

The Dynamics of Risk Premiums in Australian Electricity Futures Markets

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Outline

- **Introduction and Motivation**
- **The Australian National Electricity Market**
- **Electricity Futures Markets**
- **Empirical Analysis**
- **Conclusions and Future Work**

Introduction

Stylized facts of electricity prices

- Electricity is basically non-storable
- Prices show seasonality and mean-reverting behavior (Schwartz, 1997)
- Heteroscedasticity (Duffie and Gray, 1995)
- Electricity prices exhibit extreme volatility and price spikes (Weron, 2006; Bierbrauer et al, 2007)
- Generally complex relationship between spot and futures markets, e.g. backwardation, contango markets and significant risk premium (Stulz, 2003)
- Standard models for price behavior of financial assets need to be adjusted / extended to fit electricity price behaviour

Introduction

Research Questions

- What is the magnitude of futures premiums at different time instances, for different markets and contracts ?
What are the dynamics of futures premiums with respect to the time-to-delivery?
- What are the determinants of the observed risk premiums?

Introduction

Contributions

- First study to examine observed premiums through time across several electricity markets in Australia.
- We analyse each region and quarter separately in order to accommodate regional and seasonal properties of electricity markets.
- We investigate the behaviour and determinants of futures risk premiums in Australian electricity markets that can be considered as extremely volatile.

The Australian National Electricity Market (NEM)

- NEM includes six price regions:
 - Queensland (QLD),
 - New South Wales (NSW)
 - Victoria (VIC)
 - South Australia (SA),
 - Tasmania (TAS)
 - Aus Cap Territory (ACT)



The Australian National Electricity Market (NEM)

- Delivery periods for exchange traded futures in Australia are **quarterly** (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) and **yearly**
- Futures contracts are available for the states of NSW, VIC, SA and QLD operated by AEMO
- There are **base load** (24 hours) electricity futures and **peak load** (7am-10pm working days) electricity futures contracts available
- Contracts are priced in AUD based on delivery of 1 MW of electricity during the whole contract period

Electricity Futures Markets

Futures contracts in electricity markets

- In contrast to classical forward contracts, electricity forwards / futures refer to **delivery over a period** rather than a fixed point in time
- The **forward premium**, i.e. the difference between the forward price and the (expected) future spot price represents the compensation for facing the risk of uncertainty about future spot prices
- Storage of spot is not possible (only indirectly in water reservoirs)

Electricity Futures Markets

Ex-ante and ex-post futures premium

- Futures premium is simply calculated as the difference between futures and spot price

$$\text{PREM} = F_{t,[T_1,T_2]} - S_{[T_1,T_2]}$$

- **Ex-ante futures premium** if we use expected (model based) spot price at point in time $t < T_1$ and compare it to quoted futures price at some point in time $t < T_1$
- **Ex-post futures premium** use the realized spot price during the delivery period and calculate the premium by comparing realized spot to futures quote at some point in time $t < T_1$
- We investigate the ex-post futures premium (similar to Redl et al, 2009) using observed futures on last trading day before start of delivery period

Electricity Futures Markets

Empirical Results

Previous studies on electricity forward premium:

- **Negative and significant ex-ante premium** using one-month futures in PJM and CALPX market (Bessembiner and Lemmon, 2002, JF)
- Small positive premium for average hourly one-day ahead forward in PJM market (Longstaff and Wang, 2004, JF)
- Negative **ex-ante forward premium** for monthly, quarterly and yearly contracts at the EEX (Kolos and Ronn, 2008, EE)
- **Positive** and significant **ex-post premium** in the EEX (Redl et al, 2009, EE) using monthly and yearly futures contracts
- Positive and significant ex-post premium in EEX (Bunn and Redl, 2011) using monthly futures contracts

Empirical Analysis

The Data

- Delivery periods for exchange traded futures in Australia are **quarterly** (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) **and yearly**
- Futures contracts are available in states of NSW, VIC, SA and QLD operated at NEMMCO
- There are **base load** (24 hours) electricity futures and **peak load** (7am-10pm working days) electricity futures contracts available
- The contract is priced in AUD based on delivery of 1 MW of electricity during the whole contract period
- We cover four regions: NSW, QLD, SA and VIC and examine futures prices from Q1 2006 to Q2 2012

Empirical Analysis

Spot price behavior (daily)

Quarter 1				
Descriptive Statistics	NSW Base	QLD Base	SA Base	VIC Base
Mean	40.66	42.54	68.33	43.10
Standard Deviation	88.95	104.05	222.76	121.89
Skewness	10.91	9.97	7.36	13.70
Number of Price Spikes	160	169	267	160
Descriptive Statistics	NSW Peak	QLD Peak	SA Peak	VIC Peak
Mean	59.62	62.68	119.99	67.21
Standard Deviation	163.31	169.62	411.54	224.10
Skewness	9.30	8.83	6.10	11.55
Number of Price Spikes	143	144	242	146
Quarter 2				
Descriptive Statistics	NSW Base	QLD Base	SA Base	VIC Base
Mean	42.33	37.25	39.20	41.17
Standard Deviation	61.86	50.50	23.00	56.19
Skewness	8.82	8.20	2.33	15.78
Number of Price Spikes	152	110	40	68
Descriptive Statistics	NSW Peak	QLD Peak	SA Peak	VIC Peak
Mean	55.88	48.81	48.35	54.03
Standard Deviation	106.32	84.36	30.00	100.37
Skewness	8.00	7.54	3.04	15.02
Number of Price Spikes	125	100	31	60

Data for the period January 1, 2005 to
June 30, 2012

Empirical Analysis

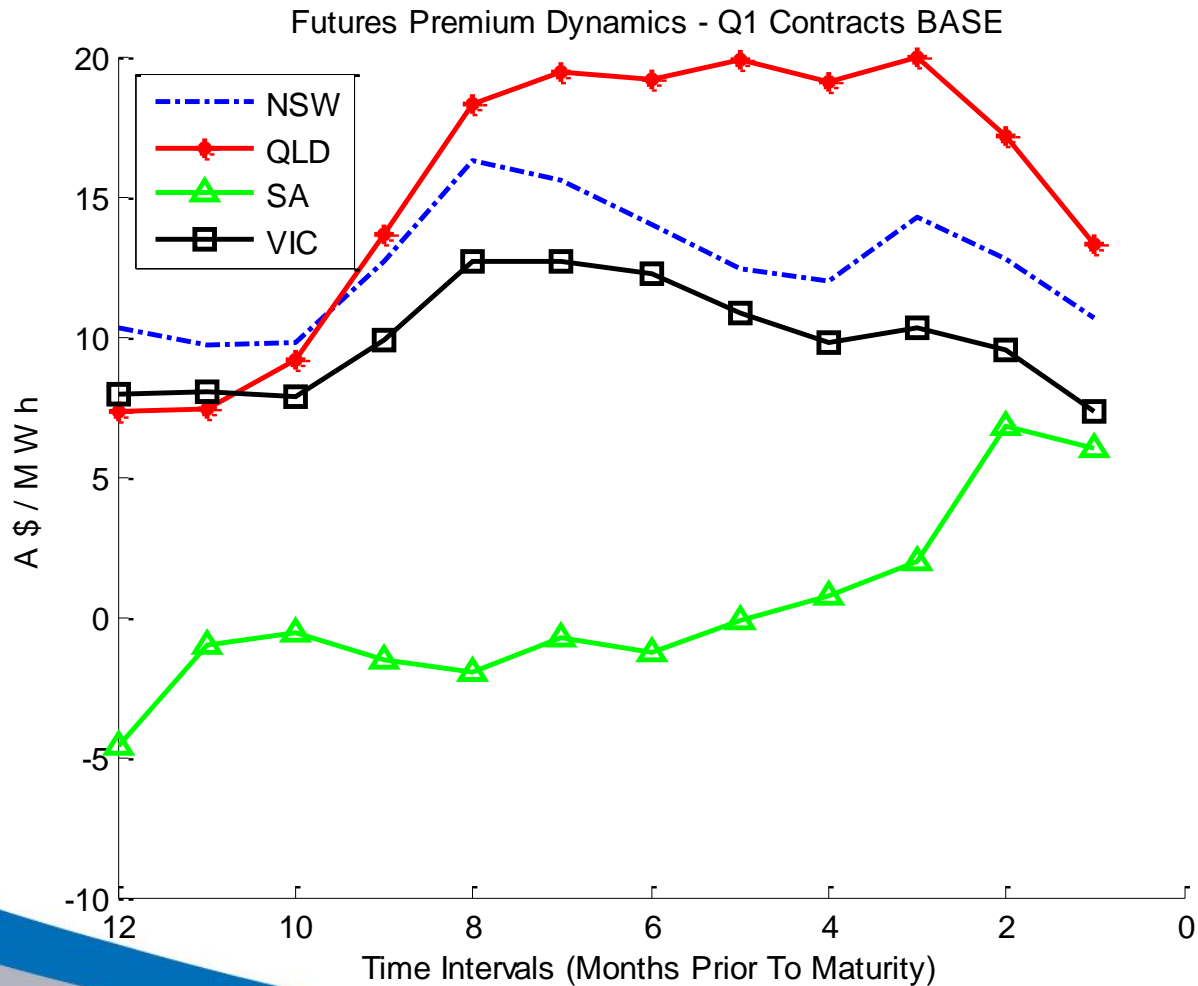
Spot price behavior (daily)

Quarter 3				
Descriptive Statistics	NSW Base	QLD Base	SA Base	VIC Base
Mean	34.61	29.65	36.39	34.46
Standard Deviation	23.29	18.39	20.83	21.10
Skewness	6.57	5.80	4.70	5.72
Number of Price Spikes	52	25	30	33
Descriptive Statistics	NSW Peak	QLD Peak	SA Peak	VIC Peak
Mean	42.63	35.97	45.22	43.32
Standard Deviation	38.83	28.95	30.47	32.72
Skewness	6.63	6.53	5.74	6.56
Number of Price Spikes	47	23	26	31
Quarter 4				
Descriptive Statistics	NSW Base	QLD Base	SA Base	VIC Base
Mean	42.81	34.38	39.95	28.51
Standard Deviation	109.68	55.96	96.51	20.30
Skewness	8.88	9.75	12.34	7.65
Number of Price Spikes	150	94	106	52
Descriptive Statistics	NSW Peak	QLD Peak	SA Peak	VIC Peak
Mean	67.08	48.51	60.81	36.97
Standard Deviation	204.18	94.00	178.70	33.62
Skewness	7.32	9.06	10.45	8.16
Number of Price Spikes	141	79	93	43

Data for the period January 1, 2005 to
June 30, 2012

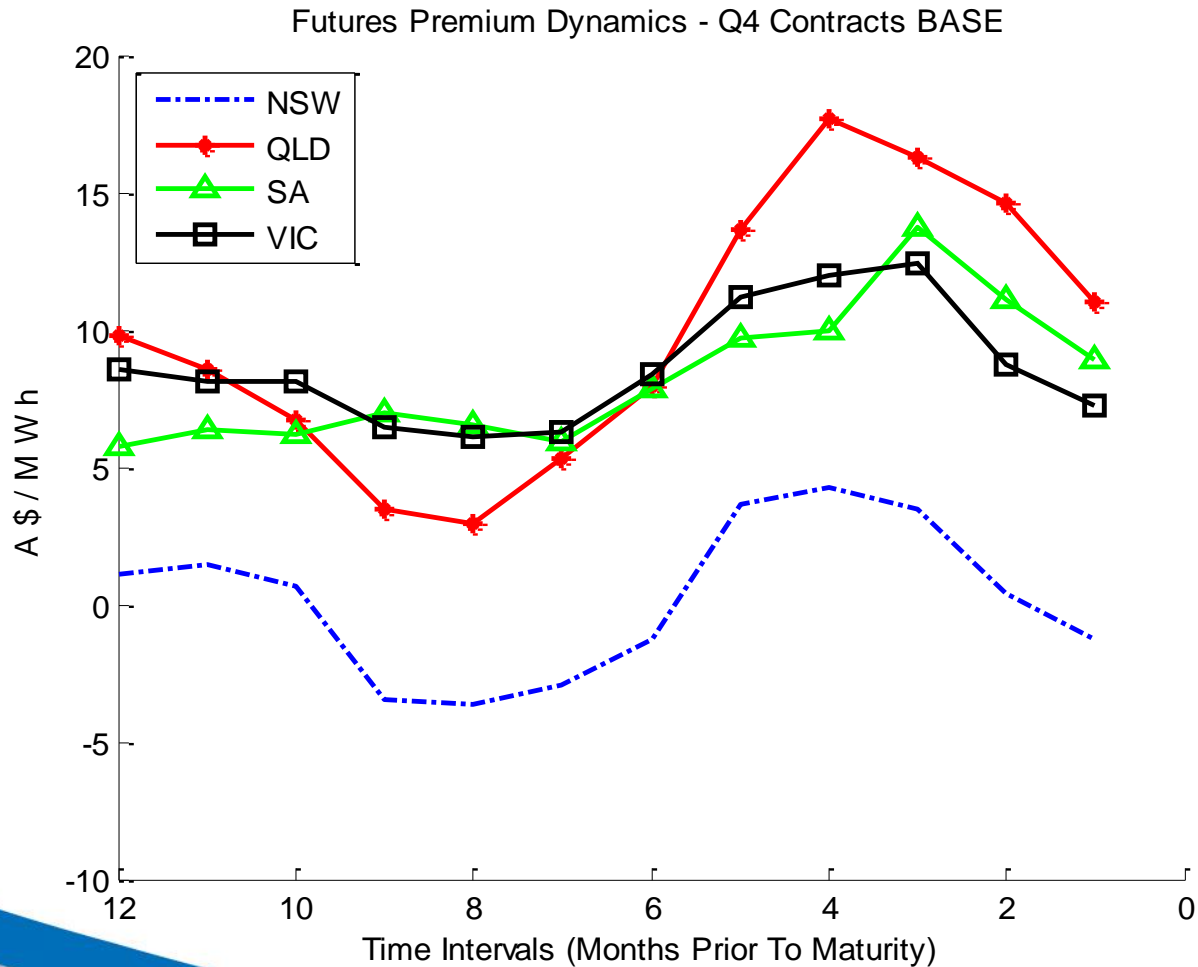
Empirical Analysis

Futures premiums dynamics



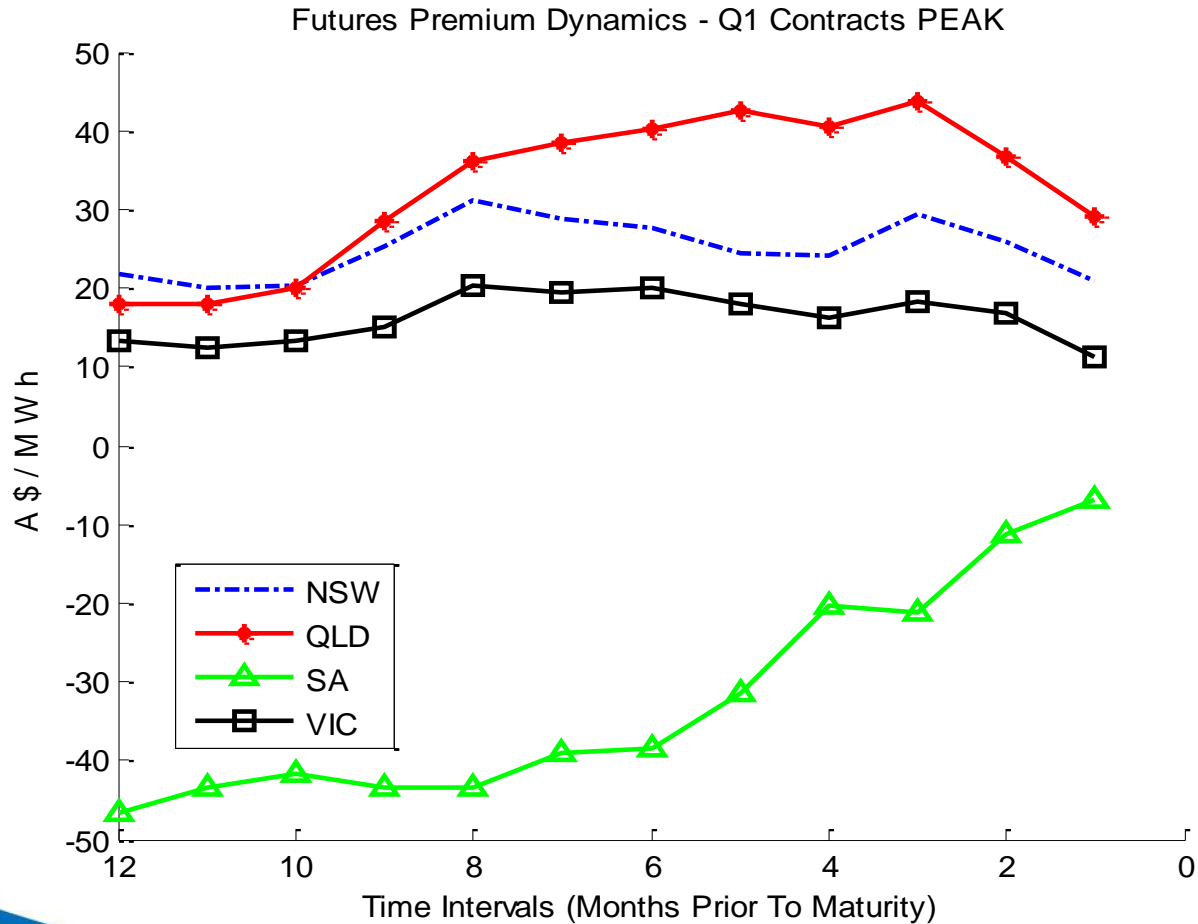
Empirical Analysis

Futures premiums dynamics



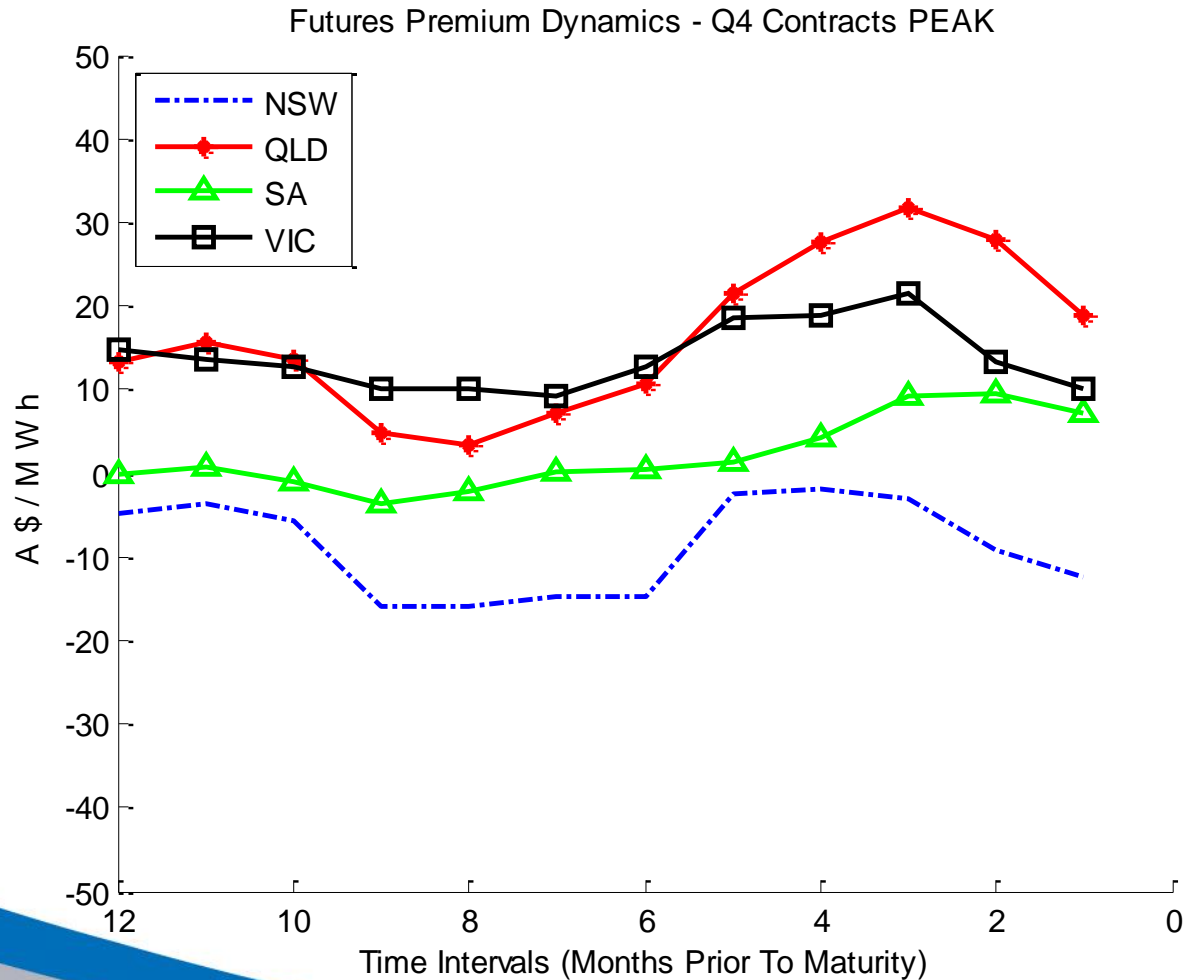
Empirical Analysis

Futures premiums dynamics



Empirical Analysis

Futures premiums dynamics



Electricity Futures Markets

Significance of premiums

- Due to the pooled data, realized risk premiums exhibit relatively high levels of autocorrelation for each contract.
- A solution to this problem is to adjust the variance, i.e. use the so-called variance inflation factor (VIF), before applying a t-test (Wilks, 1997).
- Therefore, according to Wilks (1997), we adjust the sample variance of the data by the variance inflation factor (VIF) using

$$\text{var}(x) = V \frac{s_x^2}{n} \qquad V = 1 + 2 \sum_{k=1}^{20} \left(1 - \frac{k}{n}\right) r_k$$

Empirical Analysis

Significance of premiums

QLD BASE LOAD CONTRACTS

INTERVALS	12	11	10	9	8	7	6	5	4	3	2	1
Q1 Premium	7.35	7.38	9.19	13.64	18.27	19.40	19.16	19.91	19.07	19.99	17.18	13.30
t-Stat	1.23	1.47	1.90	2.71	2.43	2.18	2.28	2.05	1.92	1.95	1.94	1.73
p-value	0.22	0.14	0.06	0.01	0.02	0.03	0.02	0.04	0.06	0.05	0.05	0.09
Number of Observations	142	141	154	135	154	148	151	156	151	153	151	141
Q2 Premium	-5.02	-4.23	-3.11	-4.31	-5.91	-5.28	-4.20	-4.42	-4.47	-5.46	-4.90	-4.25
t-Stat	-0.54	-0.40	-0.29	-0.45	-0.58	-0.54	-0.41	-0.44	-0.50	-0.58	-0.59	-0.59
p-value	0.59	0.69	0.77	0.65	0.57	0.59	0.68	0.66	0.62	0.56	0.55	0.56
Number of Observations	135	154	148	151	156	151	153	151	141	162	162	176
Q3 Premium	4.48	2.91	3.99	4.46	4.46	4.55	4.00	3.47	4.43	6.57	10.99	12.03
t-Stat	1.06	0.63	0.85	0.87	0.86	0.99	0.98	1.04	1.99	5.14	2.59	2.43
p-value	0.29	0.53	0.40	0.39	0.39	0.32	0.33	0.30	0.05	0.00	0.01	0.02
Number of Observations	130	133	129	132	129	121	142	141	154	135	154	148
Q4 Premium	9.78	8.55	6.69	3.46	2.96	5.32	7.95	13.68	17.66	16.23	14.61	11.00
t-Stat	1.85	1.97	2.49	1.36	1.37	3.78	2.99	2.54	2.14	1.81	1.89	1.63
p-value	0.07	0.05	0.01	0.18	0.17	0.00	0.00	0.01	0.03	0.07	0.06	0.11
Number of Observations	132	129	121	142	141	154	135	154	148	151	156	151

Empirical Analysis

Significance of premiums

QLD PEAK LOAD CONTRACTS

INTERVALS	12	11	10	9	8	7	6	5	4	3	2	1
Q1 Premium	17.99	17.90	20.09	28.55	36.15	38.55	40.12	42.60	40.53	43.61	36.82	29.00
t-Stat	1.64	2.14	2.27	2.92	2.51	2.22	2.28	2.06	1.96	1.92	2.00	1.76
p-value	0.10	0.03	0.02	0.00	0.01	0.03	0.02	0.04	0.05	0.06	0.05	0.08
Number of Observations	142	141	154	135	154	148	151	156	151	153	151	141
Q2 Premium	-7.82	-6.93	-5.41	-5.13	-8.41	-7.62	-6.77	-6.33	-5.85	-7.41	-6.76	-6.30
t-Stat	-0.47	-0.37	-0.29	-0.30	-0.46	-0.46	-0.37	-0.35	-0.37	-0.45	-0.47	-0.48
p-value	0.64	0.71	0.77	0.76	0.64	0.65	0.71	0.72	0.71	0.65	0.64	0.63
Number of Observations	135	154	148	151	156	151	153	151	141	162	162	176
Q3 Premium	12.82	8.44	7.75	8.97	9.83	10.28	9.93	9.06	9.74	10.64	18.87	19.37
t-Stat	1.87	1.34	1.29	1.23	1.31	1.50	1.63	2.10	3.16	6.16	2.98	2.89
p-value	0.06	0.18	0.20	0.22	0.19	0.14	0.11	0.04	0.00	0.00	0.00	0.00
Number of Observations	130	133	129	132	129	121	142	141	154	135	154	148
Q4 Premium	13.41	15.69	13.73	4.71	3.38	7.15	10.60	21.39	27.69	31.82	27.85	18.75
t-Stat	2.11	2.27	3.16	0.95	0.71	1.50	1.76	2.18	1.92	1.55	1.56	1.23
p-value	0.04	0.03	0.00	0.35	0.48	0.13	0.08	0.03	0.06	0.12	0.12	0.22
Number of Observations	132	129	121	142	141	154	135	154	148	151	156	151

Electricity Futures Markets

Determinants of Realized Futures Premiums

- Time-varying risk premium (Bailey and Ng, 1991; Bessembinder and Chan, 1992; Wilkens and Wimschulte, 2007; Bhar and Lee, 2011; Gorton et al., 2012)
- Spot price level (Chevillon and Riffart, 2009; Wilkens and Wimschulte, 2007)
- Volatility of spot market (Bessembinder and Lemmon, 2002; Douglas and Popova, 2008; Lucia and Toro, 2008; Redl et al. 2009, Todorov, 2010)
- Price spikes (Redl and Bun, 2013; Coulon et al., 2013)

Electricity Futures Markets

Determinants of Realized Futures Premiums

- The model

$$RP_{t,[T_1,T_2]} = \beta_0 + \beta_1(T_1 - t) + \beta_2\bar{S}_t + \beta_3\sigma_t + \beta_4\sigma_t^2 + \beta_5PS_t + \varepsilon_t$$

$RP_{t,[T_1,T_2]}$ is the realized risk premium

$(T_1 - t)$ is the remaining time to the beginning of the delivery period

\bar{S}_t is the one-year moving average of daily spot price at time t

σ is the volatility estimate for daily spot electricity prices at time t based on an EWMA model with $\lambda = 0.94$.

PS is the number of price spikes exceeding \$300 during the month prior to t .

Empirical Analysis

Regression Results - BASE

BASE PERIOD							
QUARTER 1							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-10.95 (-4.96)	-3.38 **) (-2.36)	0.62 ***) (13.37)	-0.01 (0.00)	-13.38 ***) (-3.05)	0.37 ***) (12.61)	0.20
QLD	-24.46 (-16.70)	-11.56 ***) (-9.70)	1.25 ***) (43.01)	7.01 (1.59)	-23.35 ***) (-6.44)	0.39 ***) (10.78)	0.56
SA	19.68 (4.61)	-12.11 ***) (-4.61)	-0.43 ***) (-7.50)	16.85 *) (1.69)	17.34 **) (2.43)	-0.80 ***) (-7.37)	0.09
VIC	5.71 (3.20)	1.06 (0.81)	0.56 ***) (15.62)	-90.57 ***) (-13.35)	59.88 ***) (9.52)	0.89 ***) (14.80)	0.25
QUARTER 2							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-55.05 (-13.25)	-0.25 (-0.09)	1.36 ***) (16.19)	-42.93 ***) (-4.55)	46.21 ***) (5.86)	0.07 (1.25)	0.14
QLD	-35.87 (-10.61)	-1.45 (-0.53)	0.95 ***) (16.40)	-18.54 **) (-1.99)	15.35 **) (2.12)	0.18 **) (2.52)	0.15
SA	-20.99 (-10.55)	-4.21 ***) (-3.27)	0.56 ***) (21.37)	-19.71 ***) (-4.22)	12.71 ***) (3.87)	-0.13 **) (-2.51)	0.22
VIC	-14.74 (-5.81)	-6.45 ***) (-3.72)	0.81 ***) (16.51)	-89.84 ***) (-9.54)	63.73 ***) (7.38)	0.34 ***) (4.18)	0.16

Empirical Analysis

Regression Results - BASE

QUARTER 3							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-10.22 (-6.90)	-7.84*** (-8.60)	0.47*** (16.05)	5.94 * (1.72)	-8.12*** (-2.86)	0.19*** (10.33)	0.24
QLD	-8.15 (-6.52)	-8.36*** (-8.67)	0.42*** (17.89)	5.98 (1.62)	-5.31 * (-1.80)	0.21*** (7.07)	0.24
SA	-17.07 (-12.63)	-5.88*** (-7.21)	0.65*** (34.50)	-29.84*** (-9.40)	14.67*** (6.46)	0.10*** (3.02)	0.46
VIC	-15.59 (-11.12)	-6.92*** (-7.76)	0.79*** (29.54)	-33.44*** (-6.74)	17.93*** (3.94)	0.31*** (7.25)	0.39
QUARTER 4							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-7.15 (-2.86)	-1.73 (-1.04)	0.31*** (6.06)	-38.67*** (-6.75)	28.98*** (6.00)	0.54*** (16.31)	0.19
QLD	-10.80 (-8.03)	-12.33*** (-9.90)	0.60*** (22.44)	9.62 ** (2.29)	-7.18 ** (-2.17)	0.47*** (13.87)	0.39
SA	-13.72 (-5.32)	-10.65*** (-6.41)	0.46*** (12.98)	10.85 * (1.73)	-2.46 (-0.55)	0.11 * (1.72)	0.14
VIC	-7.03 (-8.69)	-2.63*** (-4.56)	0.48*** (29.13)	-11.64*** (-3.70)	1.64 (0.57)	0.51*** (18.56)	0.48

Empirical Analysis

Regression Results - PEAK

PEAK PERIOD							
QUARTER 1							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	17.92 (4.43)	0.63 (0.23)	0.27*** (4.74)	-19.04** (-2.34)	-17.60*** (-3.27)	1.18*** (17.39)	0.20
QLD	-59.54 (-20.28)	-20.75*** (-8.19)	1.68*** (40.46)	81.48*** (9.75)	-82.56*** (-13.15)	0.88*** (10.81)	0.56
SA	37.83 (3.76)	-62.25*** (-7.77)	-0.94*** (-11.17)	74.83*** (3.07)	27.12 (1.63)	-3.91*** (-9.57)	0.14
VIC	25.30 (7.03)	6.59** (2.19)	0.50*** (9.17)	-174.91*** (-14.90)	106.51*** (10.75)	2.19*** (14.37)	0.21
QUARTER 2							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-52.85 (-7.37)	-3.71 (-0.72)	1.20*** (12.06)	-103.81*** (-7.29)	71.55*** (7.54)	0.30** (2.42)	0.10
QLD	-28.76 (-5.23)	-12.72*** (-2.85)	1.14*** (16.53)	-114.40*** (-8.12)	71.19*** (6.80)	0.60*** (4.45)	0.15
SA	-18.80 (-9.06)	-7.25*** (-4.27)	0.51*** (29.09)	-47.27*** (-9.66)	35.84*** (10.59)	-0.73*** (-8.55)	0.36
VIC	-16.70 (-4.80)	-10.46*** (-3.90)	0.86*** (16.23)	-127.71*** (-11.45)	72.45*** (7.55)	0.76*** (5.11)	0.19

Empirical Analysis

Regression Results - PEAK

QUARTER 3							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	6.93 (3.09)	-8.75 *** (-6.30)	0.25 *** (8.59)	-6.73 (-1.52)	-4.96 * (-1.73)	0.50 *** (14.71)	0.18
QLD	-7.72 (-4.39)	-10.28 *** (-7.68)	0.43 *** (18.87)	5.43 (1.15)	-8.42 ** (-2.39)	0.46 *** (10.28)	0.26
SA	-17.04 (-10.77)	-4.42 *** (-4.10)	0.41 *** (34.45)	-25.65 *** (-7.23)	14.45 *** (6.04)	-0.08 (-1.43)	0.45
VIC	-20.08 (-9.56)	-10.77 *** (-8.06)	0.84 *** (30.67)	-44.99 *** (-7.58)	21.34 *** (4.36)	0.46 *** (6.24)	0.43
QUARTER 4							
REGION	Intercept	Time to Maturity	Spot Price Level	Volatility	Variance	# of Price Spikes	Adj - R ²
NSW	-9.37 (-1.47)	-2.02 (-0.48)	0.38 *** (4.46)	-104.77 *** (-8.56)	65.25 *** (8.01)	1.30 *** (12.88)	0.14
QLD	-16.04 (-5.94)	-18.71 *** (-8.11)	0.84 *** (22.40)	-17.91 *** (-2.37)	4.50 (0.79)	1.37 *** (18.61)	0.39
SA	-14.67 (-2.95)	-22.52 *** (-5.60)	0.06 (1.44)	68.52 *** (5.57)	-28.47 *** (-3.41)	-0.14 (-0.67)	0.04
VIC	-14.63 (-10.22)	-3.77 *** (-3.61)	0.61 *** (29.18)	-14.09 *** (-3.15)	0.21 (0.06)	1.01 *** (17.82)	0.49

Conclusions

- We find that futures premiums are statistically significant and are generally higher as a contract is closer to the beginning of the delivery period.
- The magnitude and significance of the observed premiums, however, varies significantly for different regions and even more for contracts referring to different delivery periods.
- We suggest that there are strong seasonal effects and time-variation in futures risk premiums for regional Australian electricity markets.
- We find that futures premiums tend to increase with
 - (i) a reduction in the time to the beginning of the delivery period of the contract,
 - (ii) recent spot price levels, and
 - (iii) the frequency of price spikes in the spot market.

Conclusions

- We find some support for the convex relationship between risk premiums and volatility in the spot market that has been initially suggested by Bessembinder and Lemmon (2002).
- However, the results vary quite significantly across the examined quarters and regions.

Future Work

- An analysis of ex-ante premiums should also be of significant interest to market participants and would complement our analysis using a different perspective.
- Applying robust regression analysis using panel data.