ELECTRICITY FUTURES MARKETS IN AUSTRALIA
AN ANALYSIS OF RISK PREMIUMS DURING THE DELIVERY PERIOD

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Agenda

1. Introduction
2. Australian Electricity Market
3. Futures Risk Premiums
4. Empirical Analysis
5. Conclusion
1. Introduction
NEM operation

- The Australian National Electricity Market [NEM] operates as a Gross Pool market. All electricity delivered is traded through the market; including volume subject to bilateral agreements.
- NEM operates as a constrained real-time market. Stacked five-minute bids are matched to demand. The last increment of supply determines the dispatch price for that five-minute period.
- Bids for five-minute periods are submitted to AEMO daily by 12:30 PM on the day prior. Daily Rebidding is allowed up to about 5 min before despatch. The quantity can be changed but not the offer price.
- NEM is one of the most volatile electricity markets.
- Half-hourly price = average of 6 x five-minute period prices.
- Daily price = average of 48 x half-hourly prices.
- Market Price Cap = $13,500 per MWh (2014-15) thereafter indexed by CPI.
- Market Price Floor = - $1,000 per MWh.
Literature Findings on Premiums

- Generally complex relationship between spot and futures prices, markets often exhibit significant risk premiums
- Very different results with respect to sign and magnitude of risk premiums
- Negative and significant ex-ante premiums using one-month futures in PJM and CALPX market (Bessembinder 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 ex-ante premium for the first six months and negative for maturities over 6 months (Bierbrauer et al., 2007, JBF)
- Positive and significant ex-post premium in the EEX (Redl et al, 2009, EE) using monthly and yearly futures contracts
- Good overview in Weron and Zator (2014, EE)
Risk premiums in Australian electricity futures markets

- Note that in the following we define the futures risk premium as the difference between quoted futures price at time $t$ and the average realized spot price during the delivery period:

$$\pi_{t,[T1,T2]} = F_{t,[T1,T2]} - \bar{S}_{[T1,T2]}$$  (1)

- Handika and Truck (2013) suggest typically positive risk premiums in the Australian electricity futures market.

- On the last trading day prior to the beginning of the delivery period, market participants on average paid an additional $22,943 per purchased Q1 base load futures contract in QLD.

- However, premiums depend heavily on the considered delivery quarter, and are typically high and positive for Q1 and Q3, while they are often negative for Q2.
Research questions

- Are there also significant futures risk premiums during the delivery period of the futures contract?
- If yes, how do ex-post futures risk premiums behave during the delivery period of the contract?
- Can we explain the futures premium using information from historical electricity spot and futures price behavior together with recent behaviour of electricity spot prices market characteristics such as open interest & trading volume?
- What are the dynamics of the futures premium with respect to the remaining time to maturity of the contract?
Contribution

• One of the first studies to investigate risk premiums in extremely volatile Australian electricity futures markets
• First study to focus on the behavior of premiums during the delivery period of the contract
• We relate futures premium can to the behavior of spot prices in previous quarters and more recent spot price behavior (for example, spot price level, realised volatility, skewness)
• Provide important insights into these dynamics
2. Australian Electricity Market
The National Electricity Market

NEM Regions:
1. Queensland
2. New South Wales
3. Victoria
4. South Australia
5. Tasmania
• Snowy abolished on
  1 July 2008

The regions are connected by
Transmission Line
Interconnectors
3. Futures Risk Premiums
Relationship between commodity spot and futures prices

Cost-of-carry approach

• Based on the no-arbitrage condition between spot and futures prices (Kaldor, 1939)

\[ F_{t,T} = S e^{c(T-t)} \]

Where \( c \) denotes the cost of carry

• Since electricity is non-storable, it is very difficult to apply no-arbitrage theory (see e.g. Pirrong and Jermakyan, 1999; Eydeland and Geman, 1999; Longstaff and Wang, 2004)

Equilibrium approach

• Based on the equilibrium relationship of forward pricing. (Keynes, 1930; Bessembinder and Lemmon, 2002)

\[ F_{t,T} = E(S_T) + E(\pi) \]

• where \( E(\pi) \) denotes the expected value of the risk premium

The equilibrium approach seems more suitable to investigate futures premiums in electricity markets
Premium defined

\[ \pi_{t,[T_1,T_2]} = F_{t,[T_1,T_2]} - \bar{S}_{[T_1,T_2]} \]  \hspace{1cm} (2)

\( T_1 = \text{Start of delivery} \)
\( \text{e.g. 1}\textsuperscript{st} \text{ Jan} \)

\( T_2 = \text{Expiry} \)
\( \text{e.g. 31}\textsuperscript{st} \text{ Mar} \)

Delivered Portion
\( k_1 \text{ MWh} \)
\[ \text{[Certain]} \]

Undelivered Portion
\( k_2 \text{ MWh} \)
\[ \text{[Risky]} \]

Equation 3 gives the value of the undelivered portion of the futures contract in $/MWh

\[ \bar{Q}_{[t+1,T_2]} = \frac{1}{k_2} \left[ (k_1 + k_2)F_{t,[T_1,T_2]} - k_1\bar{S}_{[T_1,t]} \right] \]  \hspace{1cm} (3)

Equation 4 expresses the premium in the (remaining) undelivered period in $/MWh

\[ \pi_{[t+1,T_2]} = \bar{Q}_{[t+1,T_2]} - \bar{S}_{[t+1,T_2]} \]  \hspace{1cm} (4)
4. Empirical Analysis
Average daily prices
Base load NSW July 2003 to June 2014

Data in the study period
July 2007 to June 2014
Premium – Base load
NSW - July 2007 to June 2014

Chart 1
Premium for Base load as a percentage of the corresponding average spot price for the three States of NSW (solid line), Qld (dashed line) and Vic (dotted line)

Negative premium for Q2 Vic and Q4 NSW. However, they are not significantly different than zero
Premium – Peak load

NSW - July 2007 to June 2014

Chart 2
Premium for Peak load as a percentage of the corresponding average spot price for the three States of NSW (solid line), Qld (dashed line) and Vic (dotted line)

No negative premiums
Explanatory variables

- The level of participation in the market
  - Volume
  - Open Interest
- Time remaining to expiry
- The average spot price of prior periods
  - Average of the same quarter in the previous 3 years
  - Average of the previous 28 days (month)
  - Average of the previous week
- Higher moments of the spot price for the above mentioned periods – Standard deviation, skewness & kurtosis
- The number of spikes in the half-hourly spot price
  - In the previous 28 days (month)
  - In the previous week
  - Spike taken to be prices > $300/MWh corresponding to a cap product available on the futures market
- The average premium of the same quarter in the previous 3 years
- Emission scheme, with a dummy variable indicating the years when a federal emission scheme was in effect
- Dummy variables for State – NSW as base
- Dummy variable for Financial Year (1 July to 30 June) – year ending 30 June 2012 as base
Methodology

• We analyse each of base load and peak load for each quarter separately
• Run univariate regression of the premium vs each of the candidate variables to obtain a shortlist of significant variables
• Check for multicollinearity among the shortlisted variables
• Fit a multiple regression model for base load and estimated parameters separately for each quarter
• Analyse premiums on days where an actual trade occurred in the electricity futures market (indicated by volume being >0)
• There are no instruments traded for Tasmanian electricity on the futures electricity market. Tasmania is not considered in the analysis of premium.
• Additionally, the number of trades in the futures market for South Australia, particularly for the peak contract, are few. We have therefore chosen to exclude South Australia from the Analysis as well.
Multiple regression model

BASE LOAD

\[ \pi_{t,T_2} = \beta_0 + \beta_1(OI) + \beta_2(T2-t) + \beta_3(m.SD) + \beta_4(w.Spot) + \beta_5(3yr.P) + \delta_1(FY08) + \delta_2(FY09) + \delta_3(FY10) + \delta_4(FY11) + \delta_5(FY13) + \delta_6(FY14) + \theta_1(Qld) + \theta_2(Vic) \]

• One model for base with parameters estimated separately for each quarter
• Larger open interest leads to lower premium - speculation Bessembinder and Lemmon (2002) - except in Q4
• The further away from expiry, the higher the premium in Q1 & Q3 but the opposite effect in Q2 and Q4 i.e. the premium is higher closer to expiry. Matches the sign of the univariate regression coefficient (explained next).
• The premium is higher when volatility in the previous month is higher (risk aversion)
• The premium is higher when the average price level in the previous week is higher (risk aversion)
• The premium is negatively related to the average premium of the same quarter in the previous three years (indicating learning)
## Model parameters

**BASE LOAD**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Base load Q1</th>
<th>Base load Q2</th>
<th>Base load Q3</th>
<th>Base load Q4</th>
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<td>Coeff</td>
<td>Sig</td>
<td>Coeff</td>
<td>Sig</td>
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<td>5.91***</td>
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<td>-1.90**</td>
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<tr>
<td><strong>T2-t</strong></td>
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<td>-0.04***</td>
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<td><strong>m.SD</strong></td>
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<td>6.52</td>
<td>0.01</td>
<td>0.92</td>
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<td><strong>w.Spot</strong></td>
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<td>0.03**</td>
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*Dummy variables for years and States*

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Daily spot price average and std dev by month

CHART 3
Average (dotted line) and standard deviation (solid line) of daily spot price for base load by month in the sample period July 2007 to June 2014 in NSW

Q2 & Q4
Premium goes up as we near expiry of the quarterly contract because of the higher volatility of the last month relative to the quarter.
Q2 has higher magnitude than Q4 and is significant at the 0.01 level
Actual vs modeled premium

Base load Adjusted $R^2 = 0.72$

**CHART 5**

Premium remaining to expiry. Actual (solid line) vs Model (dotted line) for base load in Q3
Multiple regression models

PEAK LOAD

Peak load model

\[ \pi_{[t+1,r2]} = \beta_0 + \beta_1(T2 - t) + \beta_2(m.SD) + \beta_3(w.Skew) + \delta_1(FY08) + \delta_2(FY09) + \delta_3(FY10) + \delta_4(FY11) + \delta_5(FY13) + \delta_6(FY14) + \theta_1(Qld) + \theta_2(Vic) \]

- Overall, higher adjusted r2 for the peak model than for the base model
- Time to expiry and volatility of the previous month common with base load
- Negative coefficients in all quarters for time to expiry; matches the sign of the univariate regression coefficients
- Skewness is significant at the 0.10 level in Q1, 2 & 4. Q3 –ve (low volatility).
- Terms relating to open interest, spot level of the previous week and average of premium of the same quarter in the previous three years are absent

Base load model

\[ \pi_{[t+1,r2]} = \beta_0 + \beta_1(OI) + \beta_2(T2 - t) + \beta_3(m.SD) + \beta_4(w.Spot) + \beta_5(3yr.P) + \delta_1(FY08) + \delta_2(FY09) + \delta_3(FY10) + \delta_4(FY11) + \delta_5(FY13) + \delta_6(FY14) + \theta_1(Qld) + \theta_2(Vic) \]
Due to a clear trend in the residuals of the peak model we employ a shifted Box-Cox transformation. The shift was only needed for Q1 & Q2 (ie zero for Q3 & Q4).

As noted in the Box & Cox (1964 paper) the analysis of variance is not altered by a linear transformation.

Shifted Box & Cox transformation.

\[
y^{(\lambda)} = \frac{(y + \lambda_2)^\lambda_1 - 1}{\lambda_1} \quad (\lambda_1 \neq 0)
\]
Daily spot price
average and std dev by month

CHART 6
average (dotted line) and standard deviation (solid line) of daily spot price for peak load by month in the sample period July 2007 to June 2014 in NSW
Actual vs modeled premium

peak load $Adjusted R^2 = 0.55$

CHART 7

Premium remaining to expiry. Actual (solid line) vs Model (dotted line) for peak load in Q1
5. Conclusions
Findings – ex-post premium

BASE LOAD

- We find that the current daily premium during delivery of base load contracts varies negatively with Open Interest (OI) except in Q4;
- that it reduces as we draw closer to expiry, except for Q2 and Q4 as explained earlier in the presentation with reference to Chart 3;
- that the standard deviation of the prior month (four weeks) and the average spot price of the prior week both influence the premium positively as expected;
- that it varies negatively with the average premium of the same quarter over the previous three years, indicating a form of learning and
- that the premium in Qld and Vic is higher relative to NSW in the higher demand quarter Q4 but lower in the lower demand quarter Q2.
- These findings emphasize the strong dependency of the premium on seasonal factors and specific characteristics of the Australian market.
Findings – ex-post premium

PEAK LOAD

- For peak load the premium varies negatively with time to expiry of the contract;
- positively with the standard deviation of the prior month;
- positively with skewness of the previous week, except in Q2 as explained earlier in the presentation;
- that most of the financial years are higher than the base financial year 2011/12 except for FY 2009/10 and FY 2010/11 (FY10 & FY11 respectively) and
- Victoria has a lower premium relative to NSW except in Q1 where it is higher
- Queensland has only one quarter where the difference from NSW is significant showing a lower premium (all the other quarters were positive but not significant).
- There was no indication of dependence on longer term variables in the peak model which emphasises the greater influence of short term factors for peak compared to base load.
Conclusions

• Some of our findings agree with the literature in this area such as our finding of a positive coefficient of the standard deviation term which is in line with what was reported, among others, by Bessembinder and Lemmon (2002), Longstaff and Wang (2004), Redl et al (2009) and Redl and Bunn (2013) concerning the spot price variation term (variance in their case).

• Also while our finding of positive coefficients for time to maturity in Q1 and Q3 is in line with what is reported in Diko et al. (2006) we provide an explanation, supported by market data, of the negative sign for this coefficient in Q2 and Q4 based on the characteristics of the National Australian Electricity Market regions that we analyze; as discussed above.

• The models we propose comprise parameters that are based on accessible data pertaining to prior periods. Therefore they have potential to be widely incorporated into a strategy to manage exposure to electricity prices, in the markets studied, using Futures Electricity Contracts.
Future work

• Develop a model to extend the work to ex-ante premium using fundamental factors to explain risk premiums (demand, weather, commodity prices, etc) particularly over the medium term
• Extend the proposed models to a more fully developed hedging approach (potentially incorporating value at risk)
• Model dependence structure between risk premiums across regional markets
Thank you
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