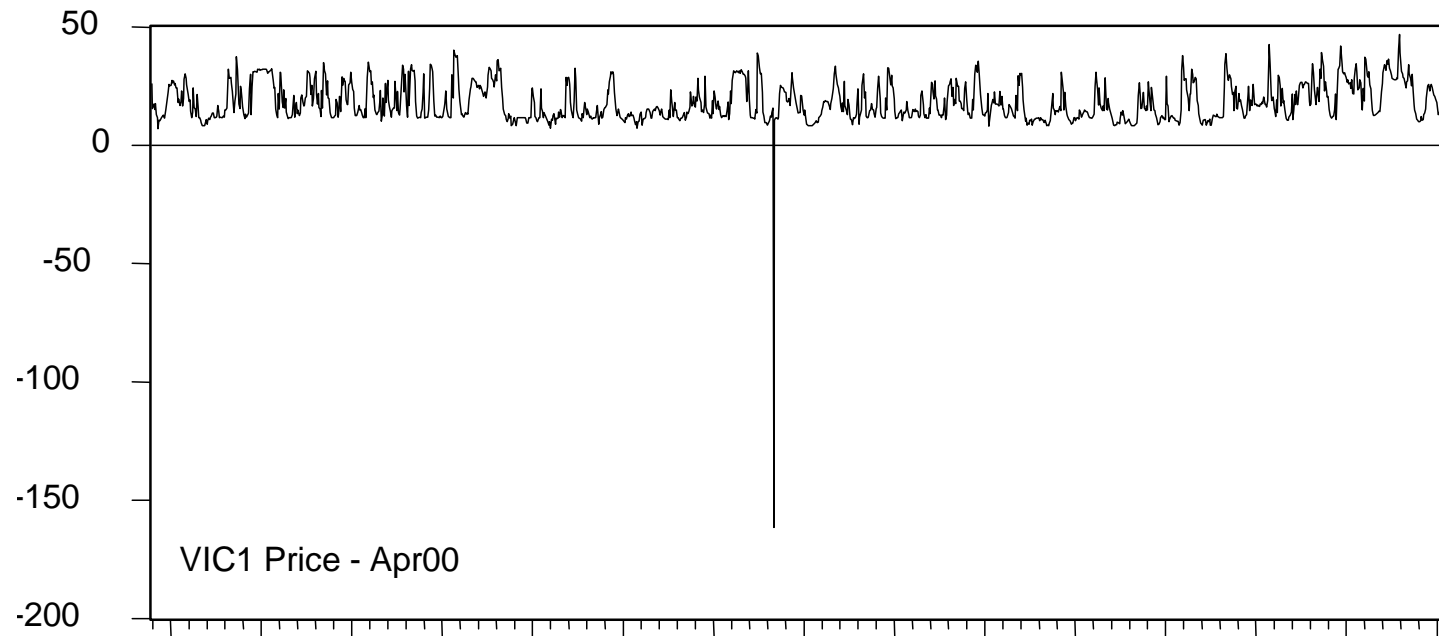


# Spike Occurrence – T.I.



# Negative Prices

(Strange but true)



VIC pool price fell to -\$161.48 at 12:30 am, 15/4/2001

# Descriptive Stats – Price

Price Series					
	NSW1	QLD1	SA1	SNOWY1	VIC1
<b>Mean</b>	34.02	36.65	41.91	31.43	30.19
<b>SD</b>	178.11	158.45	155.18	120.72	103.26
<b>Maximum</b>	9909.03	8942.60	8999.98	7500.00	6444.19
<b>Minimum</b>	-3.10	-156.14	-822.45	-3.15	-329.91
<b>Range</b>	9912.13	9098.74	9822.43	7503.15	7746.16
<b>Skewness</b>	35.37	28.56	25.40	37.12	35.38
<b>Kurtosis</b>	1468.54	1058.17	800.35	1663.18	1502.93
<b>Jarque-Bera</b>	89701	46527	26598	115071	93950
<b>ADF</b>	-36.32	-32.80	-35.14	-35.36	-36.43
<b># Observations</b>	124224	124224	124224	124224	124224

# Descriptive Stats - Price

- Highest Mean in SA1, greatest variability in NSW1
- Skewness:
  - Positive and high in all regions
- Kurtosis:
  - Very high for all regions
- J-B stats reject normality
- ADF rejects unit root

# Descriptive Stats – Returns

Returns Series					
	NSW1	QLD1	SA1	SNOWY1	VIC1
<b>Mean</b>	0.0301	0.0611	0.0603	0.0878	0.0262
<b>SD</b>	1.36	1.74	1.68	16.05	1.05
<b>Maximum</b>	231.00	369.24	390.80	4542.50	-142.43
<b>Minimum</b>	-222.00	-11.25	-32.94	-220.00	-209.50
<b>Range</b>	453.00	380.49	423.74	4762.50	351.93
<b>Skewness</b>	41.46	111.49	123.00	255.74	-15.41
<b>Kurtosis</b>	15480.38	19122.19	24820.63	66926.22	17959.48
<b>Jarque-Bera</b>	9981513	15233050	25665638	186624152	13434834
<b>ADF</b>	-41.81	-43.86	-353.92	-352.35	-42.14
<b># Observations</b>	124223	124223	124223	124223	124223

# Descriptive Stats - Returns

- Highest Mean and variability in SNOWY1
- Skewness:
  - Positive and high in NSW1, QLD1, SA1, SNOWY1 but negative in VIC1
- Kurtosis:
  - Very high for all regions
- J-B stats reject normality
- ADF rejects unit root

# Model

$$RET_{R,t} = \alpha_0 + \sum_{i=1}^5 \beta_{1,i} RET_{R,t-i} + \sum_{j=1}^6 \beta_{2,j} DAY_j + \sum_{k=1, \neq 9}^{12} \beta_{3,k} MTH_k + \sum_{l=1999, \neq 2001}^{2006} \beta_{4,l} YR_l \\ + \sum_{m=1, \neq 24}^{48} \beta_{5,m} HH_m + \sum_{o=1}^{N_{R,S}} \beta_{6,o} SPIKE_{R,o} + \sum_{p=1}^{N_{R,N}} \beta_{7,p} NEG_{R,p} + \varepsilon_t$$

- TI 1130, Sunday, September and the year 2001 were incorporated into the constant term  $\alpha$  as the base case for each respective dummy series to avoid exact collinearity.
- Base cases selected by sub-period analysis as the trading interval, day, month and year in which returns activity was consistently lowest in all five regions.

# Findings

- All spikes and negative price occurrences are statistically significant.
- Returns exhibit clear time of day effects, eg:
  - 6:30 pm effect (appears to be transient in sample)
  - 11pm effect – believed to be associated with off-peak HWS
- Marked Intraday variability:
  - significant negative returns for the small hours of the morning between 12:30 a.m. and approximately 4:00 a.m. in all regions.
  - 5:00 a.m. to 9:30 a.m. shows significant positive effect in all regions, reverting to generally negative returns in the late morning.
  - Negative returns are found in SA1 and SNOWY1 during mid-afternoon.
  - Significant positive effects are observed for all regions in the early evening, (17:00 – 19:00pm), reverting to significant negative effect for the remainder of the evening,

# Findings

- Day of week effect generally positive and significant for weekdays. With some minor variation Monday, Tuesday and Wednesday generally contribute greater influence than the other days.
- No clear pattern evident for monthly effect across regions, although:
  - Small but significant negative effect is noted for October in NSW1, SNOWY1 and VIC1.
  - Positive effects are noted for winter months in SA1
  - QLD1 demonstrates significant positive effects in spring and summer months.
- No clear pattern for year
- Lags 1,3 and 5 appear significant in most regions

# Further Work

- Replication of this study for Demand
- Examination of “spike transmission”
- Extreme Value Theory (eg Bystrom 2005)
- Regime switching?
- Intraday Markets ala Guthrie and Videbeck (2002)?
- Is ARCH really there?