Exploration of the Relationship between ASX Prices and Spot Prices

report to
Electricity Authority

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Infometrics
Economics put simply

Authorship

This report has been prepared by Adolf Stroombergen and Emily Hendy.

Email:

adolf.stroombergen@infometrics.co.nz

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1. Introduction & Summary

At the request of the Electricity Authority we present some analysis of ASX prices and spot prices for electricity. The original brief was to consider three questions:

1. Is the ASX an unbiased predictor of the spot price?
2. Is the Authority's monitoring of the spot market robust?
3. What improvements could be made to the Authority's monitoring of the spot market.

At this stage, we have looked only at the first question. Our assessment is that in early trading there is generally some downward bias in ASX prices, but the bias largely dissipates in later trades.

Irrespective of any seasonality in spot prices we find no seasonal effect on the relationship between ASX prices and spot prices.

Although the relationship between ASX prices and spot prices is strong (even in the presence of some initial bias), ASX prices do not seem to be efficient (in the econometric sense) estimators of spot prices, particularly since September 2018 when the Pohokura gas outage occurred. Settlement of the Tiwai contract and low lake levels also contributed to volatility, but there was little to no effect evident from changes in the ETS NZU price, nor from the Russian invasion of Ukraine.

Judging by the changes in spot prices, shocks such as the Pohokura outage seem to be largely unexpected. Thus the cause of the inefficiency in the relationship between ASX prices and spot prices may be related more to unexpected movements in the spot price than to any flaw in how ASX market operates. This is turn may be attributable to the wider electricity market being insufficiently competitive.

That question takes us beyond the ambit of this project, but clearly it merits further research. It may also help answer the second question above; whether the Electricity Authority's monitoring of the spot market is robust.

In Section 2 we present some statistical tests of bias and how it has evolved over time. Cointegration tests are presented in Section 3. Section 4 looks at whether there are any seasonal effects on the relationship between spot prices and ASX prices, and Section 5 looks for evidence of effects from unexpected events such as September 2018 Pohokura gas outage. Section 6 presents overall conclusions.

2. Statistical Tests

Method

Is the ASX an unbiased predictor of the spot price?

For each of the 40 quarters ending with the March quarter 2025 we compare all ASX prices for the four years (if possible) leading up to the end of the quarter with the average spot price for that quarter. The path of ASX prices is split into quintiles. This removes the noise that pervades the data as well as the effect of some potentially significant events, which we consider later.

Although unexpected shocks occur, our interest here is whether the market accommodates such shocks in the sense that there is enough other information to continually pull ASX prices towards spot prices without any permanent bias, albeit with lags and volatility. Econometrically the hypothesis is that the series are cointegrated – which we formally test later.

Two examples are shown below: for Otahuhu, quarter ended March 2024, and for Benmore, quarter ended September 2019.

Otahuhu

The average spot price for the quarter ending March 2024 was $195.55/MWh. There are 889 observations. As shown in Figure 1 it is clear that the ASX prices are consistently too low. Of course they eventually converge to the spot price over time. See Table 1.

Figure 1: Quarter ending March 2024, Otahuhu

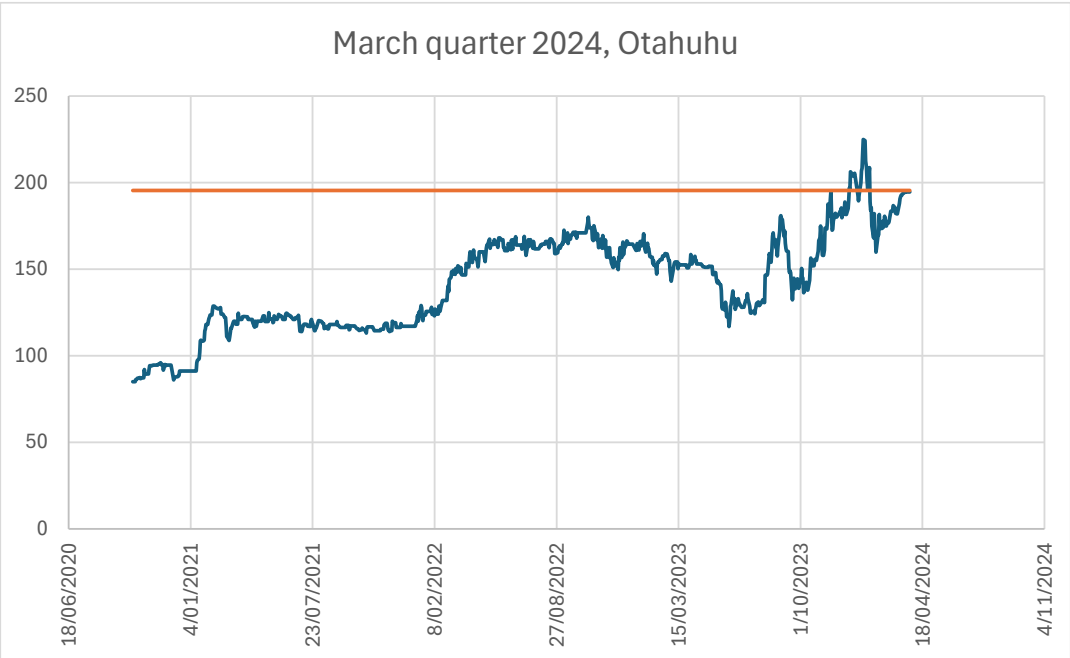


Table 1: Quarter ending March 2024, Otahuhu ($/MWh)

Quintile	No obs	mean	Stdev	Diff from average	abs(diff)
1	178	108.37	14.96	87.18	87.18
2	356	118.74	4.08	76.81	76.81
3	533	162.08	8.48	33.47	33.47
4	711	149.84	12.84	45.71	45.71
5	889	170.55	22.12	25.00	25.00

Benmore

The average spot price at Benmore for the quarter ended September 2019 was $112.39/MWh. The ASX prices are too low, but fairly flat until last quintile of observations, after which they overshoot before moving towards the spot price. See Figure 2 and Table 2

The unusual spike is in early 2019. Although this is not of particular interest here, it may have been associated with a risk alert status around that time.

Figure 2: Quarter ending September 2019, Benmore

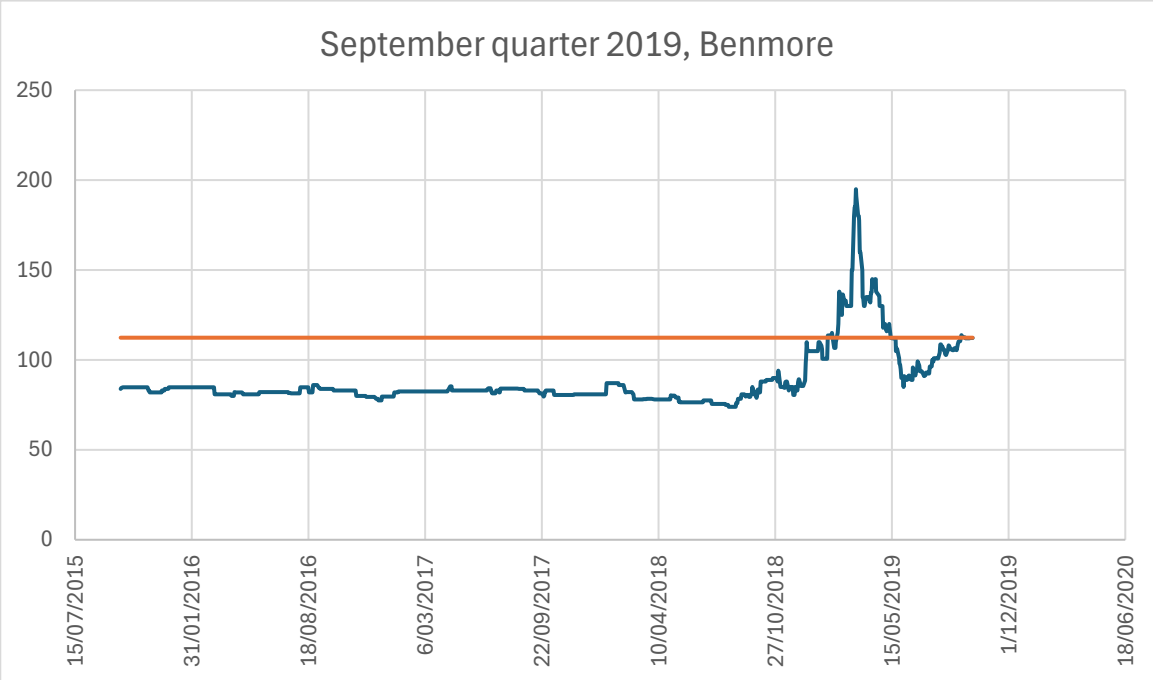


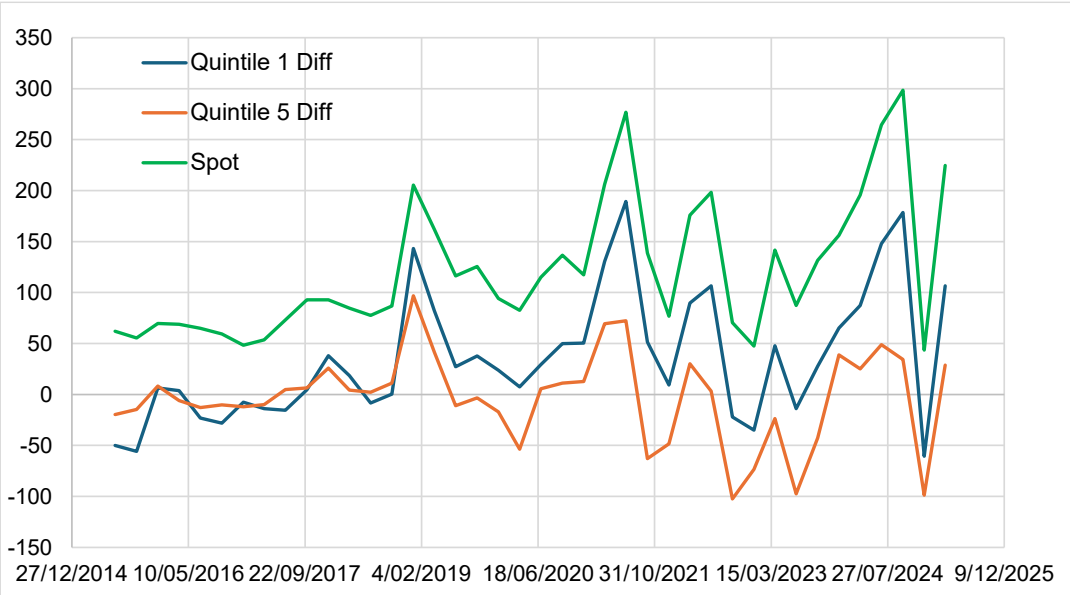
Table 2: Quarter ending September 2019, Benmore ($/MWh)

Quintile	No obs	mean	stdev	Diff from average	abs(diff)
1	203	83.06	1.61	29.33	29.33
2	407	82.29	1.78	30.10	30.10
3	610	82.77	1.86	29.62	29.62
4	814	80.00	4.64	32.39	32.39
5	1017	113.67	21.49	-1.28	1.28

Otahuhu: summary of 40 quarters

Figures 3 and 4, and Table 3 summarise the results of analysis such as the above for 40 quarters ending with the March quarter 2025, for Otahuhu. Additional data is presented in Table 4.

Figure 3: Paths for spot price and price differences, Otahuhu ($/MWh)



Some observations:

- Volatility in ASX prices has risen over time, but so has spot price volatility.
- As expected Quintile 5 price differences are generally closer to zero than Quintile 1 differences.
- Of the Quintile 1 differences, 70% are positive. That is, the ASX prices are too low.
- After September 2018, which is when the Pohokura gas outage occurred, that proportion is almost 85%.
- Quintile 5 differences are closer to an even split of over and under estimates.

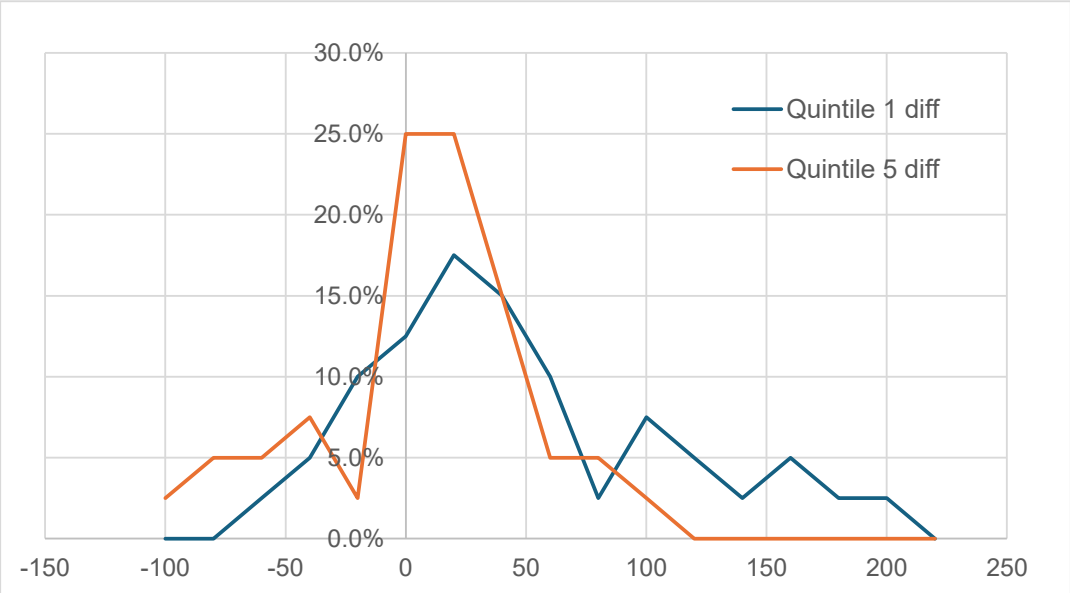
- The mean Quintile 5 absolute difference before September 2018 is $10.60, but $44.37 after September 2018 when the Pohokura outage occurred.

Table 3 Statistical summary, Otahuhu ($/MWh)

	Quintile 1 Diff	Quintile 5 Diff	|Quintile 1 Diff|	|Quintile 5 Diff|
Mean	35.68	-3.50	52.37	32.55
Stdev	66.61	62.26		
%>0	70.0%	52.5%		
%<0	30.0%	47.5%		
Up to & including Sep 2018				
Mean	-9.35	-1.64	19.58	10.60
Stdev	14.06	24.13		
%>0	42.9%	50.0%		
%<0	57.1%	50.0%		
After Sep 2018				
Mean	59.93	-4.50	70.03	44.37
Stdev	67.42	63.01		
%>0	84.6%	53.8%		
%<0	15.4%	46.2%		

As shown in Figure 4, the Quintile 5 differences display negative excess kurtosis while the Quintile 1 differences have positive excess kurtosis. Both are slightly positively skewed such that ASX prices tend to slightly understate the eventual spot price.

Figure 4: Distribution of Quintile 1 and Quintile 5 differences ($/MWh)



An Excel file of graphs in the style of Figure 1 and the underlying data is available on request. It has about 40,000 lines.

Table 4: Summary of Results, Otahuhu ($/MWh)

	No. obs	spot	Quintile 1 Diff	Quintile 5 Diff	|Quintile 1 Diff|	|Quintile 5 Diff|
30/06/2015	924	62.06	-49.92	-19.8	49.92	19.8
30/09/2015	990	55.37	-55.87	-14.77	55.87	14.77
31/12/2015	1053	69.71	6.32	8.22	6.32	8.22
31/03/2016	876	68.99	3.75	-6.02	3.75	6.02
30/06/2016	941	64.99	-23.13	-12.94	23.13	12.94
30/09/2016	1007	59.43	-28.2	-10.3	28.2	10.3
31/12/2016	1070	48.18	-7.51	-11.94	7.51	11.94
31/03/2017	884	53.49	-13.96	-9.9	13.96	9.9
30/06/2017	947	73.11	-15.49	4.93	15.49	4.93
30/09/2017	1012	92.79	4.46	6.28	4.46	6.28
31/12/2017	1075	92.91	38.06	25.87	38.06	25.87
31/03/2018	1013	84.69	18.63	4.23	18.63	4.23
30/06/2018	1077	77.51	-8.44	2.07	8.44	2.07
30/09/2018	1015	86.85	0.35	11.07	0.35	11.07
31/12/2018	1079	205.52	143.25	96.71	143.25	96.71
31/03/2019	889	161.83	82.08	41.45	82.08	41.45
30/06/2019	951	116.38	27.28	-11.12	27.28	11.12
30/09/2019	1017	125.41	37.86	-3.4	37.86	3.4
31/12/2019	1081	94.26	23.88	-17.1	23.88	17.1
31/03/2020	889	82.50	7.47	-53.6	7.47	53.6
30/06/2020	952	114.90	29.36	5.65	29.36	5.65
30/09/2020	1018	136.55	50	11.05	50	11.05
31/12/2020	1082	117.34	50.4	12.64	50.4	12.64
31/03/2021	890	206.24	130.67	69.42	130.67	69.42
30/06/2021	953	276.79	189.22	72.23	189.22	72.23
30/09/2021	1019	138.74	51.38	-63.03	51.38	63.03
31/12/2021	1083	76.89	9.23	-48.44	9.23	48.44
31/03/2022	891	175.99	89.64	29.99	89.64	29.99
30/06/2022	954	198.34	106.57	3.27	106.57	3.27
30/09/2022	1020	70.36	-22.02	-102.54	22.02	102.54
31/12/2022	1083	47.44	-34.93	-73.58	34.93	73.58
31/03/2023	892	141.51	47.85	-23.71	47.85	23.71
30/06/2023	955	87.22	-13.95	-97.54	13.95	97.54
30/09/2023	1020	131.52	27.66	-42.53	27.66	42.53
31/12/2023	1083	156.05	65.2	38.85	65.2	38.85
31/03/2024	889	195.55	87.26	25	87.26	25
30/06/2024	953	264.57	147.95	48.8	147.95	48.8
30/09/2024	1019	298.32	178.56	34.41	178.56	34.41
31/12/2024	1083	43.58	-60.51	-98.66	60.51	98.66
31/03/2025	890	224.63	106.69	28.81	106.69	28.81

Benmore: summary of 40 quarters

Figures 5 and 6, and Table 5 summarise the results of analysis such as the above for 40 quarters ending with the March quarter 2025, for Benmore. Additional data is presented in Table 6.

Figure 5: Paths for spot price and price differences, Benmore ($/MWh)

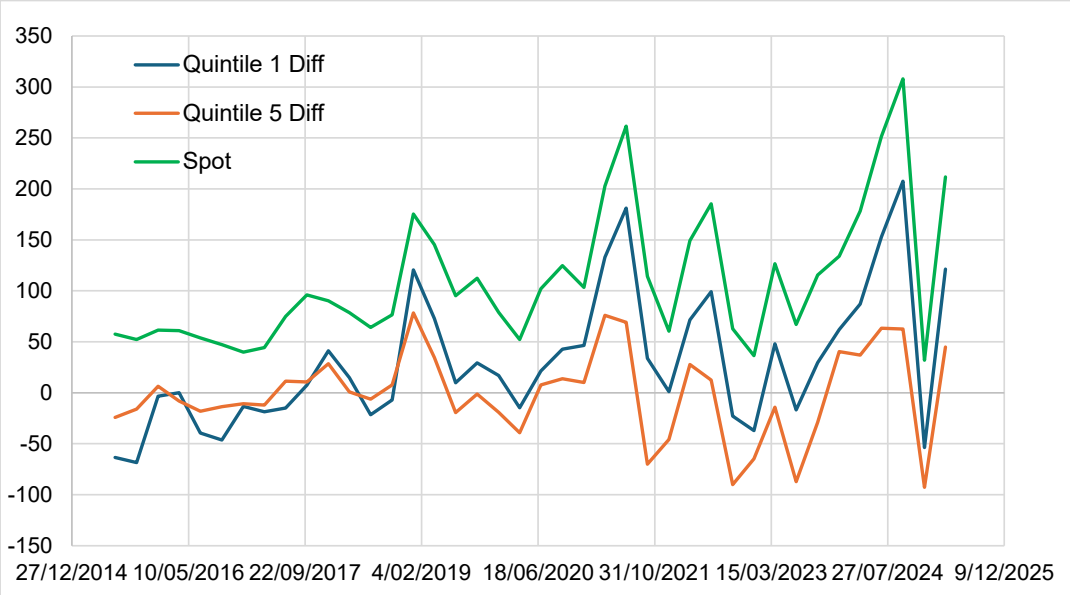


Table 5 Statistical summary, Benmore ($/MWh)

	Quintile 1 Diff	Quintile 5 Diff	|Quintile 1 Diff|	|Quintile 5 Diff|
Mean	30.22	-0.94	52.34	33.13
Stdev	66.23	65.64		
%>0	60.0%	50.0%		
%<0	40.0%	50.0%		
Up to & including Sep 2018				
Mean	-16.69	-3.10	25.76	12.45
Stdev	16.34	29.03		
%>0	21.4%	42.9%		
%<0	78.6%	57.1%		
After Sep 2018				
Mean	55.48	0.21	66.65	44.27
Stdev	69.93	65.96		
%>0	80.8%	53.8%		
%<0	19.2%	46.2%		

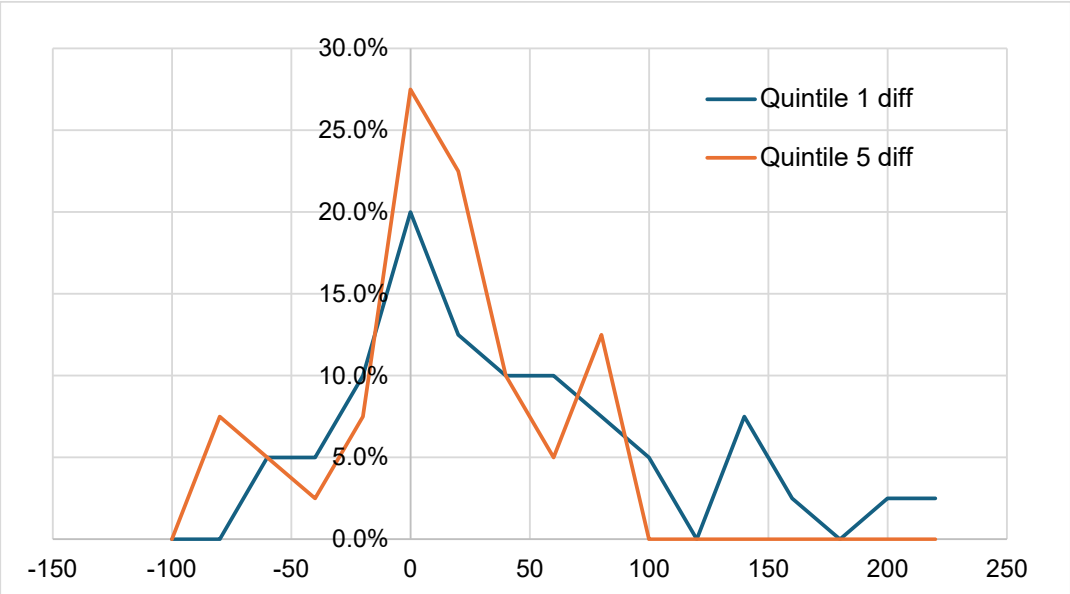
The observations about Otahuhu also apply to Benmore with similar volatility between the spot price and the Quintile 1 and Quintile 5 price differences. Also:

- Of the Quintile 1 differences, 60% are positive. That is, the ASX prices are too low.
- After September 2018 that proportion is almost 81%.
- Quintile 5 differences are closer to an even split of over and under estimates.
- The mean Quintile 5 absolute difference before September 2018 is $12.45, but $44.27 after September 2018.

As shown in Figure 6, both the Quintile 1 and Quintile 5 differences are clustered closer to zero than is the case for Otahuhu, though as for Otahuhu the Quintile 5 differences display negative excess kurtosis while the Quintile 1 differences have positive excess kurtosis.

ASX prices for Benmore tend to be marginally better predictors of the spot price than ASX prices at Otahuhu.

Figure 6: Distribution of Quintile 1 and Quintile 5 differences ($/MWh)



Conclusion

In early trading (the first 200 or so trades) there is generally some downward bias in ASX prices, but the bias largely dissipates in later trades. Figures 3 and 5 show that ASX prices generally track spot prices, even during periods of volatile prices.

In the next section we present a formal test for how well ASX prices track spot prices.

The Pohokura gas outage appears to have contributed to price differences. A 2024 report report by the Electricity Authority also mentions the Russian invasion of Ukraine as a contributing factor.[1] We look at these events in Section 4.

[1] Electricity Authority (2024) Reviewing risk management options for electricity retailers – issues paper.

Table 6: Summary of Results, Benmore ($/MWh)

	No.obs	spot	Quintile 1 Diff	Quintile 5 Diff	|Quintile 1 Diff|	|Quintile 5 Diff|
30/06/2015	924	57.62	-63.45	-24.23	63.45	24.23
30/09/2015	990	52.37	-68.53	-15.93	68.53	15.93
31/12/2015	1053	61.40	-3.33	6.38	3.33	6.38
31/03/2016	876	60.90	-0.03	-8.04	0.03	8.04
30/06/2016	941	53.92	-39.58	-18.03	39.58	18.03
30/09/2016	1007	47.30	-46.34	-13.63	46.34	13.63
31/12/2016	1070	39.83	-13.33	-10.76	13.33	10.76
31/03/2017	884	44.37	-18.75	-11.98	18.75	11.98
30/06/2017	947	74.95	-15.06	11.33	15.06	11.33
30/09/2017	1012	95.92	7.34	10.58	7.34	10.58
31/12/2017	1075	90.26	41.28	28.63	41.28	28.63
31/03/2018	1013	78.52	14.83	0.86	14.83	0.86
30/06/2018	1077	64.13	-21.62	-6.23	21.62	6.23
30/09/2018	1015	76.58	-7.15	7.72	7.15	7.72
31/12/2018	1079	175.24	120.45	78.47	120.45	78.47
31/03/2019	889	145.26	72.8	34.51	72.8	34.51
30/06/2019	951	95.28	9.74	-19.37	9.74	19.37
30/09/2019	1017	112.39	29.33	-1.28	29.33	1.28
31/12/2019	1081	78.91	16.85	-19.24	16.85	19.24
31/03/2020	889	52.38	-14.57	-39.15	14.57	39.15
30/06/2020	952	102.01	21.31	7.62	21.31	7.62
30/09/2020	1018	124.72	42.79	13.78	42.79	13.78
31/12/2020	1082	103.43	46.37	10.16	46.37	10.16
31/03/2021	890	202.88	132.93	76.07	132.93	76.07
30/06/2021	953	261.47	181.21	69.24	181.21	69.24
30/09/2021	1019	114.20	33.69	-70.17	33.69	70.17
31/12/2021	1083	60.43	1.07	-45.79	1.07	45.79
31/03/2022	891	149.35	71.38	27.72	71.38	27.72
30/06/2022	954	185.31	99.19	12.59	99.19	12.59
30/09/2022	1020	62.83	-22.82	-90.05	22.82	90.05
31/12/2022	1083	36.48	-37.21	-64.72	37.21	64.72
31/03/2023	892	126.57	48.09	-14.14	48.09	14.14
30/06/2023	955	66.97	-16.74	-87.25	16.74	87.25
30/09/2023	1020	115.58	29.62	-28.87	29.62	28.87
31/12/2023	1083	133.99	61.91	40.39	61.91	40.39
31/03/2024	889	178.30	87.17	37.02	87.17	37.02
30/06/2024	953	251.58	153.01	63.31	153.01	63.31
30/09/2024	1019	307.81	207.47	62.49	207.47	62.49
31/12/2024	1083	31.93	-53.82	-92.69	53.82	92.69
31/03/2025	890	211.85	121.38	44.91	121.38	44.91

3. Cointegration Tests

Figures 3 and 5 suggest a consistent relationship between ASX prices and spot prices. Converting the price differences back into levels and then testing for cointegration (with 40 observations in each case) produces the results shown in Table 7. The individual series are all I(1).

Table 7: Cointegration tests (Phillips-Perrron)

	Test	Test statistic	Critical value
Otahuhu			
Quintile 1	Z-test	-26.1	-17.1
	T-test	-4.5	-3.0
Quintile 5	Z-test	-29.8	-17.1
	T-test	-4.7	-3.0
Benmore			
Quintile 1	Z-test	-24.3	-17.1
	T-test	-4.2	-3.0
Quintile 5	Z-test	-31.7	-17.1
	T-test	-4.9	-3.0

All of the ASX prices show compelling evidence of being cointegrated with the corresponding spot price. Although the relationship for Quintile 5 prices is stronger than for Quintile 1 prices as expected, the difference is not large.

These results, plus the findings above (refer Figures 3 and 5 in particular) demonstrate that even the early ASX trades capture market expectations about future changes in the spot price, in spite of the greater volatility that has prevailed since September 2018. Nevertheless, it also clear that the levels of ASX prices take some time to reach the levels of the spot price.

In the previous section it was evident that price volatility increased after the September quarter of 2018, when the Pohokura gas outage occurred. Before looking at the effects of such events we check the nature of any seasonal influences on the difference between ASX prices and spot prices.

4. Seasonality

Is there any seasonality in the relationship between ASX prices and spot prices? A few graphs are presented first, followed by some econometric analysis.

Quarterly patterns

The following eight graphs are analogous to Figures 3 and 5, but present quarterly series rather than annual series.

Otahuhu

Figure 7: March ($/MWh)

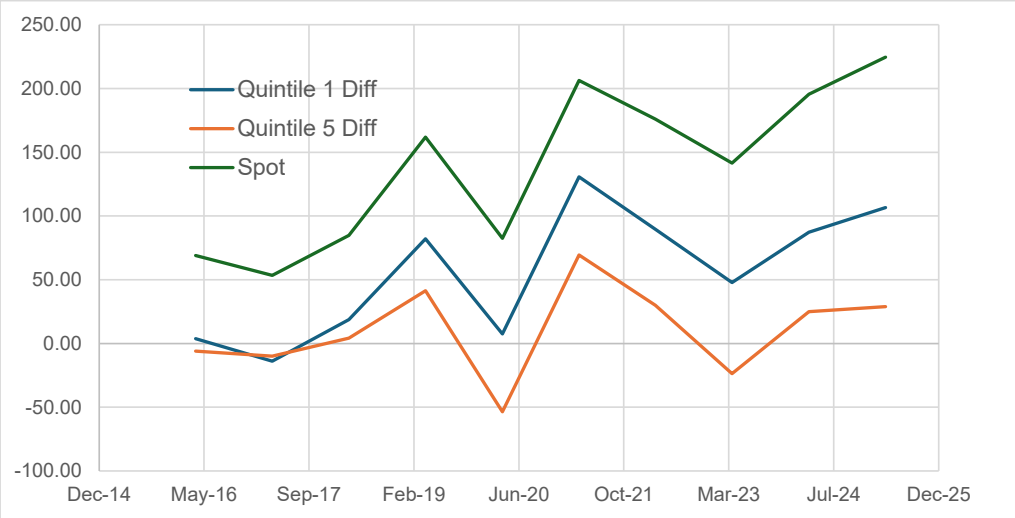


Figure 8: June ($/MWh)

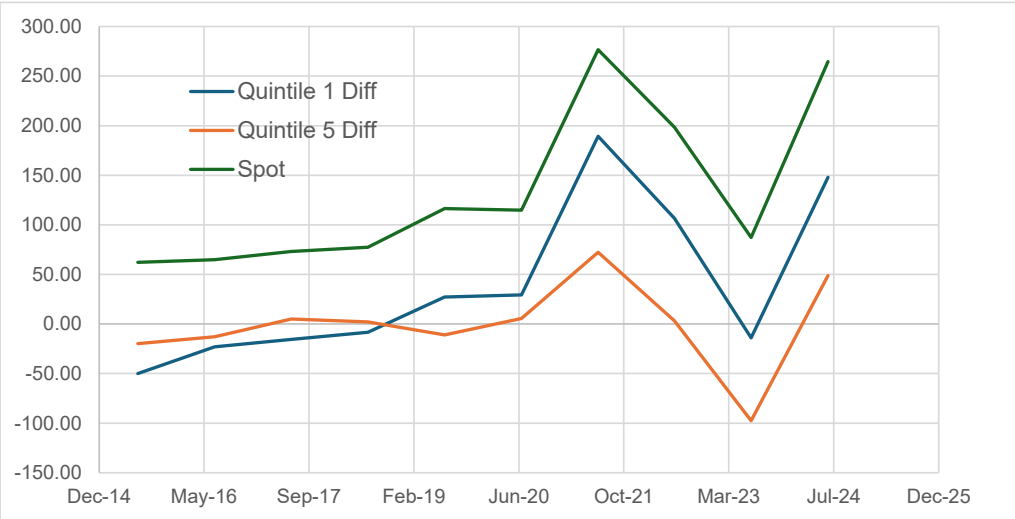


Figure 9: September ($/MWh)

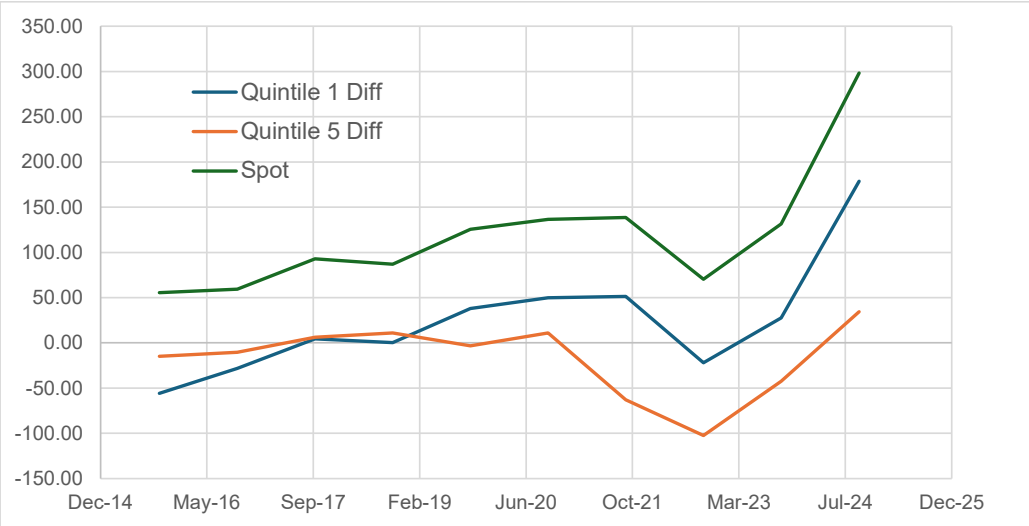
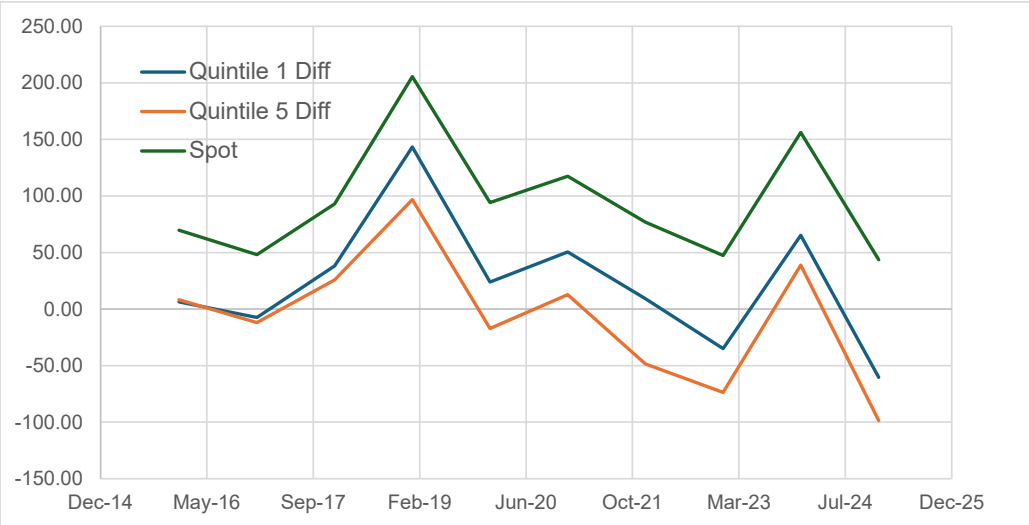


Figure 10: December ($/MWh)



Consistent with the above findings, all quarters depict higher volatility in later years. In particular:

- March: from 2019.
- June: from 2019, but particularly from June 2020.
- September: from 2018 (Pohokura outage), but particularly from September 2022.
- December: volatile over the whole period, but especially from December 2018.

As before, all quarters show ASX prices tracking spot prices. Positive and negative errors are about the same for Quintile 5, but positive errors (spot price higher than the ASX price) dominate in the Quintile 1 differences especially in later years, which is consistent with Figure 3.

Benmore

Figure 11: March ($/MWh)

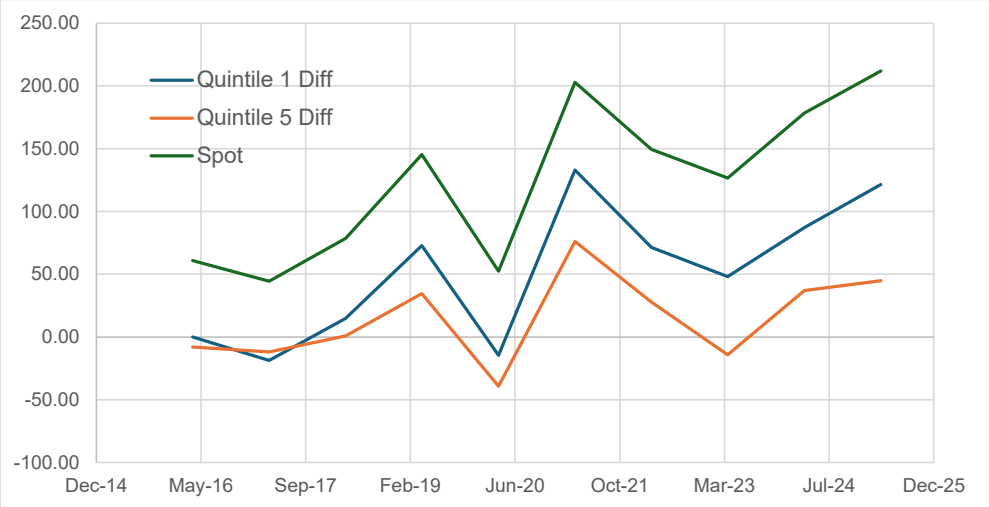


Figure 12: June ($/MWh)

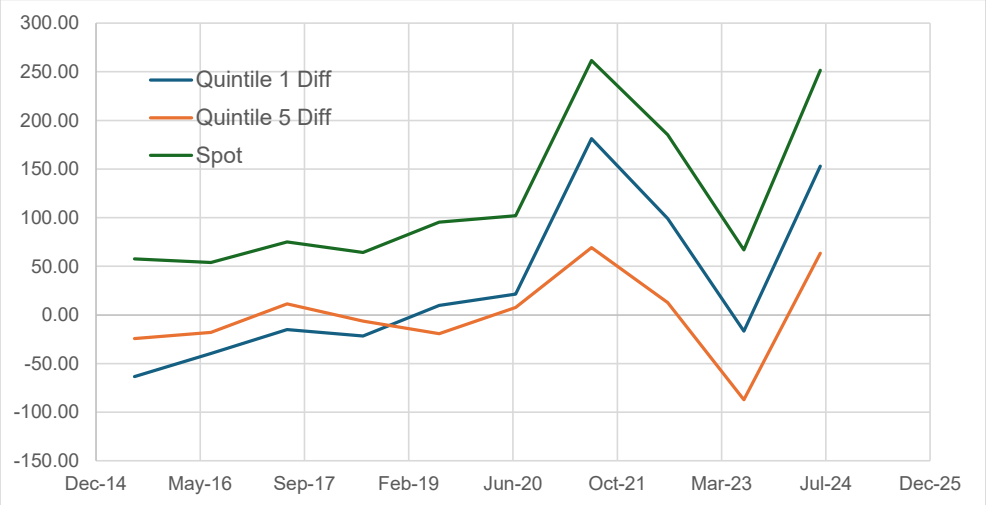


Figure 13: September ($/MWh)

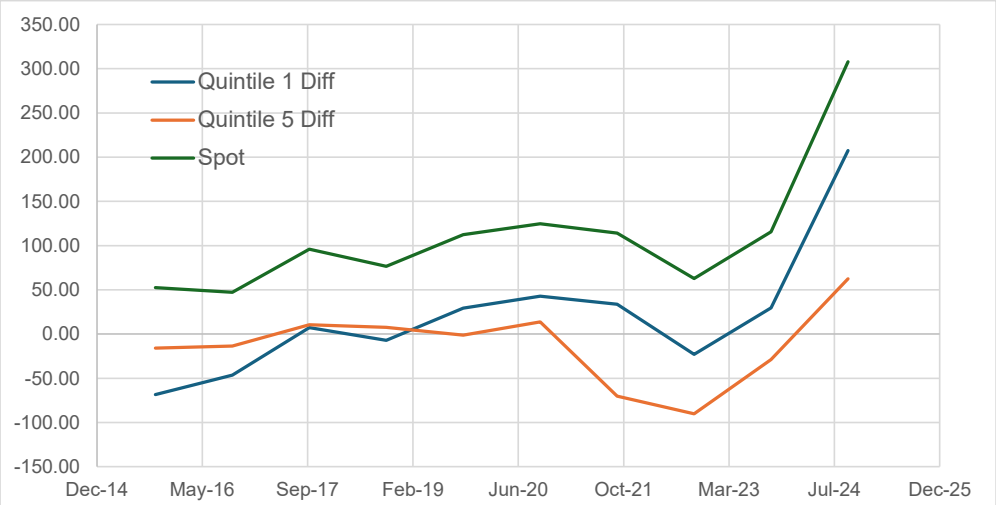
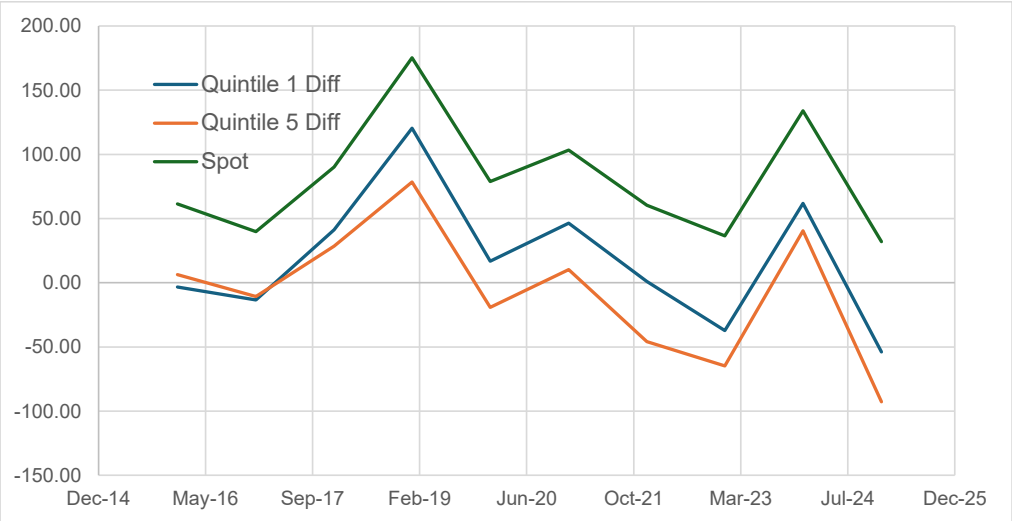


Figure 14: December ($/MWh)



The above observations for Otahuhu also apply to Benmore.

Statistical tests

In regressions of Quintile 1 differences and Quintile 5 differences, no quarterly dummy variables are statistically significant for either location. Indeed the only significant variable is a trend term for the Quintile 1 differences – $1.94/MWh per quarter and $1.84/MWh per quarter for Otahuhu and Benmore respectively, These are small effects and consistent with the cointegration findings above.

There may be no seasonality in the price differences (bias), but is there seasonality in the quarterly spot prices?

Spot prices

Tabe 8 summarises results for spot prices. Volatility notwithstanding, spot prices have trended upwards in both locations by $3.10-$3.30/MWh per quarter. The only (marginally) significant quarter is December which has lower than average prices. December also has the lowest variance in spot prices, consistent with a report by the Electricity Authority (2024), which found that December has the lowest daily range in ASX prices. Coefficients for the other quarters, while positive and significantly different from zero, are revealed by an F-test to not be significantly different from each other. Thus they are subsumed into the constant term.

Table 8: spot prices and seasonality

	Otahuhu		Benmore	
	Coeff	p- value	Coeff	p- value
Trend	3.30	0.000	3.11	0.000
December	-37.9	0.065	-40.0	0.055
Constant	63.7	0.001	55.9	0.004

Outliers (regression residuals >|$119|) for both locations occur in December 2018, June 2021, June-September 2024 (all positive) and December 2024 (negative), suggesting some unusual circumstances in those quarters. The December quarter 2018 was the quarter

immediately following the Pohokura outage, and the June 2021 quarter was immediately after the Tiwai Point contract and also saw unusually high coal-fired electricity generation. Coal-fired generation was again high in the June and September quarters of 2024. That may have been better anticipated by traders.

We thus re-run the above equations with dummy variables for December 2018, June 2021 and June-September 2024. Table 9 has the results. All are statistically significant and also have the more subtle effect of lowering the coefficients on the trend terms, suggesting that the three events further lifted the underlying upward trend in spot prices.

There may be merit in further investigating the effects of events such as the Pohokura outage on the trend in spot prices. However, that is beyond the ambit of this project.

Returning to the difference between ASX prices and spot prices, and the question of bias, in the following section we look at the effect of events such as Pohokura using a graphical approach that spans the entire trading period for each of the 40 quarterly settlement dates.

Table 9: spot prices and events

	Otahuhu		Benmore	
	Coeff	p- value	Coeff	p- value
Trend	2.56	0.000	2.23	0.000
December qtr	-38.5	0.014	-37.4	0.019
December 2018	139.7	0.002	119.4	0.007
June 2021	146.8	0.001	145.9	0.001
Jun/Sep 2024	119.5	0.000	136.1	0.000
Constant	66.0	0.000	59.7	0.004
R^2	0.72		0.70	
JB Normality		0.945		0.980
Breusch-Pagan		0.257		0.369

5. Pohokura and Other Events

Note that in this section the price difference is defined as the ASX price minus the spot Price, whereas previously it was spot minus ASX. Thus negative errors mean that the spot price is higher than the ASX price.

The analysis in Sections 2 shows a clear increase in volatility in spot prices, albeit without any consistent effect on bias in ASX prices. Based on the findings in Section 4 there are other events that may have contributed to either spot price volatility or bias in ASX prices. The EA report (op cit) mentions the Russian invasion of Ukraine. From the foregoing section, other possibilities are:

- The contract with the Tiwai Point aluminium smelter which was settled in the March quarter of 2021 after much uncertainty stemming from a July 2020 announcement of possible closure.
- Spikes in the NZU carbon price around June quarter 2016 and September quarter 2020.
- Spikes in coal-fired electricity generation in the June quarters of 2021 and 2024.

Figure 15 graphs al trades underlying the data in Table 4 for Otahuhu. Distinguishing individual paths is admittedly not easy, although it is possible with the Excel version. However, that is not the intention. The aim is to provide a visual guide to when there are marked changes in either bias or volatility.

For example, the increase in volatility from after the September quarter 2018 (the Pohokura outage) is clear. And, as observed above with regard to Quartile 1, in early trades around that date ASX prices tended to understate spot prices.

Figure 16 shows all trades normalised to their period endpoints, and then split into two groups; trades before and after September 2018. The change in the sign of the error is clear, with those after September 2018 being predominantly negative – spot price exceeds the ASX price.

It is possible to construct graphs such as Figure 16 for other events, but no event after that date is sufficiently large to be visible above the Pohokura effect. Thus we do not present them here, but they are available on request.

Referring back to Figure 15, and Pohokura aside, there are apparent spikes in:

- March/June 2021, corresponding to settlement of the Tiwai Point contract, but also to higher coal-fired generation.
- September 2024, corresponding to high coal-fired generation.

And less consistently:

- March 2022, corresponding to the Russian invasion of Ukraine.
- December 2022, but a possible reason is not readily apparent.

Figure 15: All Otahuhu contracts

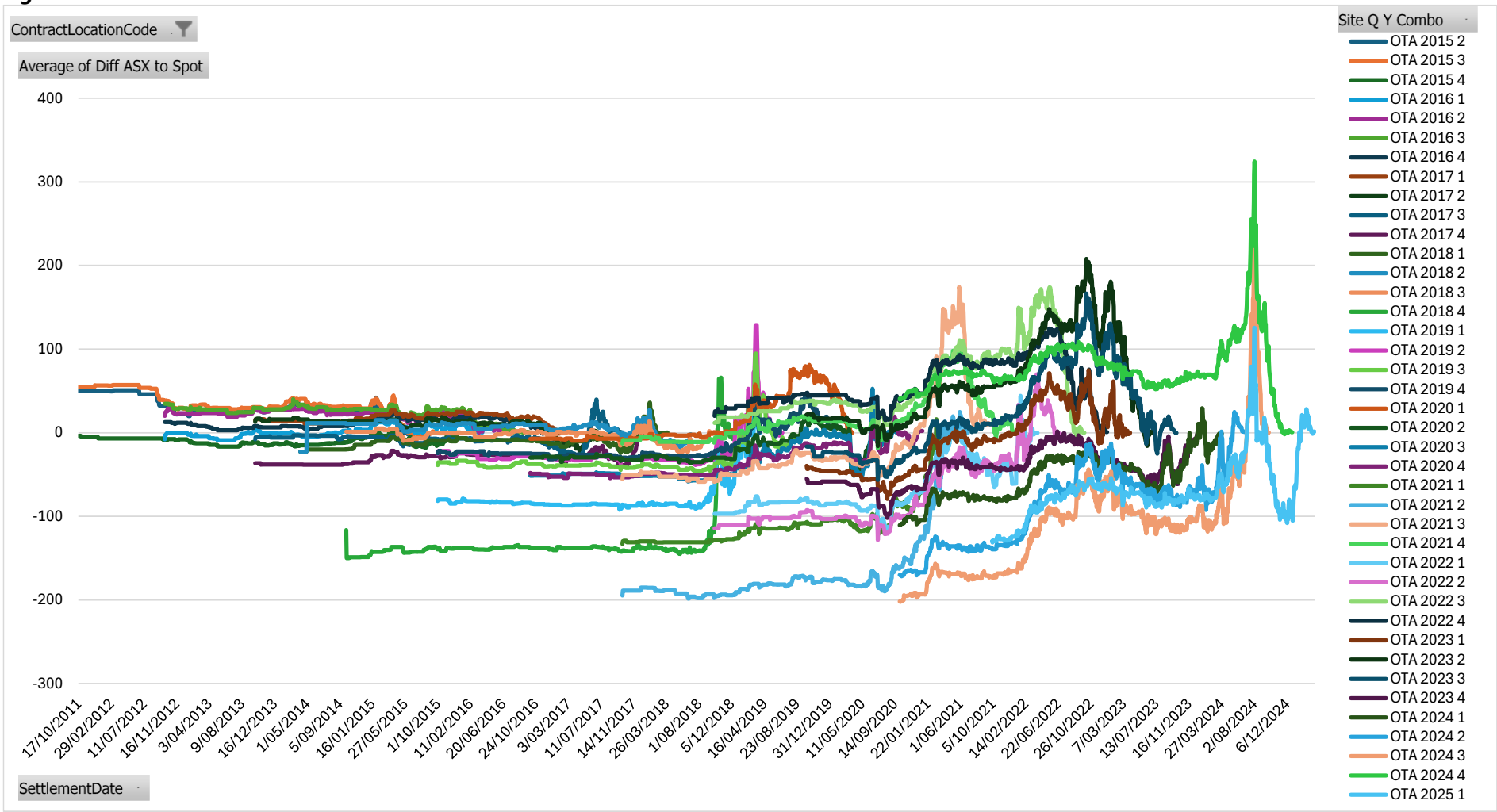


Figure 16: Contracts normalised to settlement dates

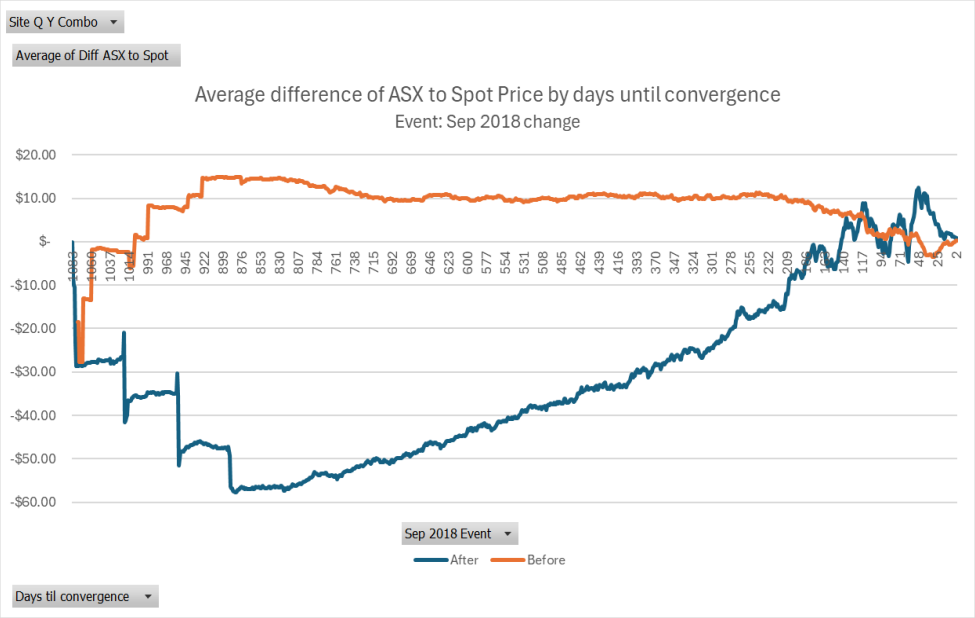


Figure 17 presents a window of Figure 15 for the six months between the dates of 1 January 2021 and 30 June 2021 for Benmore, which surround the settlement date of the Tiwai contract. The top line with the discernible intercept shift at 18-25 March is for contracts ended September 2021. None of the other trades display such a shift.

Figure 17: Contracts with settlement dates around March 2021 (Tiwai)

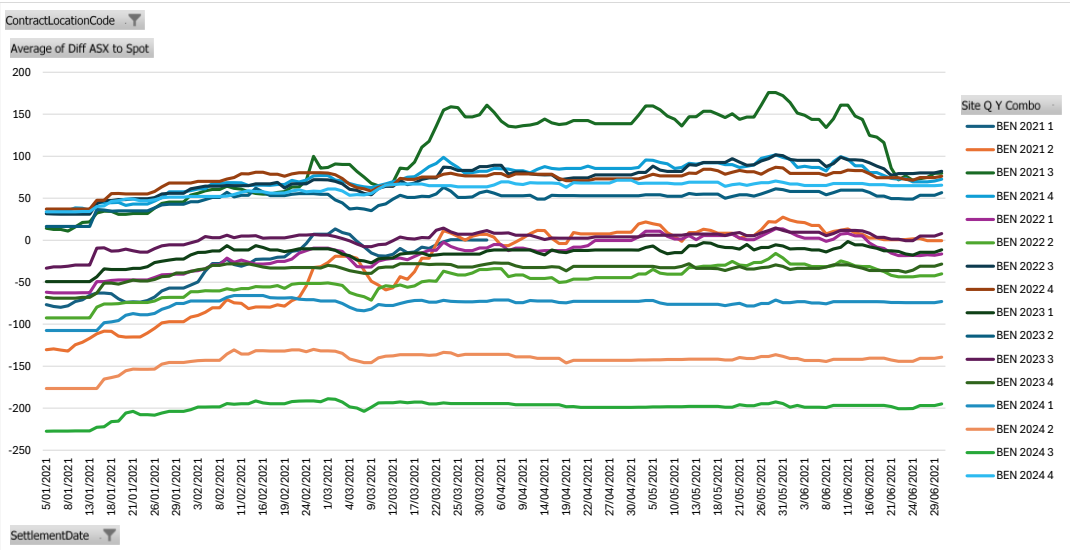


Figure 18 presents an analogous 6-month picture centred on the Pohokura outage. The pronounced spike is for contracts ended December 2018 at Otahuhu.

Figure 19 covers the 6-month period from 1 June 2024 to 31 December 20241, at Otahuhu, and clearly illustrates the spike at the time of higher coal generation.

A similar graph for Russia's invasion of Ukraine shows a small effect, while December 2022 shows nothing. Also, no marked effect from around the time of spikes in the NZU carbon price (June quarter 2016 and September quarter 2020) is evident, but for two months over

July- August 2020 the negative error is exacerbated. That is, spot prices were much higher than ASX prices. That seems to be an effect of an easing in Covid restrictions.

Figure 18: Contracts with settlement dates around September 2018 (Pohokura)

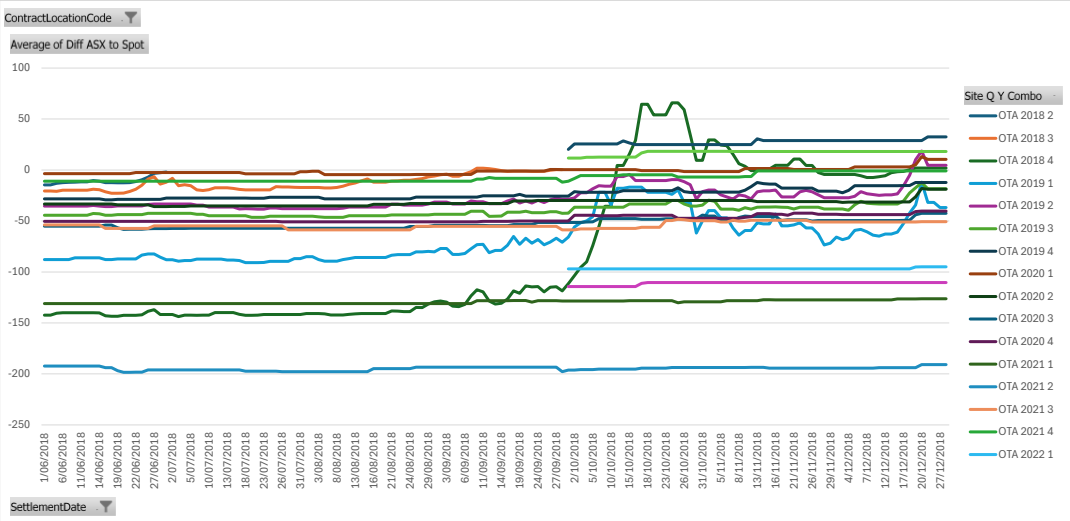
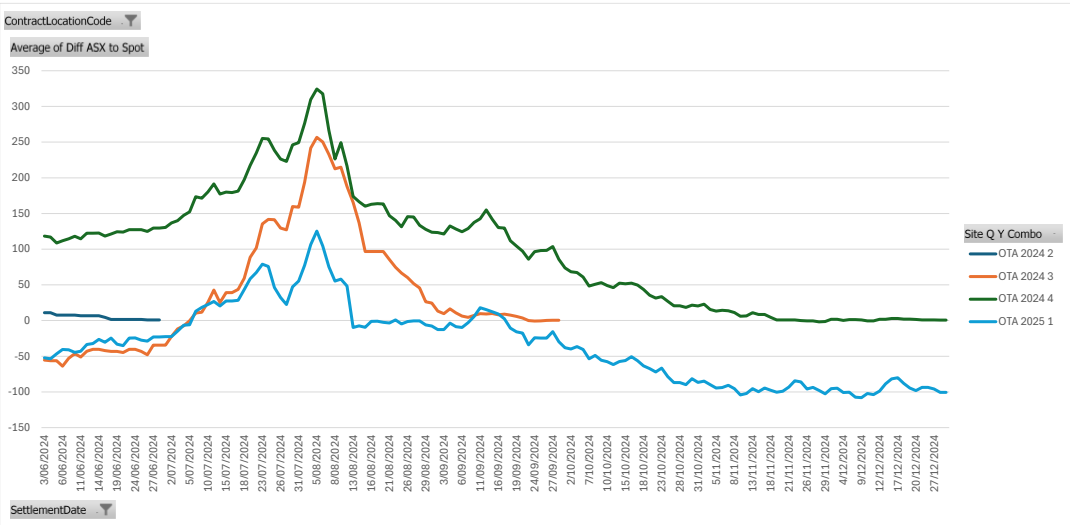


Figure 19: Contracts with settlement dates around September 2024 (coal use)



Conclusion

In conclusion it is clear that the Pohokura outage marked a shift to higher volatility and – with regard to early trades within a contract period – a noticeable increase in the frequency with which ASX prices understated spot prices.

Two other events also had an effect; the Tiwai contract decision early in 2021 and the low lake levels in latter half of 2024. The Russian invasion of Ukraine and changes in the NZU carbon price seem to have had little to no effect on the differences between ASX prices and spot prices, but there is a small effect coinciding with the easing of the tightest Covid restrictions.

These events seem to have any had only temporary effects on bias, but have exacerbated volatility since September 2018.

6. Conclusion

Are ASX prices an unbiased predictor of spot prices? One would have to answer that in early trading there is generally some downward bias in ASX prices, but the bias largely disappears in later trades (the last 200 or so). It is also worth noting that:

- Since September 2018 (the time of the Pohokura outage), volatility in ASX prices and spot prices has been high, so a downward bias in ASX prices in early trades is not surprising. Against that background, the lack of notable bias in later trades is fairly remarkable.
- Although bias is usually low, ASX prices are not efficient estimators of spot prices. That is, the standard deviation of the errors are relatively high.

A similar conclusion is drawn in Appendix A of Electricity Authority (2024):

> *Between 2018 and 2023 traded prices were lower than the settled price two thirds of the time, but this appears to have been driven by unexpected shocks, most notably declining and less predictable output from several natural gas fields from around March 2018 and Russia's invasion of Ukraine in early 2022.*
>
> *This means that the under-pricing we observe in futures expiring between 2018 and 2023 can likely be explained by these external shocks rather than indicating a systemic bias.*

However, because the time period for the EA's analysis does not extend as far back as ours, the EA report could not capture the change in volatility from 2018. The EA report focusses more on issues such market liquidity and shape premia (for peak and super-peak periods). With regard to the latter, the EA report mentions volatility indirectly:

> *An increase in intermittent generation may change expected prices at different times of the day or in different seasons. Continuing scarcity in the market to meet peak demand will also impact these shape factors. Since there is more uncertainty about how shape factors will change in a more renewable world, there is more risk associated with selling shaped contracts for the future. This means these shape premia could be even higher.*

That concern, plus our finding of increased volatility beyond time of day effects imply that there is an *a priori* case for measures that are directed at avoiding supply scarcity or at least ensuring that it is signaled well in advance. Inefficiency (in the econometric sense) of the ASX prices points to difficulty in predicting spot prices to within a narrow range especially in earlier trading periods, exacerbated by the upward trend in prices and (seemingly) unexpected movements in spot prices, such as occurred when the Tiwai situation was resolved.

It is possible that market participants do not have sufficient information (such as on predicted lake levels) to efficiently price and manage risk. Less uncertainty is key to producing a more efficient market.