The Relationship between Spot and Futures Prices: an Empirical Analysis of Australian Electricity Markets

Rangga Handika, Stefan Trück

Macquarie University, Sydney

Abstract

This paper presents an empirical analysis of the relationship between spot and futures prices in regional Australian electricity markets. Based on economic theory, we expect that the forward prices will be related to the expected spot price according to fundamental market expectations. Examining ex-post futures premiums, we find that Australian electricity markets exhibit positive and significant risk premiums for several of the considered regions such that futures prices cannot be considered as an unbiased estimator of the future spot price. We also show that there is strong and positive correlation between the observed futures premiums across different regional markets in Australia. The price formation in the considered markets seems to be influenced by historical spot price behaviour. Further investigating the issue, we find that for some of the markets the bias can at least partially be explained by the level, standard deviation, skewness and kurtosis of spot prices in the month prior to delivery.

Keywords: *Electricity Markets, Spot and Futures Prices, Risk Premium, Regional Markets*

1. Introduction

The deregulation of electricity markets worldwide has led to a significant change in the market structure from monopoly to liberalized markets. With the introduction of power exchanges, as pointed out by Shawky et al. (2003), the behaviour of electricity market prices now tends to be much more affected by the nature of how electricity is produced and consumed: inelastic demand, seasonal effects, and the non-storability of electricity. As a consequence, electricity as a flow commodity exhibits price behaviour that is almost unique in financial markets. Electricity spot prices can be characterized by mean-reversion, seasonality, extreme volatility and short-lasting but quite pronounced price spikes, see e.g. Lucia and Schwartz (2002), Weron (2006), Bierbrauer et al. (2007), Kanamura and Ohashi (2008), Karakatsani and Bunn (2008). Lucia and Schwartz (2002) suggest that electricity is strongly characterised by its very limited transportability and storability. Given the extremely volatile behaviour of electricity spot prices, market participants are required to hedge these risks at least partially by entering electricity forward and futures contracts. As pointed out in early studies on electricity forward markets (Bessembinder and Lemon, 2002; Longstaff and Wang, 2004), the non-storability of electricity limits the standard no-arbitrage approach in modelling electricity futures prices: inventories cannot be used to smooth out electricity supply and demand shocks (Bowden and Payne, 2008). Therefore, as argued by many authors the dynamic relationship between electricity spot and futures prices reflects expectations about future supply and demand characteristics for electricity as well as risk aversion amongst agents with heterogeneous requirements for hedging the uncertainty of future spot prices (Shawky et al., 2003).

This paper represents a pioneering study on examining the relationship between spot and futures prices in regional electricity markets in Australia. While there is some existing work on the Australian National electricity market (NEM), see e.g. Worthington et al. (2005), Higgs and Worthington (2008), Becker et al (2007), Higgs (2009), Thomas et al (2011), these authors usually concentrate on the behaviour of electricity spot prices in Australia. Therefore, the relationship between spot and futures prices across different regional markets in Australia has not been investigated yet. However, an analysis of these markets is of particular interest due to a number of reasons: first, as pointed out by Higgs and Worthington (2008), Australian electricity markets can be considered as being significantly more volatile and spike-prone than other comparable markets. Second, the Australian NEM operates on one of the world's longest interconnected power systems comprising several regional networks providing supply of electricity to retailers and end-users. As a consequence, an analysis of the relationship between spot and futures prices may provide important insights on explaining risk premiums and risk aversion of market participants in extremely volatile markets. Therefore, this study focuses on the futures premium, defined as the excess of the futures price over the expected realized spot price in the considered markets. Using an extended version of the general equilibrium model initially suggested by Bessembinder and Lemon (2002), we also examine whether the bias in electricity forward prices can be explained by the behaviour of the spot price during periods previous to the delivery.

The remainder of this paper is organised as follow. Section 2 provides a brief overview on spot and futures trading in the Australian NEM. Section 3 reviews other empirical work on examining the relationship between electricity spot and futures markets and explains the theoretical framework adopted in this paper. Section 4 describes the data and discusses the empirical results. Section 5 concludes.

2. The Australian Electricity Market

The Australian electricity market has experienced significant changes during the last two decades. Prior to 1997 the market consisted of vertically integrated businesses operating in each of the states and there was no connection between the individual states. The businesses were owned by the government and used to operate as monopolies. Overall, there were twenty-five electricity distributors being protected by the government from competition. To promote energy efficiency and reduce the costs of electricity production, in the late 1990s the Australian government commenced a significant structural reform which, among others, had the following objectives: the separation of transmission from electricity generation, the merge of twenty-five electricity distributors into a smaller number of distributors, and the functional separation of electricity distribution from the retail supply of electricity. Also retail competition was introduced through the electricity reform: state's electricity purchases could be made through the competitive retail market and customers were now free to choose their retail supplier.

As a wholesale market the National Electricity Market (NEM) in Australia began operating in December 1998. It is now an interconnected grid comprising several regional networks which provide supply of electricity to retailers and end-users. The NEM includes the states of QLD, NSW, VIC, SA and the ACT while TAS is connected to the state of VIC via an undersea inter-connector. The link between electricity producers and electricity consumers is established through a pool which is used to aggregate the output from all generators in order to meet the forecasted demand. The pool is managed by the Australian Energy Market Operator (AEMO) which follows the National Electricity Law and is in conjunction with market participants and regulatory agencies. Unlike many other markets, the Australian spot electricity market is not a day-ahead market but electricity is traded in a constrained real time spot market where prices are set each 5 minutes by AEMO. Therefore, generators submit offers every five minutes. This information is used to determine generators required to produce electricity in a more cost-efficient way based on the existing demand. The final price is determined every half-hour for each of the regions as an average over the 5-minute spot prices for each trading interval. Based on the half-hourly spot prices, also a daily average spot price for each regional market can be calculated. AEMO determines the half-hourly spot prices for each of the regional markets separately.

In recent years, also market for electricity derivatives has developed rapidly including electricity forward, futures and option contracts. Anderson et al (2007) note that there are three types of the Australian electricity forward contracts: (i) Bilateral over-the-counter (OTC) transaction between two entities directly, (ii) Bilateral over-the-counter (OTC) transaction on standard products executed through brokers, and (iii) Derivatives traded on the Sydney Futures Exchange (SFE). In our study we will concentrate on futures contracts traded in the SFE during the time period 2003-2010. Note that the SFE also offers a number of alternative derivatives including option contracts or $300 cap products that will not be considered in this study.

Like in almost every electricity exchange, futures contracts traded in the SFE refer to the average electricity price during a delivery period. Thus, for a base period futures contract the contract unit is one Megawatt of electricity per hour (MWH) for each hour from 00:00 hours to 24:00 hours over the duration of the contract. For a quarterly base load contract, the size (in MWH) will vary depending on the number of days within the quarter. For example, for a quarter with 90 days, a contract refers to 2,160 MWH during the delivery period while for a quarter with 92 days, a contract refers to 2208 MWH. Next to base load futures contracts, also peak period contracts are being traded. Given that electricity prices show strong intra-day variation and are heavily affected by its demand in every precise moment (Lucia and Schwartz, 2002), the distinction between the whole day and the peak delivery period of electricity is important for market participants. In Australia, the peak period refers to the hours from 07:00 to 22:00 on weekdays (excluding public holidays) over the duration of the contract quarter. This implies that the off peak period includes the hours from 22:00 to 07:00 on weekdays and all hours on Saturday and Sunday. Therefore, the size of a quarterly peak period futures contract will vary depending on the number of days and peak-load hours within the quarter: for example a contract with 62 weekdays during a quarter (so-called 62 day contract quarter) will equate to 930 MWH.

The contracts do not require physical delivery of electricity but are settled financially. Therefore, market participants can participate in electricity futures market and increase market liquidity without owning physical generation assets. The cash settlement price of a base (peak) period contract is calculated by taking the arithmetic average of the NEM final base (peak) load spot prices on a half hourly basis, rounded to two decimal places over the contract quarter. A provisional cash settlement price is declared on the first business day after expiry of the contract while the final cash settlement takes place on the fourth business day after expiry of the contract.

3. Modeling Framework

In the following we will describe the theoretical framework that is applied in our empirical analysis in order to investigate the relationship between spot and futures prices in regional Australian electricity markets. Generally, there are two theories explaining the relationship between spot and futures prices in commodity markets, see e.g. Botterud et al. (2002); Redl et al (2009).

The first theory argues that the cost and convenience of holding inventories explains the difference between the spot and futures price of a commodity. This theory is well known as the 'cost of carry' approach and goes back to Kaldor (1939). According to the 'cost of carry' approach, the forward price can be determined as a function of the current spot price, the interest rate and cost of storage. As mentioned previously, electricity as a flow commodity is produced and consumed instantaneously and continuously. Therefore, a standard cost of carry approach towards spot and forward markets cannot be applied. Instead the literature usually follows the second theory that considers equilibrium in expectations and risk aversion amongst agents with heterogeneous requirements for hedging the uncertainty of future spot prices (Keynes, 1930). From this angle the electricity forward price is then determined as the expected spot price plus an ex ante risk premium of the market. The difference between forward price and the expected spot price can then be interpreted as a compensation of bearing the spot price risk (Bessembinder and Lemmon, 2002; Longstaff and Wang, 2004). However, as the ex ante premium is basically unobservable, empirical analysis often concentrates on the realized or ex post forward premium

$$PREM_{t,T} = F_{t,T} - S_T. \quad (1)$$

Hereby, $F_{t,T}$ denotes the forward price quoted at time t, for delivery at time or period T, while S_T refers to the realized (average) spot price at time or period T. As illustrated by Redl et al. (2009) the realized forward premium equals the ex ante premium plus a random error in the (rational) spot price expectation that is a result of shocks to the electricity price between t and T. Based on a random error distribution with zero mean, the realized premium can be considered as a consistent estimator of the ex ante premium. Decomposing ex-post premiums, one could argue that only a part of the premium reflects a compensation for the spot price risk while the other part can be considered as an error in the expectations by market participants about the actual spot price during the delivery period. In their seminal paper, Bessembinder and Lemmon (2002) suggest a general equilibrium model where the ex-ante one-month forward premium in the Pennsylvania, New Jersey, Maryland (PJM) and California Power Exchange (CALPX) markets is modelled as dependent on the mean, standard deviation and variance of electricity demand:

$$PREM_{it} = \alpha_0 + \alpha_1 MEAN_{it} + \alpha_2 STD_{it} + \alpha_3 VAR_{it} + \eta_{it} \quad (2)$$

Hereby, $PREM_{it}$ equals the forward premium as the one-month-forward price for delivery in month t minus the cost-based estimate of the expected spot price in month t for market i, $MEAN_{it}$ is the average normalized load for month t in the market i, STD_{it} is the standard deviation of daily load during month t in market i, and VAR_{it} is the square of STD_{it}. Based o their theoretical model, the authors suggest that the forward premium should increase with mean demand and should be convex, initially decreasing and then increasing in demand risk. Thus, one would expect a negative coefficient for the standard deviation and a positive coefficient for the variance. In their empirical study, the authors find significant forward premiums in the market. With respect to explaining the premium, however, they obtain rather insignificant results for the coefficients. While the demand level seems to have a significantly positive impact on the forward premium, both standard deviation and variance of the demand are insignificant. A similar approach has been suggested by Redl et al. (2009) who examine the ex-post premium in the European Energy Exchange (EEX) and Scandinavian Nordpool electricity markets. Considering monthly forward contracts, they suggest a slightly different model that also incorporates the volatility and skewness of daily spot prices in the month prior to the delivery period as well as a consumption and generation index.

Empirical studies have generally found significant positive premiums in electricity forward markets. Longstaff and Wang (2004) find positive risk premiums up to 14% for the PJM day ahead market while Redl et al. (2009) find positive premiums for month-ahead forward contracts in the Nordpool and EEX market. They report premiums ranging from 8% for considered baseload forward contracts in the Nordpool market and 9% for baseload and 13% for peak load contracts in the EEX market. Botterud et al. (2010) report premiums ranging from 1.3 to 4.4% for the Nord Pool market when considering forward contracts with one week up to six weeks ahead. Also a number of other studies confirm the significance of forward premiums in various electricity markets. Significant premiums are reported, for example, by Hadsell and Shawky (2006) for the NYISO, Diko et al. (2006) for the APX, Bierbrauer et al. (2007) for the EEX, Weron (2008) for the Nordpool, Kolos and Ronn (2008) and Daskalakis and Markellos (2009) for the EEX, Nordpool and Powernext market. Interestingly, the studies provide quite different results on the actual sign of the risk premium even for the same markets: while Redl et al (2009) find significant positive premiums for monthly baseload and peakload futures contracts in the EEX market, Kolos and Ronn (2008) find a negative forward premium for monthly, quarterly and yearly contracts at the EEX during the 2002-2003 trading period. Bierbrauer et al (2007), find positive ex-ante risk premiums for short-term futures contracts while for contracts with maturities more than six months ahead the observed premiums are negative. Also Diko et al. (2006), investigating EEX peak load contracts, find that forward premiums decrease as time to maturity increases. Therefore, the majority of authors seem to find rather positive risk premiums in electricity futures markets, even for the same market.

Also empirical studies on the significance of variance and skewness in the risk premia so far provide rather mixed results, see e.g. Bessembinder and Lemmon (2002), Douglas and Popova (2008), Lucia and Torro (2008), Redl et al. (2009), Botterud et al. (2010), Furio and Meneu (2010). Bessembinder and Lemmon (2002) find a positive coefficient for the standard deviation and a negative coefficient for the variance of the daily load in the PJM and CALPX markets. However, their results are not statistically significant. Douglas and Popova (2008) estimate a negative coefficient for the variance and a positive coefficient for the skewness of the recent spot price in the PJM market. Most of their results are statistically significant. Lucia and Torro (2008) observe a positive coefficient for the variance and a negative coefficient for the skewness of spot prices during the delivery period in the Nord Pool power market for the time period mid 2003 til end of 2007. However, they find a negative coefficient for the variance and a positive coefficient for the skewness when considering futures prices from early 1998 til mid 2002. Their results are statistically significant for the skewness while for the variance, significant results are obtained only for the so-called pre-shock periods from 1998-2002. Redl et al. (2009) find positive coefficients for both variance and skewness of spot prices in the month prior to the delivery period when examining the EEX market. However, they also obtain a positive coefficient for the variance and a negative coefficient for the skewness parameter for the Nord Pool market. Their results are statistically significant only for the estimated variance coefficient (EEX peak period) and the skewness coefficient (EEX base period). Botterud et al. (2010) find mainly negative coefficients for both variance and skewness of the spot price in the week prior to the delivery period in the Nord Pool market. However, only the coefficient for the variance one week prior to the delivery period is statistically significant. Finally, Furio and Meneu (2010) find negative coefficients for both variance and skewness in the Spanish electricity market. Also in their study, only the coefficient for the variance is found to be statistically significant.

As mentioned above, so far no study has investigated the significance of risk premiums or the influence of spot price characteristics on the forward premium in regional Australian electricity markets. However, the analysis of the relationship between spot and futures prices in these markets might be of particular interest given the comparably high frequency of price spikes and extreme volatility in the market. Thus, in our empirical analysis we examine the following model for the ex-post forward premium in regional Australian electricity markets:

$$PREM_{t,Q} = b_1 + b_2 Mean(S_{tq}) + b_3 Std(S_{tq}) + b_4 Var(S_{tq}) + b_5 Skew(S_{tq}) + b_6 Kurt(S_{tq}) + \varepsilon_t \qquad (4)$$

Hereby, $PREM_{t,Q}$ denotes the difference between the quote for the futures contract with delivery in quarter Q on the last trading day t before the beginning of the delivery period and the average spot price during the delivery period (quarter Q). $Mean_{tq}$ is the average spot price during period t denoting either the last month or last quarter before the delivery period Q. Further Std_{tq} is the realized standard deviation, Var_{tq} the realized variance, $Skew_{tq}$ the realized skewness and $Kurt_{tq}$ the realized kurtosis of the spot price during period t, again denoting either the last month or last quarter before the delivery period Q.

4 Empirical Analysis

4.1 The Data

Our sample includes the electricity spot and futures prices in four Australian regional markets: NSW, QLD, SA and VIC. These four states show by far the highest electricity demand in Australia (Higgs, 2009) and are the only regions that also offer futures contracts being traded on an exchange. In our empirical analysis we consider daily electricity spot prices for the period ranging from January 1, 2000 to December 31, 2010 that were obtained provided by AEMO. Note that for the Australian market only quarterly and yearly futures contracts are traded on an exchange. Data for quarterly base load and peak load futures contracts from 2003 to 2010 were obtained from d-cypha Trade Limited[1]. Hereby, base load futures are settled with reference to the average half-hourly spot price during the delivery quarter, while peak load futures are cash settled with reference to the average of only those half hours during the quarter between 7am to 10pm on working weekdays. In the following, both spot and futures prices are quoted in Australian dollars per Megawatt hour (A$/MWh).

Table 1 shows descriptive statistics of daily electricity spot prices for the base and peak (7am-10pm working weekdays) periods from January 1, 2000 to December 31, 2010 in the four regions NSW, QLD, SA and VIC. Figure 1 and 2 provide plots for the time series of daily base and peak load electricity prices during the considered period.

[1] http://www.d-cyphatrade.com.au

	NSW BASE	QLD BASE	SA BASE	VIC BASE
MEAN	38.92	37.43	45.42	35.95
STDEV	71.45	66.27	104.62	64.11
MIN	11.65	-13.98	-95.78	-8.94
MAX	1,394.18	1,487.33	2,533.96	2,376.06
# OF DATA	4,018	4,018	4,018	4,018
	NSW PEAK	QLD PEAK	SA PEAK	VIC PEAK
MEAN	57.09	54.45	70.07	51.61
STDEV	150.63	121.43	223.87	132.23
MIN	13.73	-32.58	-1.38	11.30
MAX	2,538.49	2,726.58	4,654.74	4,304.45
# OF DATA	2,802	2,802	2,802	2,802

Table 1: Descriptive statistics of daily base and peak load electricity spot prices for the period January 1, 2000 to December 31, 2010. The table provides the mean, standard deviation, minimum, maximum as well as the number of observations for the considered regions NSW, QLD, SA and VIC.

We find that for the considered period average daily electricity spot prices range from 35.95 A$/MWh in VIC to 45.42 A$/MWh in SA for the base load, while they range from from 51.61 A$/MWh in VIC to 70.07 A$/MWh in SA during the peak period. For both cases, the lowest average daily prices are observed in VIC, followed by QLD and NSW, while the highest prices can be observed in the SA market. Also for the standard deviation, there are significant differences between the regional markets with a range from 64.11 for VIC up to 104.62 for SA for base period and 121.43 for QLD to 223.87 for VIC during the peak period. As expected spot electricity prices are driven by demand and supply mechanisms such that electricity prices and volatility are generally higher during the peak load period where also the demand is usually significantly higher and more volatile. As indicated by Table 1 in the QLD, SA and VIC markets also negative prices could be observed. According to the AEMO Information Centre (2011), negative spot prices can be explained by electricity generators bidding negative prices since they want to ensure that they are dispatched, as it is actually cheaper for them to stay running and pay to be dispatched rather than ramp down their power plants. Usually, generating units cannot be switched on and off in a short time due to efficiency and safety reasons (Hu et al., 2005). Therefore, producers might be better off actually paying the retailers for the consumption of electricity for a short period of time. The strategy is also referred to as tactical strategy (Thomas et al., 2011) to ensure that generators will get the contract. For a modelling framework that can also be used to model negative price spikes, see Fanone et al (2011).

We also examine seasonality in the market by calculating average spot prices for the calendar months. Table 2 displays average daily spot prices for each quarter during the considered time period from 2000-2010. We find some evidence of seasonality in electricity spot prices with the highest average prices observed during summer in the first quarter for QLD, SA and VIC while in NSW they were the highest in the second quarter. For NSW, QLD and SA we observe prices to be the lowest during the third quarter, while for VIC lowest average daily prices during the considered period were observed during the last quarter. Note that there are quite significant differences between the calendar months: for example, average daily prices in SA were A$65.81 during the first quarter while they were only A$36.45 during the third quarter. Overall, this does not come as a surprise, since strong seasonality for electricity prices has been reported by many authors, see e.g. Bessembinder and Lemmon (2002), Lucia and Schwartz (2002), Weron (2006), Bierbrauer et al. (2007) just to name a few.

4.2 Realized Risk Premiums in the Futures Market

In a next step analyse the ex-post or realized futures premium in the considered markets. We calculate the premium as the difference between the quote for the futures contract with delivery in quarter Q on the last trading day before the beginning of the delivery period and the realized average spot price during the delivery period. In a first step we do not distinguish between different quarters such that for each market the realized premiums for the first quarter (Q1), second quarter (Q2), third quarter (Q3) and fourth quarter (Q4) are jointly examined. However, we distinguish between regional markets as well as between base and peak load futures contracts. Thus, for the considered time period from Q1 2003 to Q4 2010 we have 32 base load contracts and the same number of peak load contracts for each market.

Results for the realized futures premiums in each market are provided in Table 3. We find that for all markets we observe a positive ex-post premium indicating that futures quotes immediately before the beginning of the delivery period are on average higher than the realized average spot price during the delivery period. The size of the premium varies dependent on the considered market but is also different for base load in comparison to peak load contracts. For the base load period we find that the premium is the highest in QLD where the futures quote per MWH exceeds the realized spot price during the delivery period by A$8.59. Note that for a quarter with e.g. 90 days where a contract refers to 2,160 MWH this corresponds to a price difference of approximately A$18,550 per contract. The average realized premium is the lowest for NSW with A$3.71 while in SA and VIC the corresponding figures are A$4.71 and A$4.93, respectively. For the peak load contracts, we also find positive premiums that range from A$2.55 in NSW up to A$15.07 in the QLD market. The sign of the observed premiums indicates that buyers or retailers of electricity are willing to pay an additional premium in the electricity forward market in order to avoid potentially extreme losses that might occur when the spot market exhibits extreme prices due to high volatility or price spikes.

AVG Quarter	NSW	QLD	SA	VIC
Quarter 1	37.63	42.39	65.81	40.65
Quarter 2	42.33	39.23	40.53	39.82
Quarter 3	35.03	31.65	36.45	34.08
Quarter 4	40.68	36.52	39.16	29.43
BASE	NSW	QLD	SA	VIC
MAX	42.33 (Q2)	42.39 (Q1)	65.81 (Q1)	40.65 (Q1)
MIN	35.03 (Q3)	31.65 (Q3)	36.45 (Q3)	29.43 (Q4)

Table 2: Average quarterly spot prices for NSW, QLD, SA and VIC base load contracts. The considered time period is January 1, 2000 to December 31, 2010.

We also conduct statistical tests to investigate whether the realized futures premiums are statistically significant. Table 3 also provides the t-statistics for the premiums. Interestingly, only the QLD market exhibits futures premiums that are significantly greater than zero at the 5% significance level for both base load and peak load contracts. While the realized premiums for the VIC market are significantly greater than zero at the 10% level, for the NSW and SA they are not statistically significant. We conclude that for Australian electricity markets there is a tendency of futures quotes prior to exceed realized spot prices during the delivery period, only in the QLD and VIC region the observed premiums are significant. Note that since we considered quotes of the nearest futures contract immediately before the beginning of the delivery period our results are in line with what theoretical models suggest on the sign of the risk premium in the short term forward market. In empirical studies similar results with respect to the sign of the risk premiums have also been obtained in the PJM (Longstaff and Wang, 2004) and EEX (Redl et al., 2009) market. However, other studies also find negative electricity premiums in the PJM (Bessembiner and Lemmon, 2002) and Nord Pool (Botterud et al., 2010) market.

PREMIUM	NSW BASE	QLD BASE	SA BASE	VIC BASE
Average	3.71	8.59	4.71	4.93
Standard Deviation	24.14	20.80	20.14	17.39
# of Observation (n)	32	32	32	32
t-Statistic	0.87	2.34 **)	1.32	1.60

PREMIUM	NSW PEAK	QLD PEAK	SA PEAK	VIC PEAK
Average	2.55	15.07	3.64	7.31
Standard Deviation	47.85	38.50	42.48	30.77
# of Observation (n)	32	32	32	32
t-Statistic	0.30	2.21 **)	0.48	1.34

*Table 3: Realized futures premiums for NSW, QLD, SA and VIC base load and peak load contracts for the considered time period Q1 2003 to Q4 2010. The asterisk indicate a significant risk premium at the *) 10% significance level, **) 5% significance level, ***) 1% significance level.*

Figure 1 plots the realized futures premiums for electricity base load and peak load futures contracts from Q1 2003 to Q4 2010. The figure confirms the high volatility of the realized risk premium through time for both base and peak load contracts. We further find that the premiums for base load and peak load contracts generally show a very similar pattern through time for each of the considered markets. Also across different markets, the premiums seem to be highly correlated and usually show the same sign and sometimes also a similar magnitude. The figure also illustrates some seasonal pattern in the risk premiums: while the premium usually seems to be positive for the first and third quarter of the year, it is sometimes becomes highly negative for the second and fourth quarter.

Figure 2 provides a plot of the average realized risk premiums for base load and peak load contracts from Q1 2003 to Q4 2010 across all markets. The figure further illustrates the very similar behaviour for the realized ex-post futures premiums for base load and peak load contracts. While the realized premiums are more volatile and higher in terms of absolute values for peak load contracts, premiums for base and peak load contracts referring to the same period usually show the same sign. The figure also illustrates more clearly the detected seasonal pattern in the risk premiums.

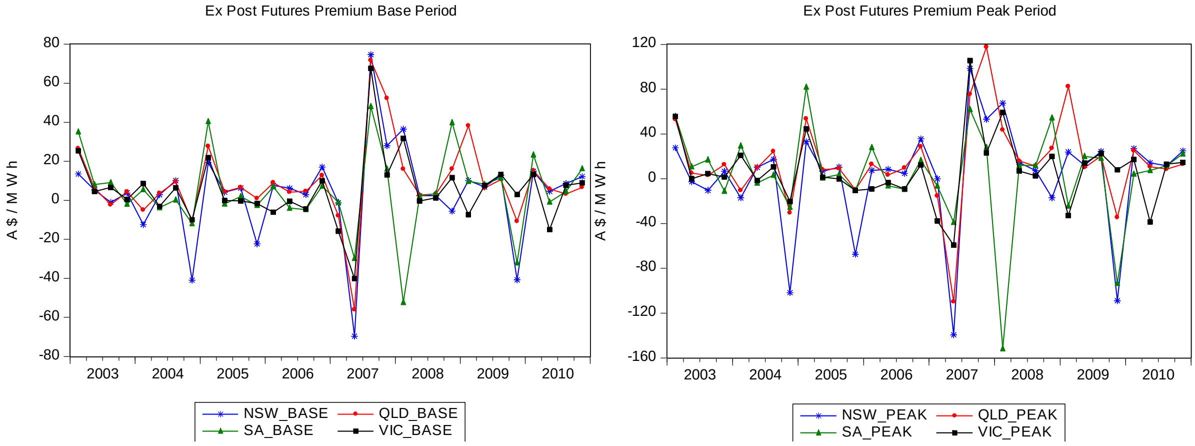

Figure 1: Realized risk premium for the NSW, QLD, SA and VIC for contracts from Q1 2003 to Q4 2010. The figure provides the ex-post premiums for base load (left panel) and peak load contracts (right panel).

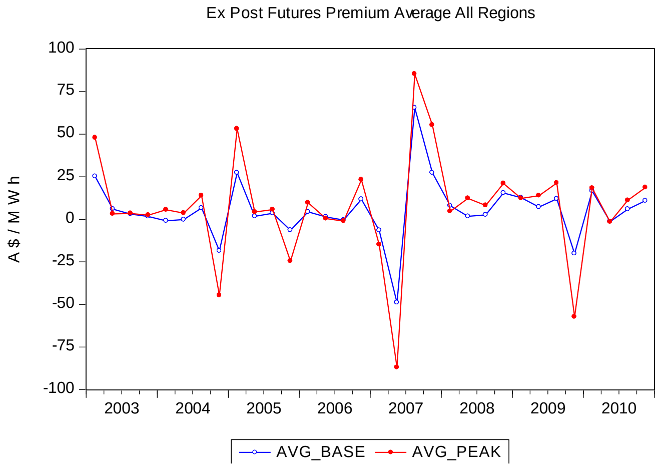

Figure 2: Realized risk premium for base load and peak load contracts averaged over all markets from Q1 2003 to Q4 2010.

To further investigate the relationship between realized futures premiums, in a next step we examine the correlation between the premiums across the considered markets. Table 4 presents the estimated correlation coefficients for the ex-post risk premiums for both base load and peak load contracts in NSW, QLD, SA and VIC. We observe strong and significant positive correlations in the futures premium across the considered markets. We further observe that adjoining regions like e.g. NSW-QLD, NSW-VIC usually exhibit higher degrees of correlation than markets that are geographically more distant like e.g. QLD-SA or NSW-SA. Given the nature of the Australian market operating as an interconnected grid this does not come as a surprise. Within the national power grid, electricity can be transmitted between different regions via so-called interconnectors. The interconnectors may be of particular importance when the price of electricity in adjoining regions is low enough to displace local supply, but also when the energy demand in a particular region is higher than the amount of electricity that can be provided by local generators. Therefore, one could expect adjoining regions to exhibit similar price behaviour and, therefore, also higher correlations between realized risk premiums.

Note that overall correlations between realized premiums seem to be lower for peak load contracts what can probably be explained by the higher volatility and number of price spikes during the peak periods. In case there are a number of price spikes happening during the same quarter in one market, this can have significant impact on the realized risk premiums for this market. Recall that a quarterly peak load futures contract refers to less than 1000 MWH while a base load contract refers to more than 2000 MWH. Therefore, the usually short-lasting periods of spikes or extreme prices will have a higher impact on average prices, and, therefore on realized risk premiums in each market for the peak period. This could explain the lower degree of correlation in risk premiums for peak load contracts.

Given the obvious seasonality in the observed risk premiums, in a next step we examine the ex-post futures premiums for each quarter separately in Table 5. Note that with 32 observations in total, we only observe the realized risk premiums for eight contracts for each of the quarters. Therefore, results for the size of the premium and statistical tests have to be considered with care. We find that realized base load and peak load futures premiums are positive in all markets for contracts referring to Q1 and Q3 while they are almost invariably negative for Q2. For Q4 the results are rather mixed suggesting a negative premium for NSW and a positive premium for QLD and VIC while for SA the premium for Q4 is positive for base load contracts and negative for peak load contracts. In most cases the magnitude of the premium is higher for peak load contracts where the average realized premiums range from -$21.91 for Q4 NSW contracts to $30.53 for Q1 QLD contracts. For base load contracts the highest average premium is observed for Q1 QLD contracts with $14.95, while the highest negative premium is observed for Q4 NSW contracts with -$6.09. While for several of the quarters and markets, average realized premiums seem to be quite large, from a statistical perspective at the 5% level for base load contracts only the Q1 futures premiums for NSW and QLD are significantly greater than zero. For peak load contracts, premiums for NSW and QLD for Q1 and the Q3 premium for QLD are significantly greater than zero.

All Quarters

	NSW PREM BASE	QLD PREM BASE	SA PREM BASE	VIC PREM BASE
NSW PREM BASE	1.0000			
(P-value)	(1.0000)	( )	( )	( )
QLD PREM BASE	0.8677	1.0000		
(P-value)	(0.0000)	(1.0000)	( )	( )
SA PREM BASE	0.4985	0.6261	1.0000	
(P-value)	(0.0037)	(0.0001)	(1.0000)	( )
VIC PREM BASE	0.7953	0.7821	0.4960	1.0000
(P-value)	(0.0000)	(0.0000)	(0.0039)	(1.0000)

	NSW PREM PEAK	QLD PREM PEAK	SA PREM PEAK	VIC PREM PEAK
NSW PREM PEAK	1.0000			
(P-value)	(1.0000)	( )	( )	( )
QLD PREM PEAK	0.8274	1.0000		
(P-value)	(0.0000)	(1.0000)	( )	( )
SA PREM PEAK	0.3257	0.3312	1.0000	
(P-value)	(0.0689)	(0.0641)	(1.0000)	( )
VIC PREM PEAK	0.6224	0.5895	0.2517	1.0000
(P-value)	(0.0001)	(0.0004)	(0.1646)	(1.0000)

Table 4: Estimated correlation between realized risk premiums for base load and peak load contracts in the considered NSW, QLD, SA and VIC markets.

The literature provides a number of reasons for the comparably large premiums in electricity futures markets. As pointed out by Benth et al (2008), economic intuition would suggest that a long-term negative and short-term positive risk premium should be observed in electricity markets. The reasons for this are that long-term contracts with maturities greater than several months will be mainly used by producers to hedge their future electricity production. They might be willing to accept prices lower than the actual expected spot price in order to guarantee that the produced electricity can be sold in the market what will result in a negative long-term risk premium. On the other hand, in the short-term, retailers or consumers aiming to hedge the risk of price spikes might be willing pay an additional premium for locking in prices in the short term. Such behaviour will result in a positive short-term risk premium as it can be observed in our study for the considered Australian markets and also for a variety of other markets, see e.g. Longstaff and Wang (2004); Hadsell and Shawky (2006); Diko et al. (2006); Bierbrauer et al. (2007); Daskalakis and Markellos (2009); Redl et al. (2009).

According to Shawky et al. (2003), the non-storability and presence of relatively few big players in electricity markets requires a high premium for market participants. Furthermore, due to high volatility, skewed distribution of electricity spot prices and the risk of extreme price spikes, buyers of electricity might be willing to pay a large premium in the futures market in order to avoid the risk of substantial losses when buying the electricity in the spot market (Bessembinder and Lemmon, 2002; Longstaff and Wang, 2004). Note that for Australian electricity markets, Anderson et al (2007) conducted interviews with retailers who argue that if they had not bought electricity futures contracts, the spot price would have risen even higher than the futures price. Also these finding imply that the futures premium can be seen as a compensation for market participants in bearing high risks of extreme spot prices.

4.2 Explaining the Futures Risk Premium

In the following we investigate whether the bias in the futures price can be explained by the behaviour of the spot price during the month or quarter prior to delivery of the futures contract. Hereby, as pointed out in Section 3, our reasoning follows the work by e.g. Bessembinder and Lemmon (2002), Lucia and Torro (2008), Redl et al. (2009), Botterud et al (2010). We use equation (4) in order to examine whether realized futures risk premiums in the regional markets can be explained by the level, standard deviation, variance, skewness and kurtosis of electricity spot prices prior to the delivery period of the futures contract.

The explanatory variables in the regression model were based on the spot price behaviour either during the last month or the last quarter prior to the delivery period. With respect to the explanatory power of the model,

Quarter 1

PREMIUM	Q1 NSW BASE	Q1 QLD BASE	Q1 SA BASE	Q1 VIC BASE
Average	11.01	14.95	8.44	8.93
Standard Deviation	14.41	16.01	28.63	17.25
# of Observation (n)	8	8	8	8
t Statistic	2.16 **)	2.64 **)	0.83	1.46

PREMIUM	Q1 NSW PEAK	Q1 QLD PEAK	Q1 SA PEAK	Q1 VIC PEAK
Average	21.16	30.53	2.04	14.69
Standard Deviation	25.30	33.84	70.79	38.08
# of Observation (n)	8	8	8	8
t Statistic	2.36 **)	2.55 **)	0.08	1.09

Quarter 2

PREMIUM	Q2 NSW BASE	Q2 QLD BASE	Q2 SA BASE	Q2 VIC BASE
Average	-4.67	-2.87	-2.72	-5.90
Standard Deviation	26.29	21.51	11.93	15.35
# of Observation (n)	8	8	8	8
t Statistic	-0.50	-0.38	-0.64	-1.09

PREMIUM	Q2 NSW PEAK	Q2 QLD PEAK	Q2 SA PEAK	Q2 VIC PEAK
Average	-9.54	-5.89	0.21	-10.14
Standard Deviation	52.80	42.21	18.07	25.24
# of Observation (n)	8	8	8	8
t Statistic	-0.51	-0.39	0.03	-1.14

Quarter 3

PREMIUM	Q3 NSW BASE	Q3 QLD BASE	Q3 SA BASE	Q3 VIC BASE
Average	14.58	13.39	9.26	12.25
Standard Deviation	24.69	23.88	16.48	23.00
# of Observation (n)	8	8	8	8
t Statistic	1.67	1.59	1.59	1.51

PREMIUM	Q3 NSW PEAK	Q3 QLD PEAK	Q3 SA PEAK	Q3 VIC PEAK
Average	20.48	20.19	14.76	18.65
Standard Deviation	33.12	23.36	21.06	36.35
# of Observation (n)	8	8	8	8
t Statistic	1.75 ***)	2.44 **)	1.98 ***)	1.45

Quarter 4

PREMIUM	Q4 NSW BASE	Q4 QLD BASE	Q4 SA BASE	Q4 VIC BASE
Average	-6.09	8.89	3.86	4.42
Standard Deviation	26.18	20.09	21.44	7.92
# of Observation (n)	8	8	8	8
t Statistic	-0.66	1.25	0.51	1.58

PREMIUM	Q4 NSW PEAK	Q4 QLD PEAK	Q4 SA PEAK	Q4 VIC PEAK
Average	-21.91	15.47	-2.45	6.04
Standard Deviation	63.25	47.82	44.83	15.02
# of Observation (n)	8	8	8	8
t Statistic	-0.98	0.92	-0.15	1.14

*Table 5: Realized futures premiums for each quarter in NSW, QLD, SA and VIC. Results are reported for base load and peak load contracts for the considered time period Q1 2003 to Q4 2010. The asterisk indicate a significant risk premium at the *) 10% significance level, **) 5% significance level, ***) 1% significance level.*

we obtained clearly better results when the calculated moments were based on last month's spot prices instead of the last quarter. In the following we will therefore only report the results for using the spot price behaviour during the month prior to the delivery period.[2] Since several of the considered explanatory variables were not statistically significant, we also apply a stepwise regression analysis to the data. Hereby, we use stepwise backward regression, starting with a model that includes all explanatory variables and then sequentially removing the insignificant variables from the model. Results for the estimated models including all variables and the optimal model based on the stepwise regression approach are reported in Table 6 and 8.

[2] Results for regression models using moments being based on the spot price behaviour during the quarter prior to the delivery period are available upon request to the authors.

Examining the explanatory power of the models in Table 6 we find considerable differences between the regional markets and considered contracts. For base load contracts, results for the coefficient of determination range from 0.11 for SA up to 0.41, respectively 0.46 for VIC and NSW. The explanatory power of the regression model for peak load contracts is usually slightly lower and ranges from 0.06 for SA to 0.39 for NSW. While these results indicate only a limited explanatory power of the model, the coefficients of determination are still roughly in the same range or even higher than what has been reported in earlier studies. For example, using a similar approach, Lucia and Torro (2008) find values for R^2 ranging from 1% to 30% for short term risk premiums in the Nordpool market while Redl et al (2009) obtain values of R^2 between 0.02 and 0.11 when modelling monthly futures contract in the European EEX and Nordpool market.

With respect to the included variables, Table 6 illustrates that for most of the considered markets and contracts only the level of the spot price during the month prior to delivery is significant. For all markets, estimated coefficients for the level of the spot price are positive, indicating that the higher the level of the spot price the more pronounced is the realized risk premium, i.e. the more the futures quote will overestimate the average spot price during the delivery period. On the other hand the estimated coefficients for the standard deviation and skewness are negative for almost all equations. Only for the equation for peakload futures contracts in QLD, the estimated coefficient for the skewness parameter is positive. The negative sign of these coefficients suggests a general tendency for the ex-post futures premium to decrease with increasing skewness and standard deviation of the spot prize prior to the delivery period. Therefore, our results somehow contradict the relationship between skewness and the forward premium as it is generally suggested in the literature (Bessembiner and Lemmon, 2002): since positive skewness implies the possibility of higher upward spikes, both the forward price and the forward premium should be positively related to skewness. On the other hand, our results are in line with several other empirical studies, e.g. Lucia and Torro (2008) and Botterud et al. (2010) in the Nord Pool market or Furio and Meneu (2010) in the Spanish electricity market. These authors also find negative coefficients for the skewness parameter, however, similar to our results the coefficients in these studies are usually not significant.

Coefficient / **Premium**	**Constant** (t-Stat)	**Mean** (t-Stat)	**Stdev** (t-Stat)	**Var** (t-Stat)	**Skew** (t-Stat)	**Kurt** (t-Stat)	R^2	**Adj** R^2	**F-stat**
Using last month data for independent variables									
NSW BASE	3.78 (0.32)	0.54 (3.52)	-0.19 (-0.56)	0.000421 (0.32)	-27.69 (-2.16)	5.05 (2.55)	0.46	0.36	4.46
QLD BASE	-3.21 (-0.33)	0.48 (2.29)	-0.17 (-0.49)	0.000443 (0.35)	-2.25 (-0.22)	0.35 (0.20)	0.34	0.22	2.73
SA BASE	0.66 (0.05)	0.32 (0.72)	-0.03 (-0.06)	-0.000289 (-0.30)	-4.16 (-0.41)	0.31 (0.15)	0.11	-0.06	0.67
VIC BASE	-8.03 (-0.96)	0.64 (2.41)	-0.87 (-1.21)	0.006974 (0.95)	-3.37 (-0.53)	1.12 (0.92)	0.41	0.29	3.59
NSW PEAK	24.17 (0.89)	0.46 (2.59)	-0.19 (-0.60)	0.000169 (0.31)	-61.85 (-2.32)	13.07 (2.75)	0.39	0.27	3.26
QLD PEAK	7.37 (0.46)	0.26 (1.09)	-0.10 (-0.29)	0.000179 (0.30)	0.86 (0.07)	-0.71 (-0.26)	0.15	-0.01	0.92
SA PEAK	-4.98 (-0.17)	0.45 (0.72)	-0.25 (-0.51)	-0.000025 (-0.07)	-1.81 (-0.09)	-0.03 (-0.01)	0.06	-0.12	0.32
VIC PEAK	-16.33 (-1.26)	0.80 (3.23)	-0.56 (-1.02)	0.001187 (0.43)	-8.22 (-0.67)	2.67 (1.00)	0.37	0.25	3.08

Table 6 Results of regression analysis (4) for realized futures premium of quarterly base load and peak load contracts in NSW, QLD, SA and VIC. Explanatory variables are based on the spot price behaviour during the month prior to the delivery period of the futures contract.

As indicated in Table 7 only for the NSW market the estimated coefficients for skewness are significant for baseload and peakload contracts. On the other hand, in these equations also the estimated coefficients for the kurtosis are significantly greater than zero suggesting that the realized premium may also increase with the risk of extreme price outcomes. For NSW base and peak load futures contracts we also obtain the highest explanatory power for the considered regression model with a coefficient of determination of 0.44 for base load and 0.36 for peak load contracts.

Overall, our results partially support the model suggested by Bessembinder and Lemmon (2002). Their model predicts that the electricity forward bias that is reflected in the realized or ex-post forward premium should increase with the expected power demand and, therefore, also possibly with the mean price level. The authors also suggest that the equilibrium premium is convex, initially decreasing and then increasing in the variability of power demand and electricity spot prices. This means, that in our model we would expect the coefficient for the standard deviation to be negative while the coefficient for the variance should be positive. Table 6 shows that in the estimated models for NSW, QLD and VIC, the coefficients generally show the expected signs. Note that for SA both the coefficient for standard deviation and variance become negative, but for this market the model yields a

Coefficient / Premium	Constant (t-Stat)	Mean (t-Stat)	Stdev (t-Stat)	Var (t-Stat)	Skew (t-Stat)	Kurt (t-Stat)	R^2	Adj R^2	F-stat
Using last month data for independent variables									
NSW BASE	8.59 (0.81)	0.42 (4.34)	( )	( )	-30.02 (-2.54)	5.15 (2.71)	0.44	0.38	7.31
QLD BASE	-4.63 (-0.99)	0.36 (3.75)	( )	( )	( )	( )	0.32	0.30	14.05
SA BASE	4.71 (1.32)	( )	( )	( )	( )	( )	0.00	0.00	
VIC BASE	-10.49 (-2.83)	0.46 (3.71)	( )	( )	( )	( )	0.34	0.32	15.27
NSW PEAK	32.53 (1.27)	0.30 (3.14)	( )	( )	-64.58 (-2.51)	12.85 (2.76)	0.36	0.29	5.16
QLD PEAK	3.03 (0.35)	0.21 (2.06)	( )	( )	( )	( )	0.12	0.10	4.25
SA PEAK	3.64 (0.48)	( )	( )	( )	( )	( )	0.00	0.00	
VIC PEAK	-13.29 (-1.75)	0.43 (3.44)	( )	( )	( )	( )	0.28	0.26	11.85

*)

Table 7 Results for stepwise regression for realized futures premium of quarterly base load and peak load contracts in NSW, QLD, SA and VIC. Explanatory variables are based on the spot price behaviour during the month prior to the delivery period of the futures contract.

very low explanatory power and none of the examined variables is significant. One explanation why the Bessembinder and Lemon (2002) concept of convexity of the forward premium, i.e. the premium initially decreasing and then increasing in the variability of electricity spot prices, holds in the Australian market is the assumption of risk averse market participants. According to Anderson et al. (2007), most retailers participating in Australian electricity markets are highly risk-averse.

4. Summary and Conclusions

This paper studies the relationship between spot and futures prices in regional Australian electricity markets. The National Electricity Market (NEM) in Australia began operating in December 1998 and operates in an interconnected grid comprising several regional networks in different states. Interestingly, Australian electricity markets can be considered as being significantly more volatile and spike-prone than other comparable markets (Higgs and Worthington, 2008). While there have been a number of publications on the behaviour of electricity spot prices in Australia, we provide a pioneer study focusing on futures markets and risk premiums in regional Australian electricity markets. The literature usually follows equilibrium considerations in expectations and risk aversion amongst agents where the electricity forward price is then determined as the expected spot price plus a risk premium. The difference between forward price and the expected spot price can then be interpreted as a compensation of bearing the spot price risk (Bessembinder and Lemmon, 2002; Longstaff and Wang, 2004). In our analysis we focus on realized or ex-post futures premiums in the four major states of New South Wales (NSW), Queensland (QLD), South Australia (SA) and Victoria (VIC).

Examining ex-post futures premiums, we find that Australian electricity markets exhibit positive risk premiums for several of the considered regions such that futures prices cannot be considered as an unbiased estimator of realized spot prices. Since the average of the realized futures premiums is positive, we conclude that there is a tendency for futures prices to overstate average spot prices during the delivery period. In particular, we find economically and statistically significant positive ex-post futures premium for futures contracts referring to the first and third quarter of the year in NSW and QLD. Not taking into account particular quarters, the QLD region still yields statistically significant futures premiums with average magnitude of $8.59 for base load and $15.07 for peak load contracts. We also observe positive correlations between the observed futures premiums across different regional markets.

Further investigating the issue, we find that the price formation in the considered markets seems to be influenced by historical spot price behaviour. Our results suggest that for some of the markets the bias can at least partially be explained by the level, standard deviation, skewness and kurtosis of spot prices during the month prior to delivery. In particular, we find that the realized risk premium significantly increases with the level of the spot price for regional markets in NSW, QLD and VIC. Overall, our results suggest that retailers in Australian electricity markets are risk averse and willing to pay an additional risk premium in the futures market to avoid the risk of significant price spikes in the spot market.

Bibliography

Anderson, EJ, Hu, X & Winchester, D 2007, ‘Forward Contracts In Electricity Markets: The Australian Experience’, *Energy Policy*, no. 35, pp. 3089 – 3103.

Australian Energy Market Operator 2010, About AEMO – Overview, viewed 29 December 2010. http://www.aemo.com.au/corporate/aboutaemo.html,

Becker, R, Hurn, S & Pavlov, V 2007, 'Modelling Spikes in Electricity Prices', *The Economic Record*, Vol 83, December 2007, pp. 371-382.

Benth, F, Benth, S & Koekebakker, S 2008, *Stochastic Modelling of Electricity and Related Markets*, 2nd edn, World Scientific. Advanced Series on Statistical Science and Applied Probability.

Bessembinder, H & Lemmon, ML 2002, 'Equilibrium Pricing And Optimal Hedging In Electricity Forward Markets', *The Journal of Finance*, vol. 57 no. 3, pp. 1347 – 1381.

Bierbrauer, M, Menn, C, Rachev, ST & Trück, S 2007, 'Spot And Derivative Pricing In The EEX Power Market', *The Journal of Banking & Finance*, no. 31, pp. 3462 – 3485.

Botterud, A, Bhattacharyya, AK & Ilic, M 2002, 'Futures And Spot Prices – An Analysis Of The Scandinavian Electricity Market', *Working Paper*, pp. 1 – 8.

Botterud, A, Kristiansen, T & Ilic, M 2010, 'The Relationship Between Spot And Futures Prices In The Nord Pool Electricity Market', *Energy Economics*, no. 32, pp. 967 – 978.

Bowden, N & Pane, JE 2008, 'Short Term Forecasting Of Electricity Prices For MISO Hubs: Evidence From ARIMA-EGARCH Models', *Energy Economics*, no. 30, pp. 3186–3197.

Daskalakis, G & Markellos, RN 2009, 'Are Electricity Risk Premia Affected By Emission Allowance Prices? Evidence From The EEX, Nord Pool And Powernext', *Energy Policy* no. 3, pp. 2594 - 2604.

d-cyphaTrade, http://d-cyphatrade.com.au/products/overview_of_the_australian_el, viewed 29 December 2010.

Diko, P, Lawford, S & Limpens, V 2006, 'Risk Premia In Electricity Forward Markets', *Studies in Nonlinear Dynamics & Econometrics*, vol. 10 no. 3, pp. 1 – 22.

Douglas, S & Popova, J 2008, 'Storage And The Electricity Forward Premium', *Energy Economics*, no. 30, pp. 1712 - 1727.

Fanone, E., Gamba, A., Prokopczuk, M., 2011. 'The case of negative day-ahead electricity prices'. Working Paper.

Furio, D & Meneu, V 2010, 'Expectations And Forward Risk Premium In The Spanish Deregulated Power Market', *Energy Policy*, no. 38, pp. 784 - 793.

Hadsell, L & Shawky, HA 2006, 'Electricity Price Volatility And The Marginal Cost Of Congestion: An Empirical Study Of Peak Hours On The NYISO Market 2001-2004', *The Energy Journal*, vol. 27 no. 2, pp. 157 - 179.

Higgs, H 2009, 'Modeling Price And Volatility Inter-Relationship In The Australia Wholesale Spot Electricity Markets', *Energy Economics*, no. 31, pp. 748 – 756.

Hull, J 2007, *Risk Management and Financial Institutions*, Pearson Education Inc., New Jersey USA.

Kaldor, N 1939. 'Speculation And Economic Stability', *The Review of Economic Studies*, vol. 7, no. 1, pp. 1 – 27.

Kanamura, T & Ohashi, K 2008, 'On Transition Probabilities Of Regime Switching In Electricity Prices', *Energy Economics*, no. 30, pp. 1158 – 1172.

Karakatsani, NV & Bunn, DW 2008, 'Intra-Day And Regime-Switching Dynamics In Electricity Price Formation', *Energy Economics*, no. 30, pp. 1176 – 1797.

Keynes, J.M 1930, *A Treatise on Money*. Macmillan, London.

Kolos, SP & Ronn, EI 2008, 'Estimating The Commodity Market Price Of Risk For Energy Prices', *Energy Economics*, no. 30, pp. 621 - 641.

Longstaff, FA & Wang, AW 2004, 'Electricity Forward Prices: A High Frequency Empirical Analysis', *The Journal of Finance*, vol. 59, no. 4, pp. 1877 – 1900.

Lucia, JJ & Schwartz, ES 2002, 'Electricity Prices And Power Derivatives: Evidence From The Nordic Power Exchange', *Review of Derivatives Research*, no. 5, pp. 5 – 50.

Lucia, JJ & Torro, H, 2008, 'Short-Term Electricity Futures Prices: Evidence On The Time-Varying Risk Premium', *Working Paper*, pp. 1 – 34.

Redl, C & Bunn, DW 2011, 'Determinants of the Premium in Forward Contracts', *Working Paper*, pp. 1 – 29.

Redl, C, Haas, R, Huber, C & Böhm, B 2009, 'Price Formation In Electricity Forward Markets And The Relevance Of Systematic Forecast Errors', *Energy Economics*, no. 31, pp. 356 – 364.

Shawky, AH, Marathe, A & Barrett, CL 2003, 'A First Look At The Empirical Relation Between Spot And Futures Electricity Prices In The Unites States', *The Journal of Futures Markets*, vol. 23, no. 10, pp. 931 – 955.

Thomas, S, Ramiah, V, Mitchell, H & Heaney, R 2011, 'Seasonal Factors And Outlier Effects In Returns On Electricity Spot Prices In Australia's National Electricity Market', *Applied Economics*, vol. 43 no. 3, pp. 355 – 369.

Weron, R 2006, *Modeling And Forecasting Loads And Prices In Deregulated Electricity Markets*, Agencja Rynku Energii S A, Warszawa Poland.

Weron, R, 2008. Market price of risk implied by Asian-style electricity options and futures. *Energy Economics* 30(3), 1098-1115.

Worthington, A, Kay-Spratley, A & Higgs, H 2005, 'Transmission Of Prices And Price Volatility In Australian Electricity Markets', *Energy Economics*, no. 27, pp. 337 – 350.