Liquidity and Risk Premia in the New Zealand Electricity Futures Market

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Abstract

Despite being one of the early adopters of electricity markets and an example of 'textbook' reform, to date, no academic research on the liquidity or risk premia of electricity futures markets is discernible for New Zealand. Using data from October 2009 to December 2015 we address this gap in the literature. We find that liquidity has been gradually increasing and that a policy intervention to impose a maximum bid-offer spread was associated with a liquidity-enhancing structural breaks, but this was evident only in the nearest-to-maturity futures contracts. Further, we develop models to explain risk premia that include a range of risk factors which we categorise as either statistical, physical market, production cost, investor behaviour and liquidity variables. From this analysis we document significant time varying premia which are driven by potentially inefficient behaviour.

JEL Classification: D46; G12; G13; L94; Q41; Q48

KEYWORDS: Electricity markets, electricity prices, electricity futures, liquidity, risk premium

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1. Introduction

Electricity markets have unique characteristics, for example the fact that electricity cannot be stored economically at the grid level, and have evolved rapidly. Ever since a rise of deregulation and privatisation in the 1990s, various electricity markets models have emerged. The New Zealand (NZ) electricity market (NZEM) is an early example of a deregulated market structure, and is considered by some to be a 'textbook' reform (Joskow, 2006)**.** A characteristic inherent in the nature of electricity markets is the high degree of volatility in spot prices. As in any market, this creates challenges for both market participants and regulators alike, and in the NZEM volatility of spot prices is exacerbated by the predominance of hydro-electric generation which has limited storage and exhibits a high degree of volatility in the inflows into storage lakes. In order for these participants, whether they be generators, retailers or large consumers, to successfully operate in this sector effective hedge instruments need to be available to mitigate risk. One such tool available in the NZEM are futures contracts.

A consultation by the Electricity Authority (EA), the regulatory body of the electricity market in NZ, suggested that the hedge market should provide effective means of managing spot price risk whilst giving a transparent view of future prices (EA, 2014). The EA added that the "more liquid the hedge market is, the better these ends will meet" (EA, 2014;p.11). Unfortunately, responses from market participants to the EA consultation indicated that the futures market may not be supporting risk management and price transparency as it might. These concerns primarily stem from the illiquidity of the futures markets as reflected by low depth of volume and large spreads (EA, 2014;p18-19). This is despite EA interventions that attempted to promote liquidity and stimulate trading activity (most prominently on 5th January 2010 the ASX introduced market making for the four largest generators and after work commissioned by the EA recommended reducing the maximum bid-ask spread, on the 3rd October 2011 the market-making moved to a maximum bid-offer spread of 5% in the futures market).

Futures contracts allow participants to manage their overall risk profile and exposure to the underlying spot market. The ability to do so has inherent value. Such value will be reflected in the risk premium present in these futures contracts. Previous research has found significant premia in electricity futures which are relatively large in comparison to those found in other commodities (Shawky, Marathe, & Barrett, 2003). Indeed, within the NZ context there have been concerns that large positive risk premia exist and that these may potentially be indicative of inefficiencies in the market (EL, 2014;p.1).

Despite being one of the early adopters of electricity markets and an example of 'textbook' reform, to date, no academic research on the liquidity or risk premia of electricity futures markets is discernible for New Zealand. Accordingly we provide the first detailed examination of both liquidity and risk premia in the New Zealand electricity futures market. In doing so we address two research questions:

- *Q1: How has the liquidity of the NZ electricity futures market evolved over time, and have efforts to increase liquidity succeeded?*
- *Q2: What drives risk premia in the NZ electricity futures markets and is illiquidity a factor in these premia?*

These questions are addressed by using data for the period 2nd October 2009 to 31st December 2015. We employ from the literature two measures of liquidity/illiquidity) on which we run structural break tests (Bai and Perron, 2003). Further we develop models to explain risk premia that include a range of risk factors which we categorise as either statistical, physical market, production cost, investor behaviour or liquidity variables.

The rest of the paper is structured as follows. Section 2 provides more background on the NZEM and the related futures market. Section 3 reviews respectively the relevant literatures on liquidity and on risk premia in electricity futures markets. Section 4 outlines the data and models we employ. Section 5 presents our results and section 7 provides some conclusions.

2. The New Zealand Electricity Market: An Overview

The NZEM utilises locational marginal pricing, or nodal pricing, with spot prices set half hourly. This mechanism simply refers to the fact that there is no single market price and that spot prices vary across the country, reflecting the marginal cost of supplying electricity at that particular location. Another characteristic of the NZEM is the use of a mandatory pool, meaning that apart from a small portion of supply generated and consumed entirely within a consumer's site, all electricity must be traded through the spot market. This differs from, for example, Great Britain, where the majority of wholesale electricity is contracted prior to real-time and only a small portion is traded through a balancing market at real-time.

Due to the natural resources NZ is endowed with, in particular voluminous rivers and lakes, generation in the NZEM comes primarily in the form of hydro – currently around 57% of total energy generated (MBIE, 2015). In this sense the NZEM is similar to the Nord Pool market, which has received considerable academic attention (See, for example, Botterud *et al.,* 2010; Fleten *et al.,* 2015; Weron & Zator, 2014). As a result, the approach we employ in this paper in the context of the NZEM draws from the literature on Nord Pool.

Though much of the generation comes from hydrological sources, there is still a significant portion which comes from alternative sources. Geothermal, gas and coal comprise approximately 18, 13 and 4 percent, respectively (MBIE, 2015). The decisions to utilise these peaking plants will not only be influenced by the wholesale spot price of electricity, but also fossil fuel prices such as oil, gas and coal. Another relevant cost of production in New Zealand is the price of carbon. Since its introduction in 2008, the New Zealand Emissions Trading Scheme (NZ ETS) has applied to electricity generators (see Diaz-Rainey & Tulloch, 2016).

Trading in futures contracts in the NZEM commenced July 2009 and is referenced to two nodes, or locations, on the power grid: Benmore in the South Island and Otahuhu in the North Island. Initially both quarterly and "strip" contracts were traded, while monthly contracts were not introduced until late in 2015. This paper focuses on the quarterly contracts.

3. Literature on Liquidity and Electricity Risk Premia

3.1 Liquidity Literature

Liquid markets have long been considered to exhibit certain characteristics. Kyle (1985), building Black (1971)'s description of a liquid market, developed terms to describe the degree of liquidity in a market, for example; tightness, depth and resiliency. As we are concerned with examining the liquidity of electricity markets in this paper, it follows that we must determine how to measure or capture these characteristics.

A commonly used liquidity measure is simply trading volume. It has been shown that, all else being equal, volume is an increasing function of a market's liquidity[1]. The use of trading volume as a measure of liquidity can be justified by the argument of Brunnermeier and Pedersen (2009) that trading itself can be an important liquidity indicator. However, as noted

[1] For example, see Amihud and Mendelson (1986a), Brennan and Subrahmanyam (1995), Brennan, Chordia, and Subrahmanyam (1998) and Glosten and Harris (1988).

by Fleming (2003), increased trading volume is also associated with greater volatility, which is considered to negatively impact liquidity. Therefore, it is not always clear what an increase in trading volume is actually reflecting. All things considered, its ease of calculation and interpretation makes this an attractive measure.

Tightness and transaction costs are interrelated, so the level to which market participants are exposed to transactions costs will be reflected by the degree of tightness in a market. The bid-ask spread can be considered one of these costs, as it is the price paid for the provision of immediacy (Demsetz, 1968). Furthermore, it has been shown to display a strong negative correlation with several aspects that reflect liquidity, such as trading volume and the number of market makers. It is therefore appropriate to consider the bid-ask spread a natural measure of liquidity (Amihud & Mendelson, 1986b).

Though spreads can be effective estimates of transaction costs incurred by market participants, and by proxy liquidity, its use is not always a viable option since it requires high-frequency data that is not always easily available. In response, several authors have developed spread proxies which attempt to capture these costs with low-frequency data. For example, Roll (1984) developed the Roll Spread, Lesmond *et al.* (1999) formulated a "Zeros" measure, while Corwin and Schultz (2012) defined the High Low Spread. Though such measures have been demonstrably effective, some are relatively computationally intensive, which is to be expected considering the task they are carrying out.

In terms of the characteristics of depth and breadth, liquid markets will be better able to absorb large market orders without a significant impact on the market price than less liquid markets, *ceteris paribus*. Should markets be unable to efficiently do so, participants will suffer price impact costs as they "walk up the book". This price impact is another potential transaction cost faced by investors and one which can also be captured through proxies.

Again there are measures which can effectively capture this characteristic of liquidity, but at the cost of a need for high-frequency data. As was the case with spread proxies, several authors have attempted to overcome such issues. The most notable of these is the Illiquidity Ratio developed by Amihud (2002). This is simply the ratio of absolute daily return to daily volume and can be interpreted as the "percentage price change per dollar of daily trading volume, or the daily price impact of the order flow" (Amihud, 2002; p.34). Alternatively, it can be considered "a measure of consensus belief about new information" (Marcelo and Quiros, 2006; p.258). As the name implies, a higher value represents a greater degree of *illiquidity*.

In terms of measuring liquidity in an electricity market context, the literature is thin. Frestad (2012) examined the liquidity of the Nord Pool swaps market, utilising trading volume, open interest, bid-ask spread and trading volatility as their chosen measures. Hagemann and Weber (2013) also used volume and spread, as well as a high-low difference, to measure the liquidity of the German intraday electricity market.

3.2 Risk Premia in Electricity Markets

Within the literature examining risk premia in electricity markets, there are essentially two methods which can be employed. Researchers can either examine the *ex-post*, or realised premia, or the *ex-ante* premia. Those who examine the *ex-ante* premia must develop an estimate of the expected future spot price and, as a result, will have results which are at least partially determined by their modelling methods. To overcome such issues, a majority of the literature focuses on the ex-post premia which uses actual realised market prices.

Significant premia have been found in electricity markets all over the world: Longstaff and Wang (2004) in PJM (in the USA), Kolos and Ronn (2008) in EEX (covers Central Europe) and Botterdud *et al.* (2010) in Nord Pool (covers Nordic and Baltic markets). However, despite this, there exists no consensus with regards to the sign of this premia. For example, Furió and Meneu (2010) found both significantly negative and positive premia in the Spanish market. Viehmann (2011) also found mixed results in the German day-ahead market. This may be in some part due to the seasonal and diurnal nature of electricity markets. For example, Karakatsani and Bunn (2005) found the sign flipped throughout the day, while Lucia and Torró (2011) found that it was dependent on the season in which the contract matures.

Another strand of the literature examines the determinants of premia, which are in turn influenced by market participant's hedging decisions. The seminal paper in this area was the equilibrium hedging model developed by Bessembinder and Lemmon (2002) (hereafter the "B&L Model"), which considered the statistical risk factors of the underlying spot price to be important determinants. They express the forward premium as being linearly determined by the variance of the spot price and the standardised skewness of the spot price. That is:

$$RP_t = \alpha Var(S_t) + \gamma Skew(S_t) \quad (1)$$

Based upon their equilibrium model, $\alpha < 0$ and $\gamma > 0$, meaning that the forward premium should be positively related to the expected skewness of the spot price and negatively related to the variance of the spot price. These hypothesised relationships and coefficient signs have been given empirical support by (amongst others) Lucia and Torró (2011), Douglas and Popova (2008) and Longstaff and Wang (2004) - albeit only partial support in some cases. However, there have also been several conflicting pieces of work. For example, Bunn and Chen (2013) found a significant negative relationship between risk premia and the skewness of the underlying spot price, as well a significant positive relationship with the volatility. This led them to suggest that the mixed results in the literature are due to under specifications and that "exogenous and endogenous variables are often more significant than the statistical measures (of variance and skewness)" (Bunn and Chen, 2013;p.183) and omitting them can have a significant impact on analyses.

These other variables mentioned typically concern physical market factors. Douglas and Popova (2008) considered these in their development on the B&L Model and believed the original model "(did) not address the question of what factors cause the variance and skewness […] to vary" (p.1716). As their study was conducted in the context of the PJM Interconnection, the physical market factors they considered were related to gas storage inventories. Clearly the physical market variables used in analyses will need to reflect the conditions of the underlying physical market.

A more appropriate model to draw upon for the NZEM is that used by Botterud *et al*. (2010) for NordPool. In a similar augmentation of the B&L model, they suggested that the forward premium be related to the availability of hydro generation. Empirical analysis confirmed this relationship and was supported later by Lucia and Torró (2011). Both papers also gave evidence supporting a time-varying premia, which suggested that one should not only consider physical market factors, but also the effects of prior premia.

The third area which may influence participant's hedging decisions is the underlying cost of production. Bunn and Chen (2013) deviated from examining the effects of the physical capabilities of the systems and used factors related to generator's costs of production, such as gas, coal and carbon prices. Similar costs were also used in the model of Fleten *et al*. (2015).

4. Methodology

4.1 Data

We obtained NZEM data from Energy Link Limited. This consisted of trading volumes and daily closing prices of quarterly futures contracts, as well as hydrological inflows and storage and market demand. The contracts under consideration began trading from the 14th July 2009. However, the initial months of trading saw unusual trading behaviour. To remove the impact of this period, out sample period begins 2nd October 2009 and extends to the 31st December 2015.

Financial market data was sourced from Bloomberg. This included daily prices for carbon (New Zealand Units (NZUs) from New Zealand's Emissions Trading Scheme), oil (Dubai Fateh Oil) and a general local stock market index (NZX50 Gross Index). Attempts were made to source data for both coal and gas prices, however unfortunately no reliable data series with an appropriate frequency were available.

For the electricity futures data, at any point in time, there are contracts traded for every quarter up to three years ahead. This paper considers three of these contract "forms". The first of these is what we term the "front end" contract. This simply refers to the contract with the closest maturity. We also consider the contracts which mature in the current quarter one year ahead and two years ahead, respectively. For example, at the start of our dataset in the fourth quarter of 2009, we were considering the Q4 2009 contract, the Q4 2010 contract and the Q4 2011 contract.

Table 1 presents a description and the basic descriptive statics for the variables used in this study, this includes our two measures of liquidity which we describe below.

[INSERT TABLE 1 ABOUT HERE]

4.2 Liquidity Measures and Anticipated Structural Breaks

The first measure we employ is simply trading volume. Though we are aware of potential issues around its use, the simplicity of both calculation and interpretation overcome these. We define this as simply the number of contracts traded each trading day. In November 2015, the size of the NZEM futures contracts was reduced from 1 megawatt (MW) to 0.1MW i.e. decreased by a factor of ten. In order to correct for this and allow for accurate comparisons, the trading volume used from the 1st November 2015 is given by:

$$Trading\ Volume_t = \frac{Number\ of\ contracts\ traded_t}{10} \qquad (2)$$

The second measure utilised is the Illiquidity Ratio developed by Amihud (2002). This is defined as:

$$Illiquidity_t = \frac{|r_{ti}|}{Volume_{ti}} \qquad (3)$$

where r_{ti} is the logarithmic return[2] on futures contract i on day t. $Volume_{ti}$ is the trading volume of futures contract i on day t. As mentioned in Section 3.1, there are several liquidity proxies present in the literature. The use of this particular measure stems from the findings of Marshall *et al.* (2012), who found it was the 'best and most consistent' measure when compared to liquidity benchmarks. Though other conflicting results exist, this was carried out in the context of commodity futures and, while not directly considering electricity, is the most relevant. These conflicting results are likely due to the fact that one single measure cannot possibly capture all aspects of liquidity (Amihud, 2002).

There is one issue with the use of this Illiquidity Ratio in this context which likely hasn't been present for its previous users. The ratio can only be calculated on days where trading actually takes place, that is, when volume is positive. Due to the lack of activity present in the NZEM futures market, there are many days which do not meet this criteria. Such an issue would obviously very rarely be present in the equity markets it was initially developed for.

In order to determine the effectiveness of interventions which aimed to enhance liquidity we carry out structural break tests (Bai and Perron, 2003) and identify changes in structure using global information criteria. We do so on our two measures of liquidity and there are interventions that sought to increase liquidity that are of interest. The first occurred in January of 2010 when the mandatory market making was introduced involving the four largest generators. This involved introducing a daily window during which the four largest market participants must post bid and ask prices and be willing to trade at these quotes. The second was in October of 2011 and involved a reduction of the maximum bid-ask spread from

[2] Where the logarithmic return on day t is defined as $\ln\left(\frac{P_t}{P_{t-1}}\right)$, where P_t and P_{t-1} are the closing prices on days t and $t-1$, respectively.

10% to 5%. As already mentioned, a reduction in the bid-ask spread is a typical indicator of improving liquidity.

4.3 Modelling Risk Premia

As with much of the prior literature we examine the *ex-post*, or realised risk premia. We define this as:

$$RP_{t,T} = F_{t,T} - S_T \quad (4)$$

Where $RP_{t,T}$ is the risk premia at time t for a contract which matures at time T. $F_{t,T}$ is the closing futures price at time t for a contract which matures at time T, while S_T is the spot price at time T. NZEM futures contracts settle relative to the arithmetic average spot price over the settlement quarter, so S_T is calculated appropriately. That is, those who purchase these contracts pay/receive the differences between the future's price they entered the contract at, and the average half-hourly wholesale spot price over the settlement quarter.

We determine the drivers of premia using several models of varying complexity. The first of these considers the statistical risk measures first suggested in the B&L model. This model is defined as:

$$RP_t = \alpha_0 + \alpha_1 Skew_t + \alpha_2 Var_t + \alpha_3 S_t + \sum_{i}^{k} \alpha_{3+i} RP_{t-i} + \sum_{i=1}^{3} \alpha_{3+k+i} Q_i + \varepsilon_t \quad (5)$$

where $Var(S_j)_t$ and $Skew(S_j)_t$ are the variance and skewness of the spot price, $S_{j,t}$,at node j, at time t. In order to effectively capture the market environment which participant's hedging decisions are based upon, these are calculated based upon the past seven days for front end contracts and past thirty days for the other two forms. In each of our models, we include a set of quarterly dummies (Q_i). This is to control for the significant seasonality displayed by risk premia. We also control for the effects of the premia in previous periods to overcome any heteroscedasticity or autocorrelation issues[3].

From Bessembinder and Lemmon (2002), we anticipate that the coefficient for skewness will be positive. Greater skewness in the spot market represents a greater chance of price spikes in the market. In order to hedge against this risk, we expect that market

[3] The choice regarding the number of lags included is based upon the Durbin-Watson and Breusch-Godfrey regression diagnostics. That is, lags are included until the regression "quality" ceases to increase.

participants will demand a greater quantity of these futures contracts and, as a result, drive the price and premia up. The model developed by Bessembinder and Lemmon (2002) also suggests that there should be a negative relationship between premia and the variance of the spot market. However, intuition suggests that this should instead be a positive relationship. Greater variance brings with it greater spot price risk for both generators and retailers. Hence, the same argument can be made as for the relationship between skewness and premia. It should be noted, however, that there is no consensus in the empirical work done with regards to the signs of these coefficients.

We then include variables which reflect the physical state of the market. Due to the hydro dominated generation system present in NZ, these variables are similar to those utilised by Botterud *et al.* (2010). We define this model as:

$$RP_t = \alpha_0 + \alpha_1 Skew_t + \alpha_2 Var_t + \alpha_3 S_t + \alpha_4 Demand_t + \alpha_5 Inflow_t + \alpha_6 Storage_t + \sum_{i}^{k} \alpha_{6+i} RP_{t-i} + \sum_{i=1}^{3} \alpha_{6+k+i} Q_i + \varepsilon_t \tag{6}$$

$Storage_t$, $Inflow_t$ and $Demand_t$ represent deviations from the historical average value during that week of the year from hydrological storage, hydrological inflows and electricity demand (See Table 1). For each week of the year ($i = 1,2 \ldots 52$) over the sample period, an average is calculated for each variable. To calculate the series of deviations, we subtract the average for the particular week from the realised value. We anticipate that coefficients for both storage and inflow deviations will be negative. When hydrological storage and inflows are below expectation i.e. negative deviations, hydro generator's capacity to supply electricity is reduced. This increases the potential for spikes in the spot market (Botterud et al., 2010). Both Botterud et al. (2010) and Weron and Zator (2014) find significantly positive relationships between demand deviations and premia in the Nord Pool electricity market. We anticipate the same. When demand is higher than expected, spot prices will likely increase in response and increase the incentive for purchasers to hedge such exposure.

Drawing upon the argument of Redl and Bunn (2013) that premia will be related to the underlying fuel source, we also include production costs as these are relevant to New Zealand (See Section 2). These are carbon and oil prices and create the model:

$$RP_t = \alpha_0 + \alpha_1 Skew_t + \alpha_2 Var_t + \alpha_3 S_t + \alpha_4 Demand_t + \alpha_5 Inflow_t + \alpha_6 Storage_t + \alpha_7 Carbon_t + \alpha_8 Oil_t + \alpha_9 Stock_t + \sum_{i}^{k} \alpha_{9+i} RP_{t-i} + \sum_{i=1}^{3} \alpha_{\,9+k+i}\, Q_i + \varepsilon_t \quad (7)$$

As outlined by Fleten *et al.* (2015), increases in fossil fuel prices will lead to higher electricity spot prices due to increased production costs. This, in turn, increases demand for futures contracts and results in greater forward premia. Hence, we anticipate the coefficient for Oil_t to be positive. Since the introduction of the New Zealand Emissions Trading Scheme (NZ ETS) in July 2010, the price of NZUs is also a relevant cost of production for electricity generators and retailers (See Section 2). In the same manner that we would expect fossil fuel prices to positively affect forward premia, the coefficient for $Carbon_t$ would be expected to be positive. For both fuel variables we use the logarithmic return to overcome issues of non-stationarity. Following Fleten *et al.* (2015), we also include the logarithmic return of the NZX50 Gross Index. We do so to capture 'speculative' influences of investor sentiment and risk aversion.

As mentioned previously, we also investigate whether a liquidity premia exists in these futures contracts. In line with this, the final addition to the model is the Illiquidity Ratio outlined in the previous section. This final model is defined as:

$$RP_t = \alpha_0 + \alpha_1 Skew_t + \alpha_2 Var_t + \alpha_3 S_t + \alpha_4 Demand_t + \alpha_5 Inflow_t + \alpha_6 Storage_t + \alpha_7 Carbon + \alpha_8 Oil_t + \alpha_9 Stock_t + \alpha_{10} Illiquidity(F_t) + \sum_{i}^{k} \alpha_{10+i} RP_{t-i} + \sum_{i=1}^{3} \alpha_{\,10+k+i}\, Q_i + \varepsilon_t \quad (8)$$

As will be evident in the results, we also examine other models with slight deviations from those stated here. For the sake of brevity we have only defined those which form the basis of any alterations.

5. Results

5.1 Liquidity Results

Figure 1 displays both daily trading volume and illiquidity ratios for all three contract forms. We report the average between the Benmore and Otahuhu nodes. Volumes in the first year of trading highlight the illiquidity concerns discussed in Section 1, since only a handful of contracts traded each day.

[INSERT FIGURE 1 ABOUT HERE]

As outlined in section 5.1, we carry out structural break tests (Bai and Perron, 2003) to determine the existence of any significant changes. The results of these are presented empirically in Table 2 and graphically in Figure 2. Had the interventions achieved their desired outcome, we would expect to find breaks around January 2010 (mandatory market making) and October 2011 (reduction of bid-ask spread). What we actually observe is no statistically significant change around the introduction of mandatory market making, implying that this policy intervention failed to achieve its objective of enhanced liquidity. This may suggest that the market makers simply posted quotes with the maximum spread allowed by the exchange (10%), carrying out their duty yet making no contribution to improving market liquidity.

However, it appears the reduction of the maximum bid-ask spread from 10% to 5% did have an impact. We see that front end volumes increased in October 2011 and January 2012 for Benmore and Otahuhu, respectively. Front end trading at both nodes also experienced a decrease in the Illiquidity Ratio in October 2011. These results suggest that imposition of a smaller spread appears to have achieved its desired outcome. However this only occurred in the front end contracts. While there were some changes further out, this likely reflected the decreased sample size for the Illiquidity Ratio for these contracts. One would expect the front end contracts to be the most liquid, however anecdotal evidence suggests that there is hedging activity taking place one and two years ahead, so the lower liquidity of these contracts should still be of concern.

[INSERT TABLE 2 AND FIGURE 2 ABOUT HERE]

5.2 Risk Premia Results

Table 3 displays the average risk premia (eq. 4) for both nodes, across all contract forms and by quarter. As expected, there is evidence of significant premia at both nodes, for all contract forms. Though the overall premia for front end contracts is insignificant at both Benmore and Otahuhu, when broken down by quarter there is quite clearly significant premia. This premia generally increases further out the curve i.e. premia are greater the longer the time to maturity.

[INSERT TABLE 3 ABOUT HERE]

The premia for all six contracts examined exhibit a clear time variant nature. This is illustrated by figure 3. We see that the premia are consistently higher in Q2 and Q3 contracts. Aside from the front end Benmore contract, we see positive premia which is significant at the 1% level. By contrast, Q1 and Q4 contracts, in general, display significantly negative premia.

[INSERT FIGURE 3 ABOUT HERE]

These findings are consistent with those of Lucia and Torró (2011) for Nord Pool; they found that the premia is dependent on the season in which the contract matures. Q2 and Q3 represent the driest months of the year, when demand is at a peak while hydro storage/ and inflows are lowest. During these times the potential for price spikes is at its highest, so those market participants with downside risk from price increases, i.e. those who purchase electricity, have a greater incentive to hedge this exposure. In order to reduce their exposure to large and frequent price spikes during a dry period, they may be willing to pay a greater price than would be realised were they not hedged. On the other hand, during Q1 and Q4 the opposite is the case. There is a lull in demand, while hydro generators have excess capacity to meet demand and storage lakes are either filling (Q4) or at or near their annual peak storage (Q1). In this scenario it is likely those with downside risk from low prices, i.e. those who sell electricity, will have greater incentive to hedge and may accept a lower price than would be realised in the spot market.

These alternative arguments may be related to the balance between the relative hedging of generators and retailers, as found in Fleten *et al.* (2015). During Q2 and Q3 it may be those retailers and large consumers who utilise these futures contracts, while Q1 and Q4 sees hedging activity by generators taking place. There is potential for an investigation into this using participant data from the EA, however this is beyond the scope of this paper.

As outlined in Section 4.3, next we seek to explain this premia through a variety of models. Table 4 shows the results for our “basic” model (eq. 5). These results exhibit several surprising elements. The first of these is that we find little support for the B&L model. Though the variance and skewness coefficients for front end Benmore contracts are what is predicted by the B&L model, they are only significant at the 10% and 5% level, respectively. Furthermore, the variance coefficient changes sign and is significant at the 1% level at the Otahuhu node. This change in sign could potentially be explained by the fact that volatility incentivises both producers and consumers to hedge their exposure. As demand for futures contracts is being spurred from both sides with “competing premia” (producers will accept lower prices, whilst consumers will accept higher prices), this may reflect an almost zero-sum game i.e. a close to zero premia. Were this to be the case, it may explain the lack of agreement with regards to the sign of variance coefficients in previous empirical research. The explanatory power of skewness and variance decrease as you move further out the curve, which is to be expected if market participants behave efficiently.

The second surprising result is the significance of the current level of the spot price, as far as two years ahead. Fortunately, all the coefficients are of the same sign in this case. This result will be discussed in depth later. We also find significant lagged dependent variables, supporting the findings of Lucia and Torró (2011). As expected due to the seasonal nature of premia, we also find the quarterly dummies to be significant. These reported results for the statistical risk measures are robust when we drop the spot price as a variable.[4]

[INSERT TABLE 4 ABOUT HERE]

We then include the physical market factors of demand, inflows and storage. The results of this are reported in Table 5 (Panel A). We again find little support for the B&L hypothesised relationships. Only two coefficients are significant at the 1% level, and are of the opposite sign to that expected. One of these occurs in the two years ahead contract at the Benmore node.

In terms of the physical market factors, we find significant coefficients for both front end contracts for the hydrological variables. All four are significant at the 1% level. Significantly negative coefficients for the inflow variables imply that when inflows are lower than expected, realised premia increases. This is related to the potential for price spikes: when there are below average inflows, the ability for generators to meet demand decreases and there is greater potential for price spikes due to the reliance on hydro generation in the NZEM. Thus, the incentive to hedge increases.

One would also expect this to be the same for the storage variable. In fact, both are significantly positive. These conflicting results suggest that when lake levels are lower than expected, premia decrease, however if the water which flows into these lakes is lower than expected, premia increase. As reported in Table 5 (Panel B), the significance of the physical market variables disappears when the spot price is not included in the model. This suggests

[4] These additional results are available upon request

that there are potential issues around endogeneity between these variables. In terms of demand, it appears to have no explanatory power in this model.

[INSERT TABLE 5 ABOUT HERE]

As is expected, these physical market variables have no explanatory power one and two years ahead. The spot price again has a surprising amount of explanatory power up to one year ahead. This is puzzling considering the minimal correlation between spot price levels one year ahead. Figure 4 illustrates this further as it shows the correlation between spot prices now and in future periods, as well as between future's price changes now and in the future. We see that the spot price correlation dissipates beyond two quarters. That is, the correlation between the spot price now and only three quarters ahead is essentially zero. However, it appears that market participants are pricing the current spot price into future's prices far more than would be expected. For example, inflows into hydro lakes are highly volatile, so if inflows are low and prices are high now, this could all change only weeks or months into the future. The future's price correlations show that a change in the future's price for front end contracts is met with a similar price movement for contracts as far as two years ahead. That is, if front end futures prices increase in response to current market factors, two years ahead contracts price experience upwards movements as well. This, coupled with the explanatory power of the spot price in our regressions, suggests inefficient behaviour by market participants.

[INSERT FIGURE 4 ABOUT HERE]

[INSERT TABLE 6 ABOUT HERE]

It appears that the underlying costs of production, which Redl and Bunn (2013) suggested should explain premia, have no explanatory power in a New Zealand context. Table 6 presents the results from equation 7. We see that the significant explanatory power in the front end for our physical market factors remain robust, however the coefficients for oil and carbon are generally insignificant. We do observe a significantly positive coefficient for Benmore two years ahead contracts, however as such significance is not mirrored in the Otahuhu contract a robust interpretation of this is difficult. There is also no evidence of speculative investor behaviour in these markets, as the stock coefficient is largely insignificant. This suggests that there is no trade-off between potential returns in the stock market or electricity futures market being made by NZ investors.

Our final model considers the effect of liquidity. We adapt equation 8, dropping the costs of production variables due to their limited explanatory power. The results of this are presented in Table 7 (Panel A). Due to the previously mentioned issues around the calculation of the Illiquidity Ratio, the statistical power of these regressions is limited. Though we find some significant illiquidity coefficients, these come from regressions of sample sizes of 83, 37 and 33, respectively.

In an attempt to overcome this, we replace the Illiquidity Ratio with trading volume which provides far greater sample sizes. The results of this are reported in Table 7 (Panel B). We find some evidence of trading volume having explanatory power with regards to premia. Though the coefficient for front end Benmore contracts is significant at the 5% level, it is the opposite sign to what would be expected. A positive coefficient suggests that greater trading volume, and thus liquidity, increases premia. This may seem counterintuitive but may reflect the fact that high volume at points may reflect high volatility (See Section 3.1). This volume-volatility effect is likely to be present in the front-end futures since these should more closely reflect underlying spot conditions (from which the volatility is derived). Consistent with this interpretation, we do see significant negative coefficients two years ahead, however only one of these is significant beyond the 10% level.

[INSERT TABLE 7 ABOUT HERE]

6. Conclusions

In this paper we have documented increasing (decreasing) liquidity (illiquidity) for contracts of all maturities, a result which is encouraging for a relatively new market. The results of our structural breaks tests demonstrate that the imposition of mandatory market making did not improve liquidity, yet the reduction in the maximum bid-ask spread did, albeit at the front end only.

We also document significant premia, both positive and negative, in all three contract maturities. Premia are consistently higher during the winter quarters, yet significantly negative during the summer quarters. Regression estimations show limited support for the seminal work of Bessembinder and Lemmon (2002) and suggest that physical market factors play a role in driving front end premia. Most surprising is the significant explanatory power of the current spot price, leading to our suggestion of inefficient behaviour of market participants.

In terms of the initial goal of this paper of determining whether a liquidity premium exists in these futures contracts, the evidence is mixed. While there are several significant coefficients, we have signs opposite to that which would be expected, as well as concerns around statistical power of our regressions.

The findings of this paper may have several potentially important implications for both market participants and regulators. For regulators, this may provide support for a future reduction of the maximum bid-ask spread, however any potential liquidity increase must be traded off against the potential additional risk imposed on market makers. One should also be wary of the fact that the relationship between bid-ask spreads and liquidity is potentially non-linear. Should further reductions in the maximum allowable spread be made in the future, the returns may be diminishing. The documented inefficient behaviour may also be attractive for speculative investors who wish to take advantage of such anomalous price movements. However, due to the relative illiquidity of this market, exiting positions and realising any profits may prove difficult.

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Figure 1. Evolution of liquidity

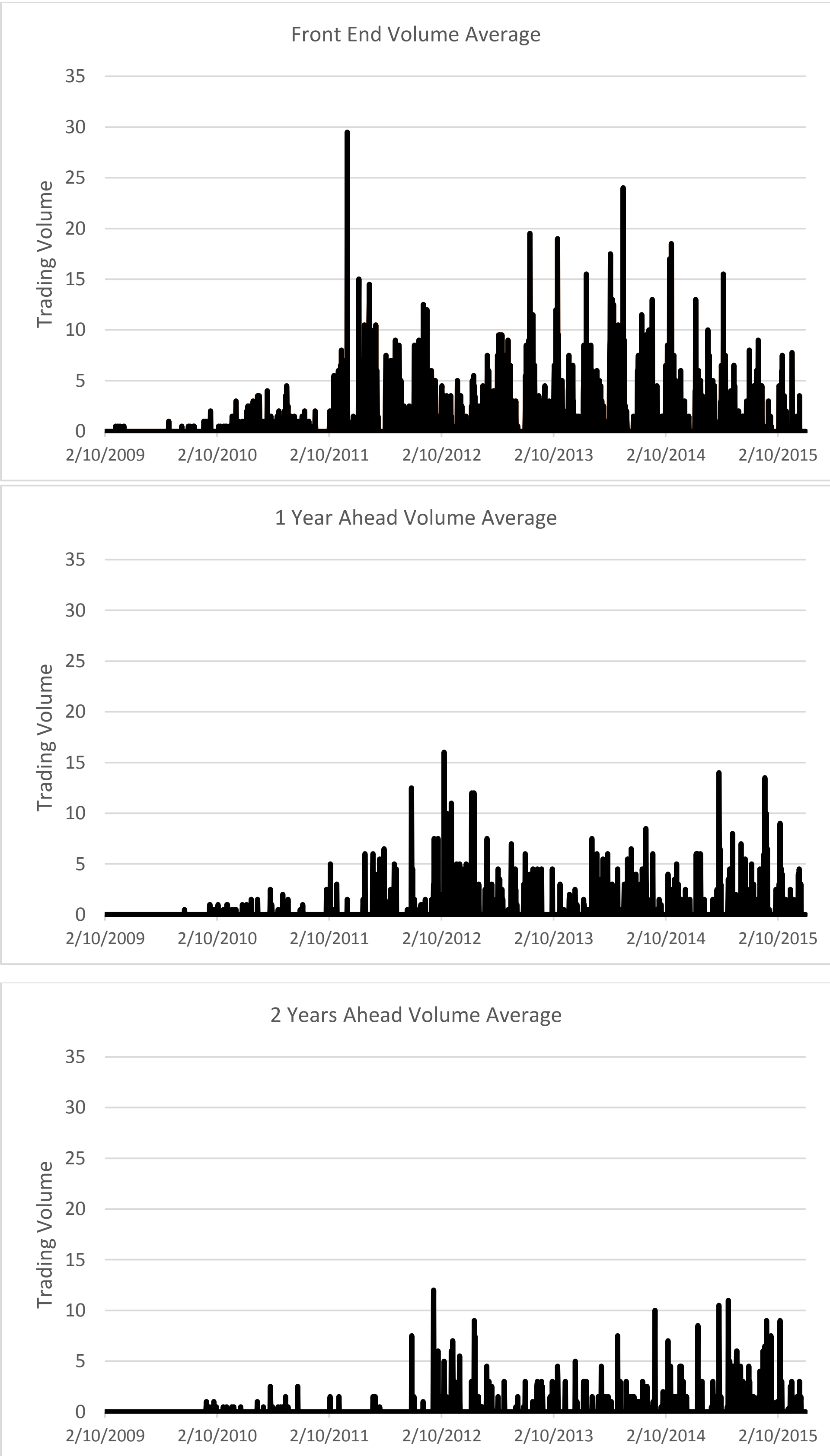
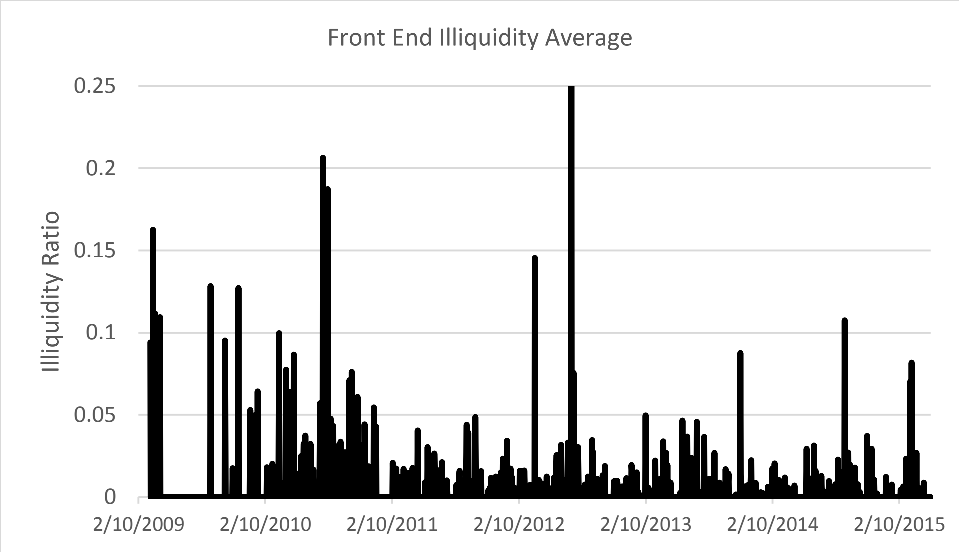
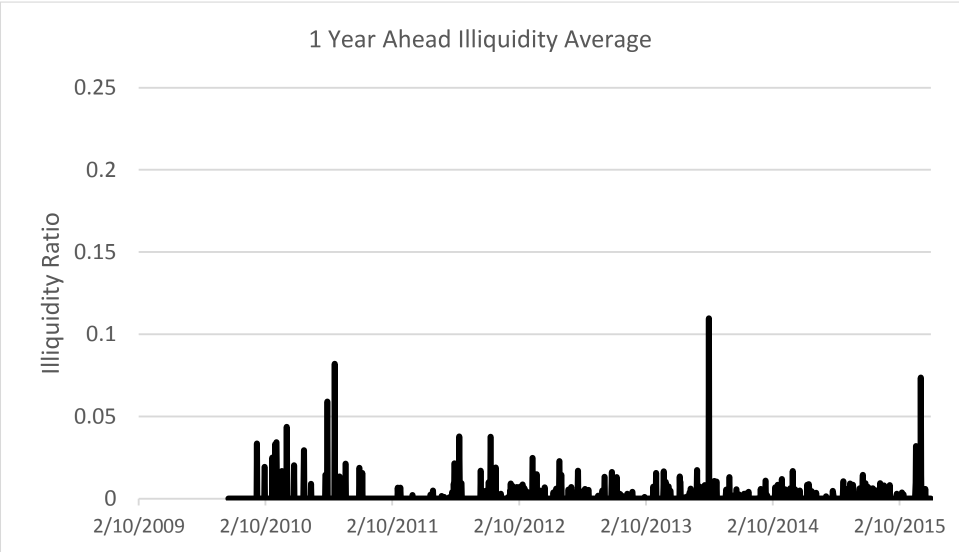


Figure 1. Evolution of liquidity (continued)





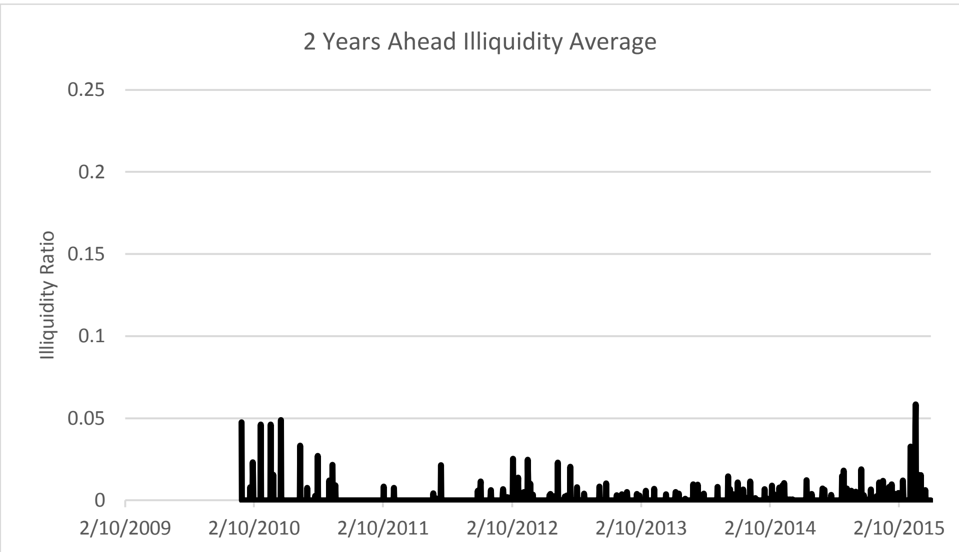
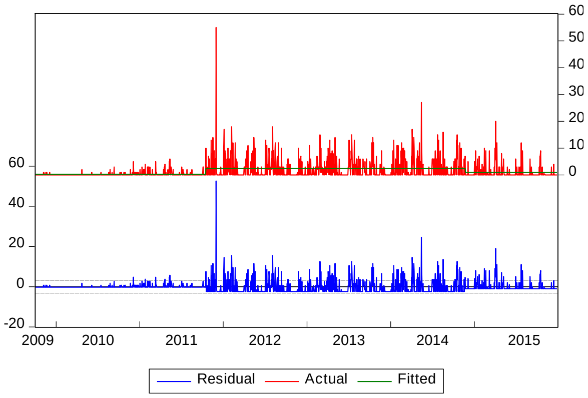
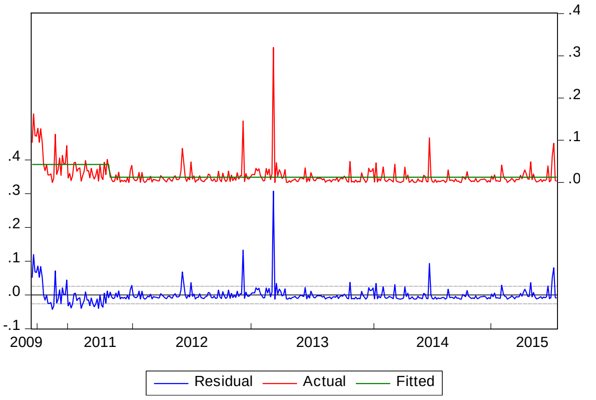


Figure 2. Structural Breaks in Liquidity Measures (selected: front end only)

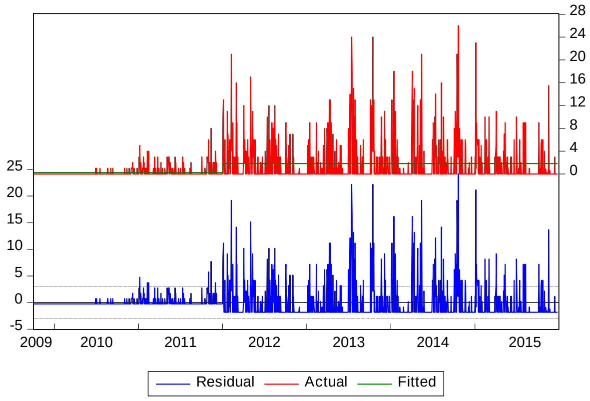
Front End Trading Volume (Benmore)



Front End Illiquidity (Benmore)



Front End Trading Volume (Otahuhu)



Front End Illiquidity (Otahuhu)

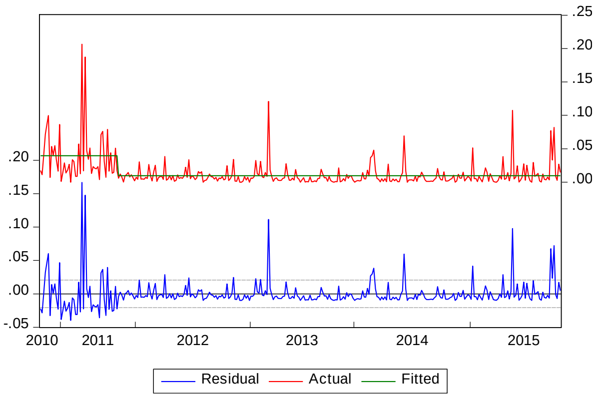


Figure 3. Evolution of Risk Premia

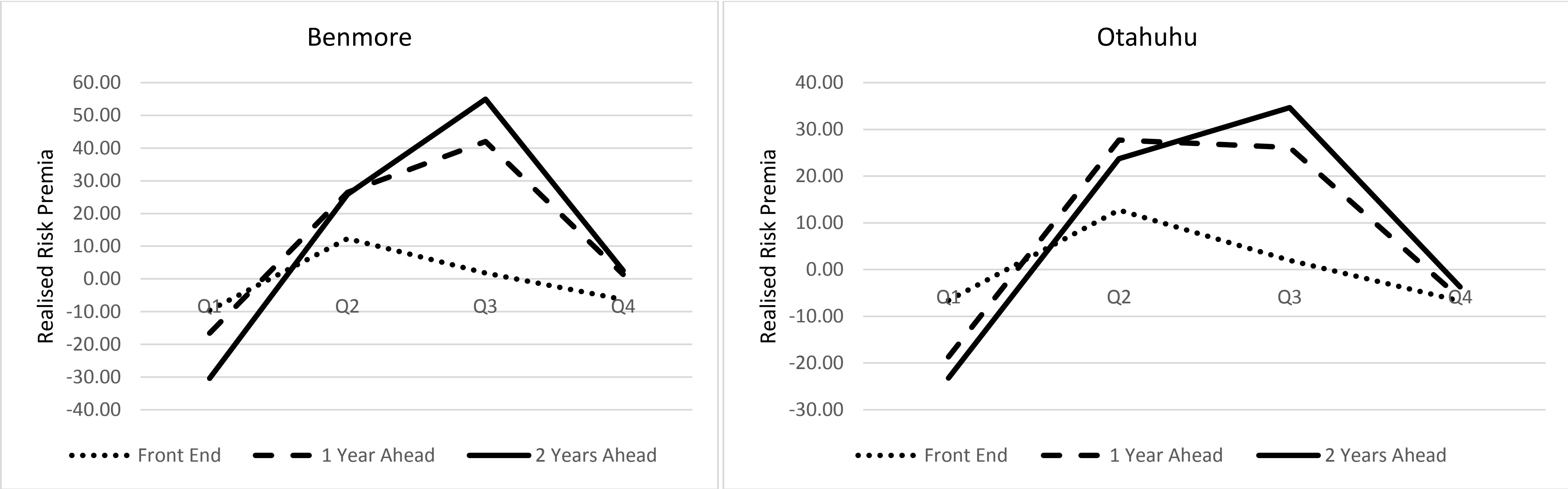


Figure 4. Correlations in Movements in BEN Futures Prices

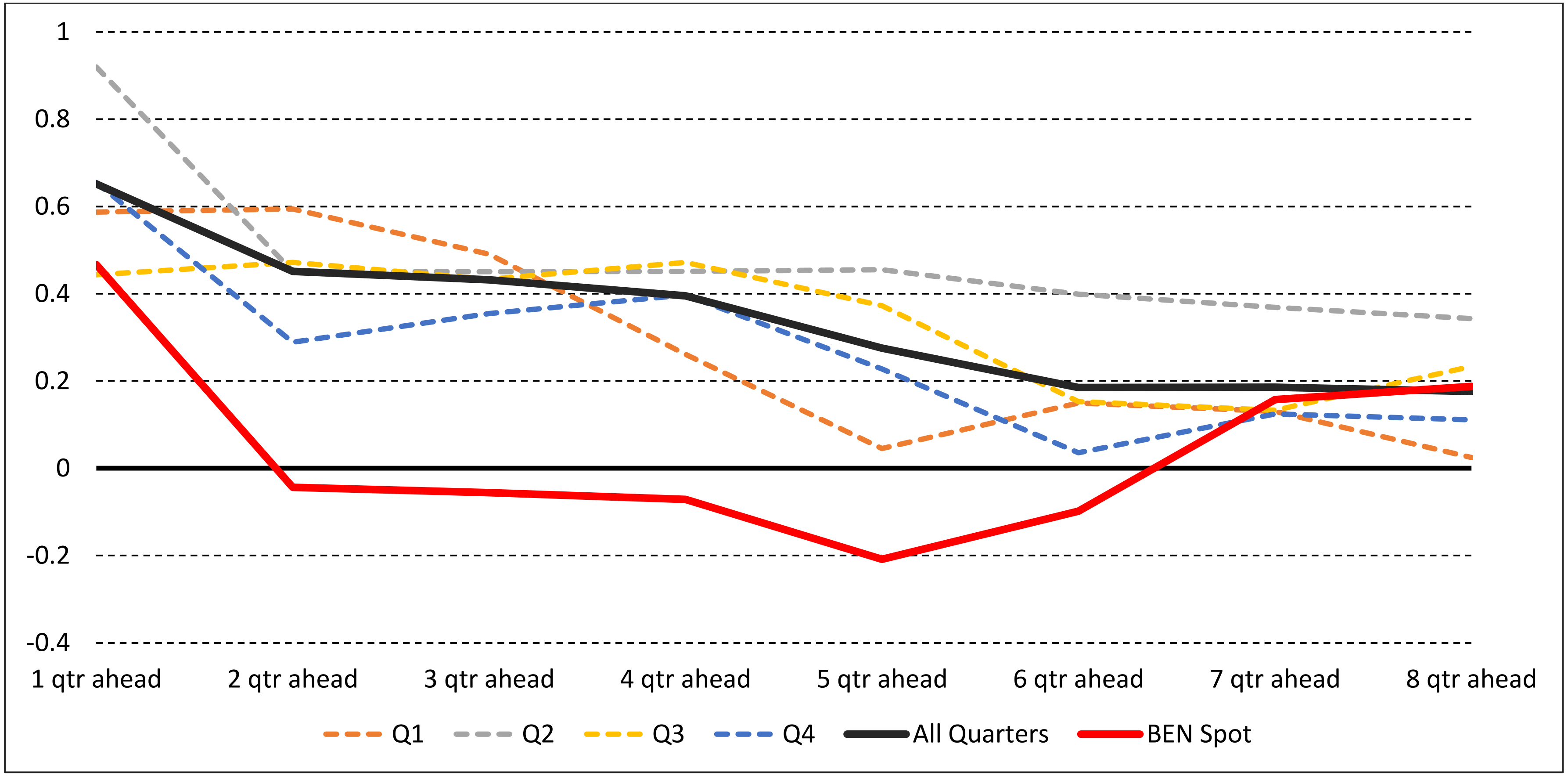


Table 1. Definition of Variables and Descriptive Statistics

Variable		Description	Source	Mean	Std. Dev.	Minimum	Maximum
RP (Risk Premia)	Front End (Benmore)	Difference between the current futures price and the average wholesale spot price over the settlement quarter	EL	-0.606	19.322	-52.233	71.167
	Front End (Otahuhu)			0.099	14.466	-40.245	56.413
	1 Year Ahead (Benmore)			13.151	33.846	-54.244	72.136
	1 Year Ahead (Otahuhu)			6.903	23.766	-43.245	58.917
	2 Years Ahead (Benmore)			13.180	37.451	-51.294	71.636
	2 Years Ahead (Otahuhu)			7.560	24.379	-30.745	39.203
Trading Volume	Front End (Benmore)	Daily trading volume in the number of contracts	EL	1.45	3.33	0.00	55.00
	Front End (Otahuhu)			1.26	3.09	0.00	26.00
	1 Year Ahead (Benmore)			0.60	2.04	0.00	26.00
	1 Year Ahead (Otahuhu)			0.51	1.78	0.00	20.00
	2 Years Ahead (Benmore)			0.32	1.36	0.00	16.00
	2 Years Ahead (Otahuhu)			0.31	1.34	0.00	13.00
Illiquidity	Front End (Benmore)	Amihud's Illiquidity measure	EL	0.02	0.03	0.00	0.32
	Front End (Otahuhu)			0.01	0.02	0.00	0.21
	1 Year Ahead (Benmore)			0.01	0.01	0.00	0.06
	1 Year Ahead (Otahuhu)			0.01	0.01	0.00	0.11
	2 Years Ahead (Benmore)			0.01	0.01	0.00	0.06
	2 Years Ahead (Otahuhu)			0.01	0.01	0.00	0.06
Open Interest	Front End (Benmore)	Number of contracts outstanding in the market	EL	70.70	50.90	0.00	171.00
	Front End (Otahuhu)			41.21	32.37	1.00	116.00
	1 Year Ahead (Benmore)			21.31	16.57	1.00	62.00
	1 Year Ahead (Otahuhu)			86.00	68.63	0.00	234.00
	2 Years Ahead (Benmore)			37.03	34.49	0.00	112.00
	2 Years Ahead (Otahuhu)			19.06	15.33	0.00	53.00
Skew(7)	Benmore	Skewness of wholesale spot price over the past seven days	EL	0.19	0.85	-2.49	2.64
	Otahuhu			0.32	0.92	-2.38	2.65
Skew(30)	Benmore	Skewness of wholesale spot price over the past thirty days	EL	0.56	1.02	-2.55	5.12
	Otahuhu			0.98	1.27	-1.34	5.12
Var(7)	Benmore	Variance of the wholesale spot price over the past seven days	EL	334.81	1060.83	2.13	13426.56
	Otahuhu			1165.15	9257.73	0.92	158056.52
Var(30)	Benmore	Variance of the wholesale spot price over the past thirty days	EL	634.87	1188.74	18.79	7526.74
	Otahuhu			1390.22	5372.01	19.62	50725.58
S(Quarter)	Benmore	Average wholesale spot price during the current quarter	EL	61.44	29.09	0.94	163.55
	Otahuhu			67.53	18.76	7.99	136.52
S(30)	Benmore	Average wholesale spot price over the past thirty days	EL	64.22	35.00	9.13	200.28
	Otahuhu			70.56	23.42	11.70	147.66
Demand	Demand(1)	Deviation from historical average demand over the past week	EL	0.00	18.86	-56.14	54.92
	Demand(4)	Deviations from historical average demand over the past four weeks	EL	0.00	14.55	-42.86	32.37

Key: EL = Energy Link Ltd; Bl =Bloomberg

Table 1. Definition of Variables and Descriptive Statistics (continued)

Variable		Description	Source	Mean	Std. Dev.	Minimum	Maximum
Inflow	Inflow(1)	Deviation from historical average hydrological inflows over the past week	EL	2.01	177.21	-434.64	773.52
	Inflow(4)	Deviations from historical average hydrological inflows over the past four weeks	EL	0.00	120.50	-309.62	389.47
Storage	Storage(1)	Deviation from historical average hydrological storage over the past week	EL	6.98	501.82	-1130.12	1224.60
	Storage(4)	Deviations from historical average hydrological storage over the past four weeks	EL	0.00	482.92	-1113.25	1023.05
Carbon	Carbon (1)	Logarithmic return of NZUs over the past week	Bl	0.00	0.07	-0.41	0.50
	Carbon(4)	Logarithmic return of NZUs over the past four weeks	Bl	-0.01	0.14	-0.49	0.76
Stock	Stock(1)	Logarithmic return of the NZX50 Gross Index over the past week	Bl	0.00	0.01	-0.06	0.05
	Stock(4)	Logarithmic return of NZX50 Gross Index over the past four weeks	Bl	0.01	0.03	-0.11	0.11
Oil	Oil(1)	Logarithmic return of Dubai Fateh oil over the past week	Bl	0.00	0.04	-0.15	0.19
	Oil(4)	Logarithmic return of Dubai Fateh oil over the past four weeks	Bl	0.00	0.09	-0.31	0.29

Key: EL = Energy Link Ltd; Bl =Bloomberg

Table 2. Structural Breaks in Liquidity Measures

Maturity	Variable	Breaks	Variable	Breaks
Front End Benmore	Volume	17/10/2011 & 20/11/2014	Illiquidity	4/10/2011
Front End Otahuhu	Volume	5/01/2012	Illiquidity	25/10/2011
1 Year Ahead Benmore	Volume	20/01/2012	Illiquidity	
1 Year Ahead Otahuhu	Volume	7/09/2012	Illiquidity	
2 Years Ahead Benmore	Volume	5/09/2012	Illiquidity	3/07/2012
2 Years Ahead Otahuhu	Volume	5/09/2012	Illiquidity	

Table 3. Average Risk Premia 2/10/2009-31/12/2015

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	Benmore		Otahuhu		Benmore		Otahuhu		Benmore		Otahuhu	
Overall	-0.61		0.10		13.15	***	6.90	***	13.18	***	7.56	***
Q1	-9.56	***	-6.63	***	-16.59	***	-18.66	***	-30.43	***	-23.20	***
Q2	12.34	***	12.73	***	26.46	***	27.72	***	25.90	***	23.71	***
Q3	1.81		2.00	***	42.04	***	26.12	***	54.93	***	34.64	***
Q4	-6.29	***	-6.72	***	1.39		-6.12	***	2.54	*	-3.69	***

*** represents statistical significance at the 1% level
** represents significance at the 5% level
* represents significance at the 10% level

Table 4. Time Series Regression Results for Equation 5

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	Benmore		Otahuhu		Benmore		Otahuhu		Benmore		Otahuhu	
Constant	-1.939	***	-3.004	***	-2.314	***	-3.249	***	-3.843	***	-5.211	***
Skewness	0.324	***	0.091		-0.013		0.020		0.344		-0.016	
Variance	0.000		0.000		0.000	**	0.000		0.000		0.000	
Spot Price	0.024	***	0.035	***	0.024	***	0.020	***	0.012	*	0.016	**
Lagged RP	1.041	***	0.974	***	0.957	***	0.917	***	0.928	***	0.847	***
Lagged RP 2	-0.094	***	-0.043									
Q2	0.708		1.088	**	2.333	***	4.698	***	5.299	***	7.997	***
Q3	0.660	*	0.854	**	3.076	***	4.104	***	7.308	***	9.527	***
Q4	0.523		0.423		0.896	**	1.142	***	2.810	***	3.267	***
Durbin Watson	1.99		1.934		1.938		1.867		1.861		1.737	
Chi-square heteroscedasticity	0.0777		0.0683		0.8939		0.499		0.892		<0.0001	
Adjusted R^2	0.9429		0.9416		0.9757		0.9725		0.977		0.9742	
n	1589		1589		1336		1336		1081		1081	

Notes:
*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level
Front end use Skew(7), Var(7) and S(Q), while the others use Skew(30), Var(30) and S(30).
Regressions run on daily data

Table 5 (Panel A): Regression results for Equation 6

Contract Form	Front End		One Year Ahead		Two Years Ahead	
Node	Benmore	Otahuhu	Benmore	Otahuhu	Benmore	Otahuhu
Constant	-13.962 ***	-17.502 ***	-12.184 ***	-15.423 ***	-12.939 ***	-13.478 ***
Skewness	0.612	0.155	-0.459	-0.163	2.573 ***	0.601
Variance	0.000	0.000 ***	-0.002 *	0.000	0.000	0.000 *
Spot Price	0.185 ***	0.208 ***	0.145 ***	0.116 ***	-0.001	-0.007
Demand Deviations	0.017	0.023	-0.099	-0.022	0.022	0.079 **
Inflow Deviations	-0.013 ***	-0.008 ***	-0.003	0.000	-0.010	0.004
Storage Deviations	0.006 ***	0.004 **	0.003	0.003 **	-0.003	-0.005 **
Lagged RP	0.730 ***	0.776 ***	0.808 ***	0.649 ***	0.689 ***	0.489 ***
Lagged RP 2		-0.122	0.013	0.051	0.013	
Q2	2.857	6.316 **	9.113 ***	18.040 ***	21.557 ***	26.605 ***
Q3	3.759 **	4.826 **	13.565 ***	16.138 ***	28.914 ***	30.366 ***
Q4	3.716 **	2.888 *	3.902 *	4.900 ***	11.148 ***	10.782 ***
Durbin Watson	1.788	1.828	1.808	1.541	1.492	1.236
Chi-square heteroscedasticity	0.8967	0.0674	0.2891	0.032	0.0652	>0.0001
Adjusted R^2	0.7039	0.7533	0.8929	0.8947	0.9115	0.923
n	325	324	272	272	218	219

Notes:

*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level

Front end use Skew(7), Var(7) and S(Q), while the others use Skew(30), Var(30) and S(30)

Front end use Demand(1), Inflow(1) and Storage(1), while the others use Demand(4), Inflow(4) and Storage(4)

Regressions run on weekly data

Table 5 (Panel B): Regression results for Equation 6 (Excluding price)

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	Benmore		Otahuhu		Benmore		Otahuhu		Benmore		Otahuhu	
Constant	-2.902	**	-2.572	***	-3.185		-6.377	***	-12.858	***	-13.971	***
Skewness	0.429		0.112		-0.709		-0.164		2.543	**	0.605	
Variance	0.001		0.000	***	0.000		0.000		0.000		0.000	**
Demand Deviations	0.061		0.052	*	-0.006		0.034		-0.001		0.075	**
Inflow Deviations	-0.005		-0.004		0.002		0.003		0.023		0.003	
Storage Deviations	-0.002		-0.002		-0.004	**	-0.001		-0.009	**	-0.004	***
Lagged RP	0.789	***	0.762	***	0.831	***	0.694	***	-0.003	***	0.492	***
Lagged RP 2									0.703			
Q2	4.852	**	5.041	***	9.738	***	17.289	***	21.479	***	26.546	***
Q3	2.650		2.629	*	11.143	***	14.434	***	28.815	***	30.361	***
Q4	1.748		0.991		1.836		3.317	**	11.052	***	10.811	***
Durbin Watson	1.844		1.732		1.791		1.566		1.504		1.24	
Chi-square heteroscedasticity	0.9807		0.6398		0.0186		0.0037		0.0433		**<0.0001**	
Adjusted R^2	0.6866		0.7214		0.8888		0.8889		0.9125		0.9265	
n	325		325		273		273		219		219	

Notes:
*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level
Front end use Skew(7) and Var(7), while the others use Skew(30) and Var(30).
Front end use Demand(1), Inflow(1) and Storage(1), while the others use Demand(4), Inflow(4) and Storage(4)
Regressions run on weekly data

Table 6: Regression Results for Equation 7

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	Benmore		Otahuhu		Benmore		Otahuhu		Benmore		Otahuhu	
Constant	-14.756	***	-17.768	***	-13.111	***	-16.414	***	-15.848	***	-13.989	***
Skewness	0.574		0.024		-0.314		-0.059		2.947	***	0.616	
Variance	0.000		0.000	***	-0.002	**	0.000		0.001		0.000	*
Spot Price	0.191	***	0.210	***	0.157	***	0.123	***	0.016		0.000	
Demand Deviations	0.008		0.025		-0.101		-0.021		-0.017		0.072	*
Inflow Deviations	-0.012	***	-0.008	***	-0.002		0.001		-0.013		0.005	
Storage Deviations	0.007	***	0.004	***	0.003		0.003	*	-0.002		-0.005	**
Oil	13.757		15.609		10.837		9.465		39.429	***	15.633	*
Carbon	5.362		5.069		-7.398		-7.162	**	-8.633		-1.452	
Stock	62.764		16.274		-33.221		-18.594		-5.635		-33.348	*
Lagged RP	0.776	***	0.765	***	0.810	***	0.686	***	0.703	***	0.494	***
Lagged RP 2	-0.073		-0.117	**								
Q2	3.817	*	6.652	***	9.596	***	18.868	***	23.336	***	26.849	***
Q3	4.222	**	4.994	***	14.565	***	17.136	***	30.054	***	30.332	***
Q4	4.076	**	3.111	**	4.529	**	5.501	***	11.598	***	10.742	***
Durbin Watson	1.899		1.819		1.812		1.621		1.523		1.236	
Chi-square heteroscedasticity	0.9998		0.4648		0.3083		0.4394		0.3363		0.1117	
Adjusted R^2	0.7032		0.7535		0.8942		0.8965		0.9145		0.9236	
n	324		324		273		273		219		219	

Notes:

*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level

Front end use Skew(7), Var(7) and S(Q), while the others use Skew(30), Var(30) and S(30).

Front end use Demand(1), Inflow(1) and Storage(1), while the others use Demand(4), Inflow(4) and Storage(4)

Front end use Oil(1), Carbon(1) and Stock (1), while others use Oil(4), Carbon(4) and Stock(4).

Table 7 (Panel A): Regression results for equation 8 (Illiquidity measure)

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	**Benmore**		**Otahuhu**		**Benmore**		**Otahuhu**		**Benmore**		**Otahuhu**	
Constant	-5.932		-5.067		-13.764	***	-11.666	**	-27.015	***	-17.817	***
Skewness	0.934		0.630		-0.752		-0.298		1.616		2.916	***
Variance	0.000		0.000	***	0.002		0.000		0.002		0.000	
Spot Price	0.096	*	0.060		0.053		0.059		0.035		-0.079	
Demand	0.014		0.012		-0.184	*	-0.115		0.032		0.119	
Inflows	-0.012	**	-0.009	**	0.014		0.003		-0.002		-0.001	
Storage	0.000		0.001		-0.008	*	-0.001		-0.005		-0.002	
Illiquidity	6.486		6.679		-167.382		296.169	***	282.359	**	99.607	*
Lagged RP	0.736	***	0.732	***	0.566	***	0.778	***	0.348	***	0.198	***
Lagged RP 2												
Q2	-0.245		3.286	**	21.782	***	11.862	***	47.413	***	42.774	***
Q3	0.568		0.346		27.872	***	11.201	**	51.618	***	47.070	***
Q4	-0.264		-0.650		13.389	***	4.605		19.347	***	8.033	***
Durbin Watson	1.809		1.884		1.699		2.015		1.965		1.673	
Chi-square heteroscedasticity	0.9609		0.9677		0.5334		0.3778		0.8485		0.5267	
Adjusted R^2	0.7099		37873		0.9085		0.9174		0.9232		0.9893	
n	197		191		96		83		37		33	

Notes:
*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level
Front end use Skew(7), Var(7) and S(Q), while the others use Skew(30), Var(30) and S(30).
Front end use Demand(1), Inflow(1) and Storage(1), while the others use Demand(4), Inflow(4) and Storage(4)Regressions run on weekly data

Table 7 (Panel B): Regression results for Equation 8 (Volume)

Contract Form	Front End				One Year Ahead				Two Years Ahead			
Node	Benmore		Otahuhu		Benmore		Otahuhu		Benmore		Otahuhu	
Constant	-14.895	***	-17.716	***	-12.615	***	-14.988	***	-12.466	***	-13.074	***
Skewness	0.545		0.143		-0.542		-0.166		2.554	***	0.526	
Variance	0.000		0.000	***	-0.001		0.000		0.000		0.000	**
Spot Price	0.181	***	0.208	***	0.143	***	0.112	***	-0.008		-0.009	
Demand	0.030		0.025		-0.090		-0.021		0.016		0.069	*
Inflows	-0.013	***	-0.008	***	-0.004		0.000		-0.008		0.005	
Storage	0.007	***	0.004	**	0.004		0.003	**	-0.004		-0.005	**
Volume	0.141	**	0.027		0.141		-0.054		-0.270	*	-0.393	***
Lagged RP	0.725	***	0.775	***	0.821	***	0.695	***	0.700	***	0.481	***
Lagged RP 2			-0.121	*								
Q2	3.279	*	6.319	***	9.356	***	17.954	***	21.742	***	26.706	***
Q3	3.874	**	4.831	***	13.831	***	16.211	***	29.214	***	30.761	***
Q4	4.021	**	2.939	*	4.247		4.982	***	11.331	***	10.917	***
Durbin Watson	1.801		1.828		1.823		1.63		1.524		1.27	
Heteroscedasticity (p)	0.8952		0.0873		0.1226		<0.0001		0.0955		<0.0001	
Adjusted R^2	0.7072		0.7528		0.8935		0.8944		0.9122		0.9238	
n	325		324		273		273		219		219	

Notes

*** represents statistical significance at the 1% level, ** represents significance at the 5% level, * represents significance at the 10% level
Front end use Skew(7), Var(7) and S(Q), while the others use Skew(30), Var(30) and S(30).
Front end use Demand(1), Inflow(1) and Storage(1), while the others use Demand(4), Inflow(4) and Storage(4)
Regressions run on weekly data.