Explanatory document for all TSOs' of Nordic CCR proposal for amendment to the methodology for the market-based allocation process of cross-zonal capacity for the exchange of balancing capacity for the Nordic CCR in accordance with Article 41(1) of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing

April 2021

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1. Introduction

Nordic TSOs have been tasked by ACER decision on methodology for the market-based allocation process of cross-zonal capacity for the exchange of balancing capacity (ACER decision no 22-2020 dated 5th August 2020) to submit an amendment proposal to the methodology.

This amendment proposal shall include at least an assessment related to the dynamic mark-up value. The mark-up in ACER decision no 22-2020 has been defined as follows:

- for negative or zero market spread the mark-up will be 0.1 EUR/MWh
- for positive market spread the mark-up will be 1 EUR/MWh

Mark-up will vary between 1 and 5 EUR/MWh in case the calculated mark-up over the last 30 days differs 1 EUR/MWh from the value for the previous day. In this calculation, 95% of market spreads are taken into account.

The requested amendment proposal shall include an evaluation of the accuracy of the forecasted market value covering:

- different historical time series
- different validity periods of mark-ups
- different reference days

These evaluations are presented in chapters 3.3 – 3.5 covering points (a) – (c) from Article 6(4) of ACER decision no 22-2020. Chapter 3.6 summaries the results from these three points.

In chapter 3.7 the accuracy of forecasted market value has been evaluated applying additional relevant factors, such as generation and demand pattern reflecting point (d) from Article 6(4). Chapter 3.8 addresses the results from welfare effect calculation for different sensitivities of forecast errors in accordance with point (e) of Article 6(4).

Chapter 4 explains the justifications for the amendment proposal based on results described in chapter 3.

2. Legal background

In accordance with Article 38(1) of EBGL Regulation two or more TSOs may at their initiative or at the request of their relevant regulatory authorities set up a proposal for the application of market-based allocation process pursuant to Article 41.

In accordance with Article 39(5) of EBGL Regulation the forecasted market value of cross-zonal capacity shall be based on one of the following alternative principles:

(a) the use of transparent market indicators that disclose the market value of cross-zonal capacity; or

(b) the use of a forecasting methodology enabling the accurate and reliable assessment of the market value of cross-zonal capacity.

The forecasted market value of cross-zonal capacity for the exchange of energy between bidding zones shall be calculated based on the expected differences in market prices of the day-ahead and, where relevant and possible, intraday markets between bidding zones. When calculating the forecasted market value, additional relevant factors influencing demand and generation patterns in the different bidding zones shall be taken duly into account.

In accordance with Article 41(1) of EBGL Regulation by two years after entry into force of this Regulation, all TSOs of a capacity calculation region may develop a proposal for a methodology for a market-based allocation process of cross-zonal capacity for the exchange of balancing capacity. This methodology shall apply for the exchange of balancing capacity with a contracting period of not more than one day and where the contracting is done not more than one week in advance of the provision of the balancing capacity.

In accordance with Article 41(3) of EBGL Regulation the methodology for a market-based allocation process of cross-zonal capacity for the exchange of balancing capacity shall be based on a comparison of the actual market value of cross-zonal capacity for the exchange of balancing capacity or sharing of reserves and the forecasted market value of cross-zonal capacity for the exchange of energy.

ACER has made decision No 22/2020 of 5 August 2020 on the market-based allocation process of cross-zonal capacity for the exchange of balancing capacity for the Nordic CCR.

Article 6 of ACER decision No 22/2020 sets requirements for determination of the forecasted market value of cross-zonal capacity for the exchange of energy in single day-ahead coupling. Article 6(1) defines the initial forecasted market value of cross-zonal capacity used for the exchange of energy, defined for each direction, for each bidding zone border and for each day-ahead market time unit, as:

a) equal to the positive market spread for each day-ahead market time unit of the reference day for the direction of the positive market spread; or
b) equal to zero for each day-ahead market time unit of the reference day for the direction of the negative market spread or in case of zero market spread.

Article 6(2) requires that a mark-up will be added to the initial forecasted market value of cross-zonal capacity calculated in accordance with Article 6(1), in order to take into account the uncertainty of the forecasted market value of cross-zonal capacity. This mark-up is defined for each direction as follows:

a) if there is a negative or zero market spread for the initial forecasted market value of cross-zonal capacity in accordance with paragraph 1, the mark-up will be 0.1 EUR/MWh; and
b) if there is a positive market spread, for the initial forecasted market value of cross-zonal capacity in accordance with paragraph 1, the mark-up will be 1 EUR/MWh.

Article 6(3) defines how this mark-up value will change due to forecasting error: If the average positive forecast error over the last 30 days, per bidding zone border and per direction, excluding the 5% hours with the highest positive forecast errors, is 1 EUR/MWh higher or lower than the mark-up applied the day before, the TSOs of this bidding zone border shall respectively increase or decrease the mark-up pursuant to Article 6(2)(b) with 1 EUR/MWh for the respective direction. The mark-up for a positive market spread, can never be lower than the default value pursuant to Article 6(2)(b) and never higher than 5 EUR/MWh.

Article 6(4) requires that no later than 12 months after approval of this methodology, the TSOs shall submit an amendment to this methodology based on one of the alternative principles pursuant to Article 39(5) of EBGL Regulation. This amendment shall at least include a calculation of a dynamic mark-up value, for each bidding zone border and for each direction, replacing Article 6(3) and Article 6(4), and shall be supported by an assessment that shows at least:

a) the accuracy of the forecasted market value when applying different ranges of historical time series as input data for determining the mark-ups, per bidding zone border and per direction;
b) the accuracy of the forecasted market value when applying different time intervals for defining and updating the mark-ups, per bidding zone border and per direction;
c) the accuracy of the forecasted market value when applying different reference days;
d) the accuracy of the forecasted market value when applying additional relevant factors influencing demand and generation patterns in the different bidding zones; and
e) the estimated welfare effect for a range of confidence levels of the positive forecast errors, per bidding zone border and per direction.

Article 6(5) sets that the forecasted market value for the exchange of energy for each direction shall be equal to the sum of the initial forecasted market value pursuant to Article 6(1) and the mark-up pursuant to Article 6(2).

In accordance with Article 6(6) the reference day shall be the previous day for which the clearing prices for each day-ahead market timeframe are available for each bidding zone. In addition, Article 6(7) requires that the TSOs shall monitor the efficiency of the forecasting methodology pursuant to Article 12(5) of EBGL Regulation.

3. Assessment of the forecasted market value of cross-zonal capacity

3.1 Background

ACER decision No 22/2020 requires the TSOs to make an assessment that shows at least:

- the accuracy of the forecasted market value when applying different ranges of historical time series as input data for determining the mark-ups, per bidding zone border and per direction;
- the accuracy of the forecasted market value when applying different time intervals for defining and updating the mark-ups, per bidding zone border and per direction;
- the accuracy of the forecasted market value when applying different reference days;
- the accuracy of the forecasted market value when applying additional relevant factors influencing demand and generation patterns in the different bidding zones; and
- the estimated welfare effect for a range of confidence levels of the positive forecast errors, per bidding zone border and per direction.

In this chapter the accuracy of forecasted market value will be evaluated comparing the methodology as defined in the ACER decision with different ranges of historical time series, different time intervals and different reference days. In addition, influence of demand and production in forecasting the market value of cross-zonal capacity and welfare effects due to forecasting errors shall be evaluated. The Norwegian based company Optimeering AS has conducted the simulations presented in this chapter.

Within the assessment, for a given bidding zone border and direction (from A to B) cross-zonal capacity cost will be calculated as:

CZC_cost(d, t) = spread(d-1, t) + markup(d)

Here the spread(d,t) = max(0, DAM_price_B(d,t) – DAM_price_A(d,t))

In the following analyses, the main focus will be the “CZC cost error”, defined as:

CZC cost error(d, t) = spread(d, t) – CZC_cost(d,t)

In the assessment it will be investigated how the CZC cost error changes with changes in the CZC cost calculation methodology.

3.2 Current methodology for forecasting market value of cross-zonal capacity

For the analyses, historical day-ahead market (DAM) bidding zone prices from 01.02.2013-30.9.2020 have been used. Some analyses have also made applying last 3 years to find out if shorter historical time period would have an effect. Analyses showed that differences are insignificant. Figures 3.2.1, 3.2.2 and 3.2.3 visualise the error in CZC cost, over all hours over the analysis time period (1.2.2013-30.9.2020). Error in CZC cost is defined for a bidding zone border from A to B, for a given hour as follows:

Spread(d,t) = max(0, DAM_price B(d,t) – DAM_price A(d,t))

CZC cost error(d,t) = spread (d,t) – CZC_cost(d,t)

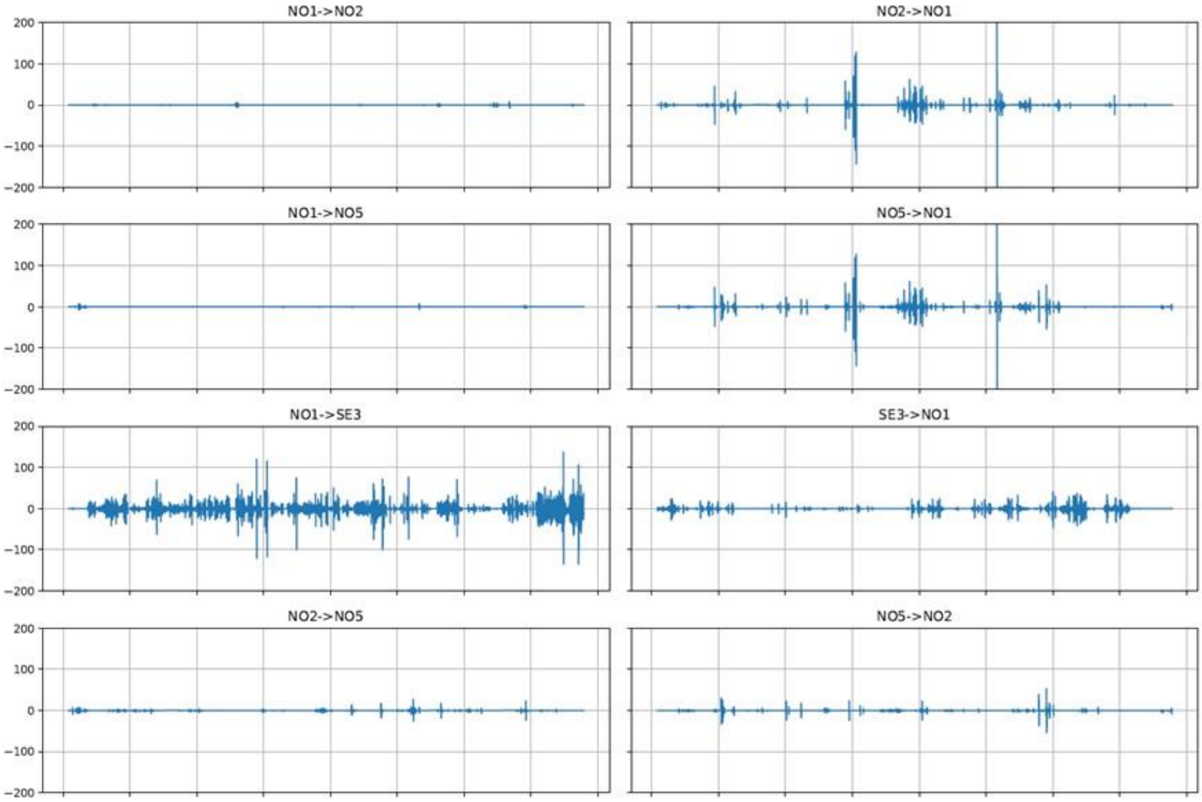

Figure 3.2.1. Error in CZC cost (in EUR) for bidding zone borders NO1 – NO2, NO1 – NO5, NO1 – SE3 and NO2 – NO5, over all hours for years 2013 - 2020.

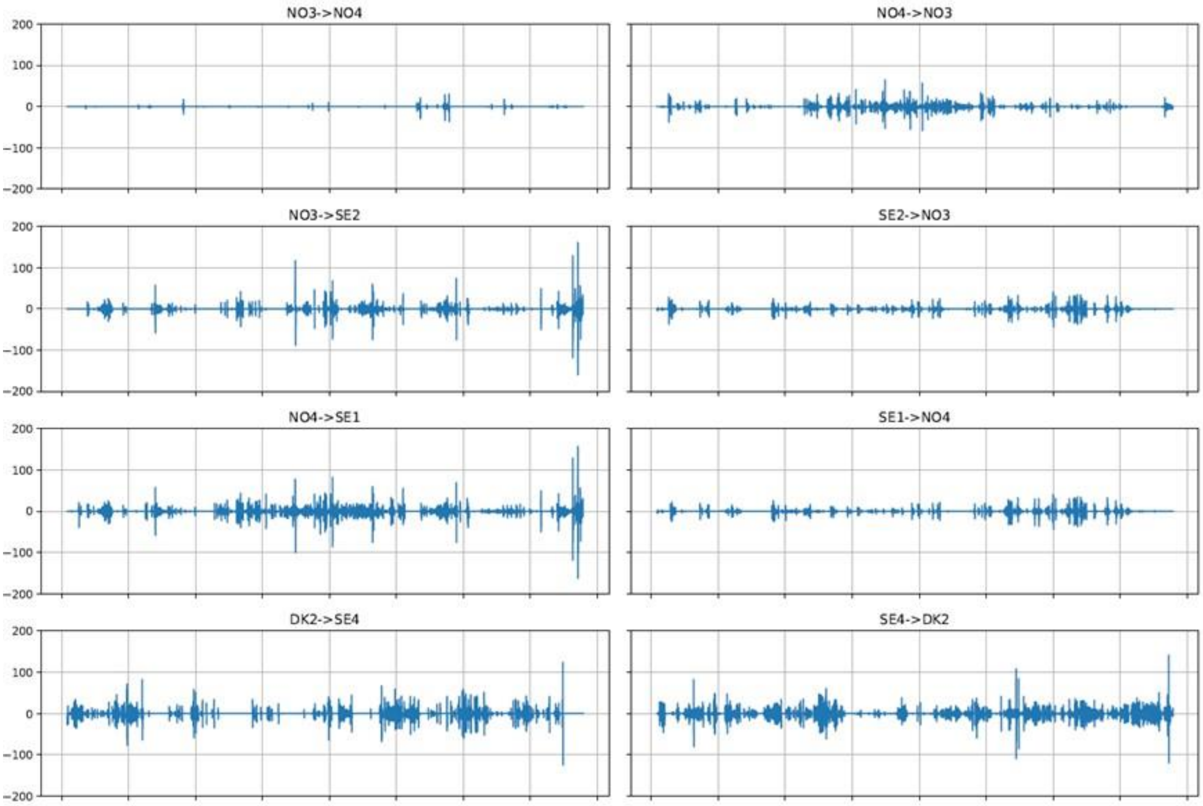

Figure 3.2.2. Error in CZC cost (in EUR) for bidding zone borders NO3 – NO4, NO3 – SE2, NO4 – SE1, DK2 – SE4, over all hours for years 2013 - 2020.

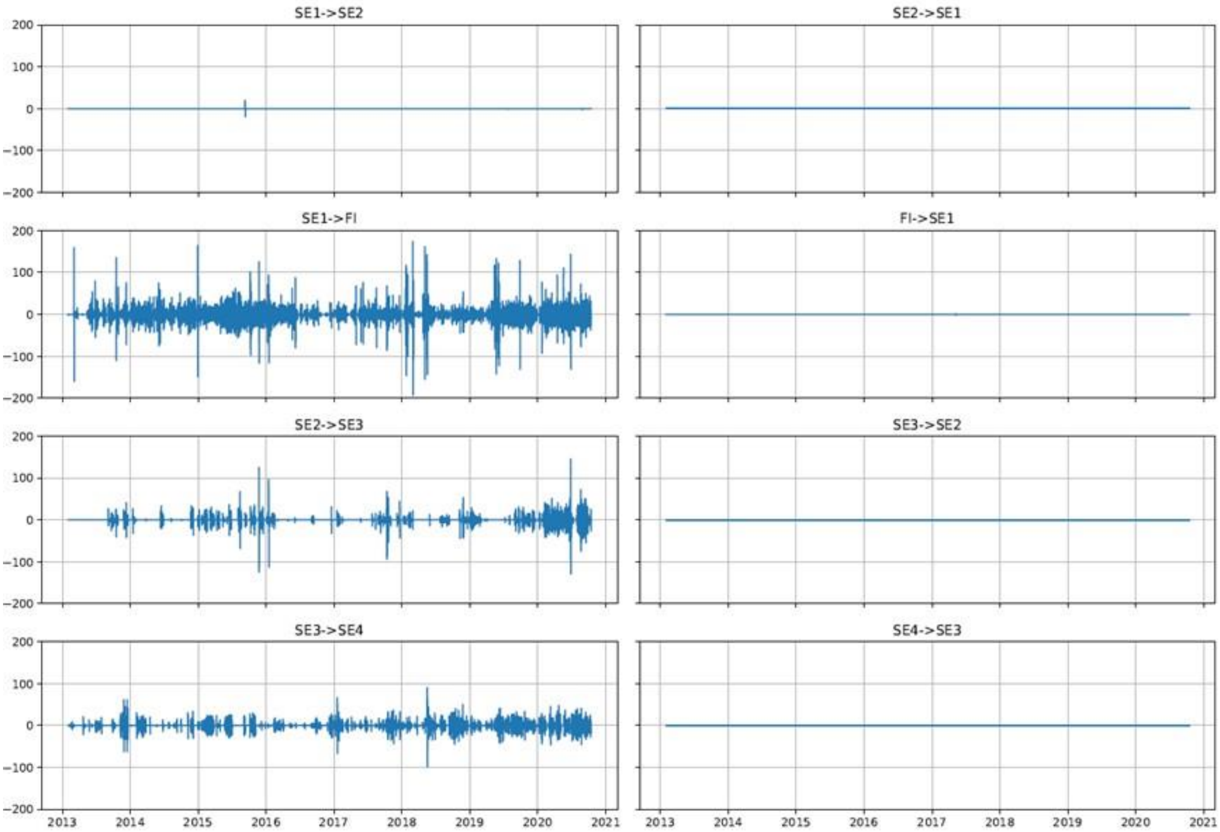

Figure 3.2.3. Error in CZC cost (in EUR) for bidding zone borders SE1 – SE2, SE1 – FI, SE2 – SE3, SE3 – SE4, over all hours for years 2013 - 2020.

Figure 3.2.4 and Table 3.2.1 show the mean error[1], mean absolute error (MAE)[2], median error[3] and standard deviation of the error[4] calculated in euros (EUR) for studied bidding zone borders. For all Nordic bidding zone borders the mean error is below zero. This means that on average the forecasted CZC cost is overestimated compared to the actual price difference (spread) on bidding zone borders. On many bidding zone borders, the mean errors are fairly small, which essentially means that negative errors tend to balance out positive errors. Mean absolute error shows, that several bidding zone borders exhibit consistent and larger absolute errors – in particular, the bidding zone borders between countries: NO1->SE3, NO4->SE1, SE4->DK2, and SE1->FI. The median error -0.1 shown in Table 3.2.1 for all bidding zone borders is a result that spreads are most of the time zero or negative for each bidding zone border and direction. The standard deviation describes the variation in the resulting errors (Figure 3.2.4 and Table 3.2.1). The variation is largest for the bidding zone borders between countries SE1->FI, NO1->SE3 and SE4->DK2 - quite consistent with mean absolute error calculation

[1] **mean error**: mean error refers to the average of all the errors in a set.
[2] **mean absolute error**: mean absolute error (MAE) uses absolute values of errors in the calculations, resulting in average errors.
[3] **median error**: median is the average value of the observations that are ranked at numbers N / 2 and [N / 2] + 1, i.e. half the values are less than or equal to median, and half the values are greater than or equal to median. When the mean and the median are the same, the dataset is more or less evenly distributed from the lowest to highest values.
[4] **standard deviation of error**: Standard deviation measures the amount of variability from the individual data values to the mean, while the standard error of the mean measures how far the sample mean (average) of the data is likely to be from the true data population mean.

results – but also quite large variations are for SE2->SE3 and SE3->SE4 bidding zone borders in Sweden. The high values from standard deviation of error calculation indicate that the errors are quite volatile on these bidding zone borders. Volatility in errors implies mispricing day-to-day and thus largest effect to welfare.

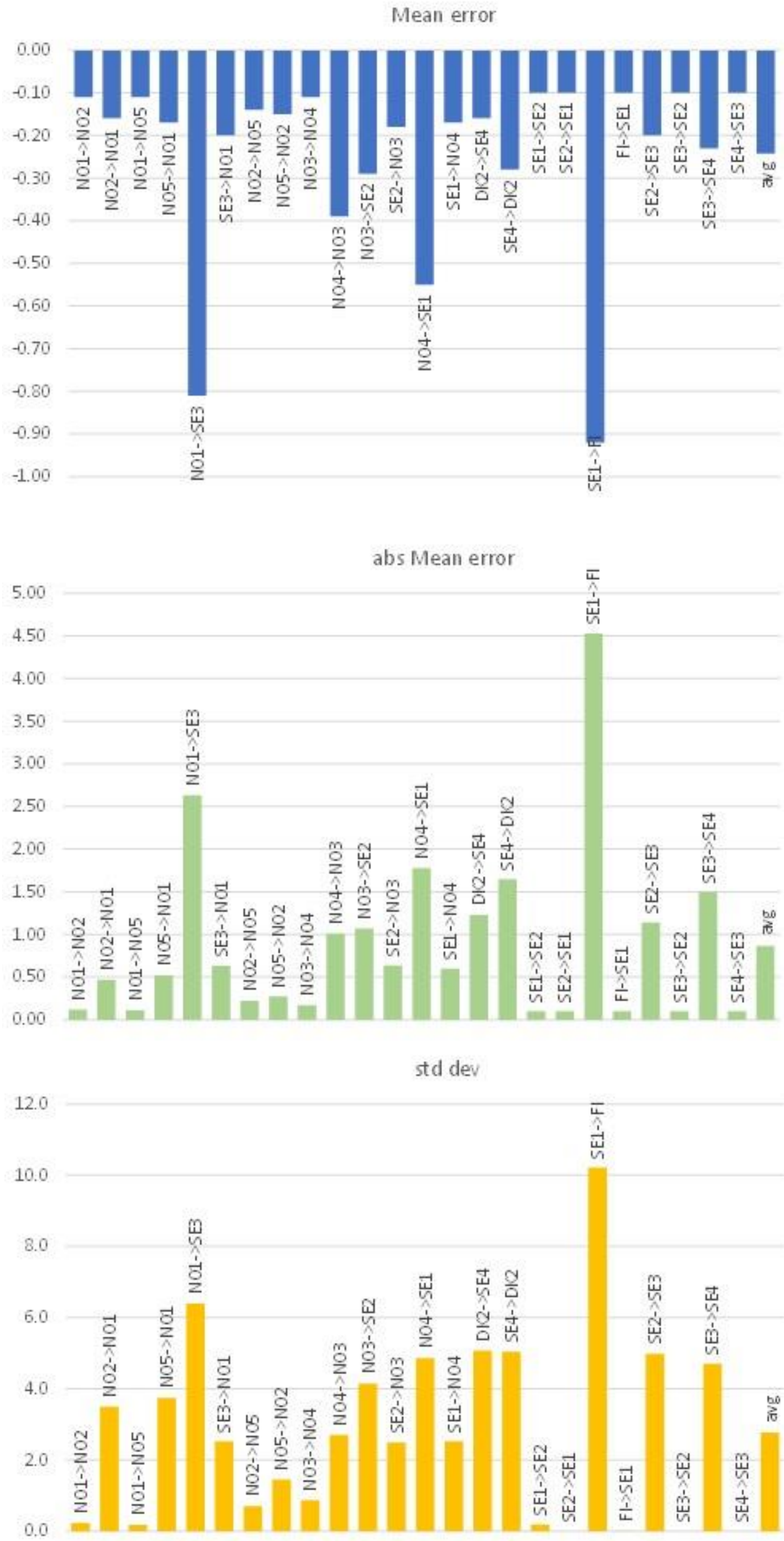

Figure 3.2.4 CZC forecasting error (in EUR) calculated as mean error, mean absolute error and standard deviation of the error for Nordic AC bidding zone borders.

	Mean	Mean_abs	Median	Std dev
NO1->NO2	-0.11	0.12	-0.1	0.23
NO2->NO1	-0.16	0.47	-0.1	3.5
NO1->NO5	-0.11	0.11	-0.1	0.18
NO5->NO1	-0.17	0.52	-0.1	3.74
NO1->SE3	-0.81	2.63	-0.1	6.39
SE3->NO1	-0.2	0.63	-0.1	2.52
NO2->NO5	-0.14	0.22	-0.1	0.7
NO5->NO2	-0.15	0.27	-0.1	1.45
NO3->NO4	-0.11	0.17	-0.1	0.87
NO4->NO3	-0.39	1.01	-0.1	2.7
NO3->SE2	-0.29	1.07	-0.1	4.15
SE2->NO3	-0.18	0.64	-0.1	2.49
NO4->SE1	-0.55	1.78	-0.1	4.86
SE1->NO4	-0.17	0.6	-0.1	2.52
DK2->SE4	-0.16	1.23	-0.1	5.07
SE4->DK2	-0.28	1.65	-0.1	5.04
SE1->SE2	-0.1	0.1	-0.1	0.19
SE2->SE1	-0.1	0.1	-0.1	0
SE1->FI	-0.92	4.53	-0.1	10.22
FI->SE1	-0.1	0.1	-0.1	0.01
SE2->SE3	-0.2	1.14	-0.1	4.99
SE3->SE2	-0.1	0.1	-0.1	0
SE3->SE4	-0.23	1.5	-0.1	4.7
SE4->SE3	-0.1	0.1	-0.1	0

Table 3.2.1 CZC forecasting error (in EUR) calculated as mean error, mean absolute error, median error and standard deviation of the error for Nordic AC bidding zone borders. Red colour shows the bidding zone borders with largest standard deviations.

Table 3.2.2 shows the share of hours for each border direction in 8 different bins of error ranges. Difference is in EUR between the actual spread and CZC cost (forecast spread). The column in the right combines bins [-1,0) and [0,1] to show how many hours of total hours go in the bin from -1 EUR error to 1 EUR error occurs. The bidding zone borders between the countries have a higher error than the bidding zone borders within countries.

	[-1000,-10)	[-10,-5)	[-5,-1)	[-1,0)	[0,1)	[1,5)	[5,10)	[10,1000]		[-1,1]
NO1->NO2	0.00	0.00	0.01	0.99	0.00	0.00	0.00	0.00		0.99
NO2->NO1	0.00	0.01	0.04	0.91	0.02	0.02	0.00	0.00		0.93
NO1->NO5	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00		0.99
NO5->NO1	0.01	0.00	0.04	0.91	0.02	0.01	0.00	0.00		0.93
NO1->SE3	0.04	0.06	0.16	0.57	0.04	0.07	0.03	0.03		0.62
SE3->NO1	0.01	0.01	0.04	0.88	0.02	0.03	0.01	0.01		0.90
NO2->NO5	0.00	0.00	0.04	0.94	0.02	0.01	0.00	0.00		0.95
NO5->NO2	0.00	0.00	0.04	0.93	0.02	0.01	0.00	0.00		0.95
NO3->NO4	0.00	0.00	0.01	0.98	0.00	0.00	0.00	0.00		0.98
NO4->NO3	0.01	0.02	0.14	0.72	0.04	0.05	0.01	0.01		0.76
NO3->SE2	0.01	0.02	0.07	0.82	0.02	0.03	0.01	0.01		0.84
SE2->NO3	0.01	0.01	0.05	0.87	0.02	0.03	0.01	0.01		0.89
NO4->SE1	0.02	0.04	0.15	0.65	0.04	0.06	0.02	0.02		0.69
SE1->NO4	0.01	0.01	0.04	0.89	0.02	0.02	0.01	0.01		0.91
DK2->SE4	0.02	0.01	0.02	0.90	0.01	0.01	0.01	0.02		0.91
SE4->DK2	0.03	0.03	0.07	0.77	0.03	0.04	0.02	0.02		0.79
SE1->SE2	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00		1.00
SE2->SE1	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00		1.00
SE1->FI	0.09	0.08	0.09	0.54	0.03	0.07	0.04	0.06		0.56
FI->SE1	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00		1.00
SE2->SE3	0.02	0.01	0.02	0.90	0.01	0.01	0.01	0.02		0.90
SE3->SE2	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00		1.00
SE3->SE4	0.03	0.02	0.03	0.84	0.01	0.03	0.02	0.03		0.85
SE4->SE3	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00		1.00

Table 3.2.2 Share of hours for each border direction for 8 different bins of error ranges for forecasting error. Difference in EUR between the actual spread and CZC cost (forecast spread). Red colour shows bidding zone borders with smallest share of hours between -1 and 1 EUR.

3.3 Accuracy of the forecasted market value when applying different historical time series as input data for determining the mark-ups

In this chapter the impact of the number of days of data used to calculate the mark-ups are analysed. More specifically, the number of days of historical data used to calculate the average forecast error will be analysed. This historical data is an input into the mark-up calculation. The historical data applied for forecasting errors are 15, 30, 60 and 120 days.

These calculation periods give approximately the same mean error, MAE and error standard deviation on most bidding zone borders (see Table 3.3.1.). However, errors are volatile. With a shorter average error period, the model has tendency to react to short term errors, which then quickly disappear or reverse. Overall longer calculation periods give marginally better results on average by reducing any (over)reaction to the short-term volatility. However, the improvement is very limited.

In Table 3.3.1, the different scenarios are labelled as *x*d*y*d, where *x* is the number of days in the average forecast error calculation, and *y* is the mark-up validity period in days, e.g., 30d1d means 30 days average forecast error and 1 day mark-up validity period. This kind of labelling is used also in the following sub-chapters.

	Mean				Absolute mean				Standard deviation			
	15d1d	30d1d	60d1d	120d1d	15d1d	30d1d	60d1d	120d1d	15d1d	30d1d	60d1d	120d1d
NO1->NO2	-0.11	-0.11	-0.11	-0.11	0.12	0.12	0.12	0.12	0.23	0.23	0.23	0.23
NO2->NO1	-0.16	-0.16	-0.16	-0.16	0.48	0.47	0.47	0.48	3.51	3.50	3.52	3.56
NO1->NO5	-0.11	-0.11	-0.11	-0.10	0.11	0.11	0.11	0.10	0.18	0.18	0.18	0.10
NO5->NO1	-0.17	-0.17	-0.17	-0.17	0.52	0.52	0.52	0.53	3.73	3.74	3.76	3.80
NO1->SE3	-0.87	-0.81	-0.70	-0.62	2.64	2.63	2.60	2.61	6.40	6.39	6.37	6.41
SE3->NO1	-0.21	-0.20	-0.19	-0.18	0.63	0.63	0.62	0.59	2.54	2.52	2.52	2.47
NO2->NO5	-0.14	-0.14	-0.14	-0.14	0.22	0.22	0.22	0.21	0.76	0.70	0.69	0.68
NO5->NO2	-0.15	-0.15	-0.15	-0.16	0.27	0.27	0.27	0.27	1.44	1.45	1.45	1.47
NO3->NO4	-0.11	-0.11	-0.11	-0.11	0.17	0.17	0.17	0.17	0.87	0.87	0.88	0.89
NO4->NO3	-0.41	-0.39	-0.36	-0.34	1.02	1.01	1.01	0.99	2.71	2.70	2.70	2.65
NO3->SE2	-0.32	-0.29	-0.27	-0.24	1.08	1.07	1.07	1.07	4.17	4.15	4.15	4.18
SE2->NO3	-0.19	-0.18	-0.18	-0.18	0.64	0.64	0.64	0.62	2.50	2.49	2.50	2.45
NO4->SE1	-0.63	-0.55	-0.54	-0.49	1.81	1.78	1.79	1.79	4.88	4.86	4.86	4.89
SE1->NO4	-0.17	-0.17	-0.17	-0.17	0.60	0.60	0.61	0.60	2.52	2.52	2.53	2.52
DK2->SE4	-0.17	-0.16	-0.16	-0.15	1.24	1.23	1.23	1.20	5.09	5.07	5.08	5.02
SE4->DK2	-0.32	-0.28	-0.28	-0.26	1.66	1.65	1.65	1.66	5.08	5.04	5.03	5.05
SE1->SE2	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.19	0.19	0.19	0.19
SE2->SE1	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00
SE1->FI	-0.98	-0.92	-0.90	-0.81	4.54	4.53	4.56	4.60	10.22	10.22	10.26	10.29
FI->SE1	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.03	0.01	0.01	0.01
SE2->SE3	-0.21	-0.20	-0.19	-0.18	1.14	1.14	1.14	1.16	5.00	4.99	4.98	5.02
SE3->SE2	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00
SE3->SE4	-0.25	-0.23	-0.22	-0.20	1.50	1.50	1.50	1.52	4.71	4.70	4.69	4.72
SE4->SE3	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00

Table 3.3.1 Mean error, mean absolute error and standard deviation in EUR for Nordic bidding zone borders when historical time series of 15, 30, 60 and 120 days are applied to as input data for determining the mark-ups.

3.4 Accuracy of the forecasted market value when applying different time intervals for defining and updating the mark-ups

In this chapter it is analysed the impact of the different time intervals over which a mark-up is valid. In the current methodology approved in the ACER decision, a single mark-up for each day is calculated implying that the mark-up is valid for a single calendar day.

Mark-up validity periods of 7 and 28 days in addition to current one day validity period are investigated. This means that e.g., for a 7-day validity period, for day d, the mark-up is calculated using historical data from d-30 to d-1, and the mark-up is valid (and used) for day d until d+6 (7 days in total).

Increase of the validity mark-up period results in slightly improved accuracy the longer the mark-up validity period. However, the change is very small; the overall trend is that the errors and the variation are reduced by increasing the mark-up validity period to 28 days, but by less than 1% on average (see Table 2.4.1). This result indicates that a consistent mark-up adjustment that does not change much or at all between days tends to perform better than one that reacts rapidly to recent changes.

To investigate this further, the changes in CZC cost due to having two mark-ups per day, one for peak and one for off-peak hours were analysed. Table 3.4.2 presents mean and standard deviation of CZC error. For the bidding zone borders where there is a change, it can be seen, that going from daily or weekly mark-ups to two mark-ups per day (peak and off-peak hours) increases the variance. The mean error with peak and off-peak mark-ups are all lower.

	Mean				Absolute mean				Standard deviation			
	30d1d	30d7d	30d28d	30d1dpeak	30d1d	30d7d	30d28d	30d1dpeak	30d1d	30d7d	30d28d	30d1dpeal
NO1->NO2	-0.11	-0.11	-0.11	-0.11	0.12	0.12	0.12	0.12	0.23	0.23	0.23	0.23
NO2->NO1	-0.16	-0.16	-0.16	-0.17	0.47	0.47	0.47	0.47	3.50	3.50	3.50	3.51
NO1->NO5	-0.11	-0.11	-0.11	-0.11	0.11	0.11	0.11	0.11	0.18	0.18	0.18	0.18
NO5->NO1	-0.17	-0.17	-0.17	-0.17	0.52	0.52	0.52	0.52	3.74	3.74	3.74	3.74
NO1->SE3	-0.81	-0.81	-0.78	-0.90	2.63	2.63	2.62	2.67	6.39	6.39	6.37	6.44
SE3->NO1	-0.20	-0.19	-0.19	-0.21	0.63	0.63	0.62	0.63	2.52	2.52	2.52	2.54
NO2->NO5	-0.14	-0.14	-0.14	-0.14	0.22	0.22	0.22	0.22	0.70	0.70	0.69	0.70
NO5->NO2	-0.15	-0.15	-0.15	-0.15	0.27	0.27	0.27	0.27	1.45	1.45	1.45	1.45
NO3->NO4	-0.11	-0.11	-0.11	-0.11	0.17	0.17	0.17	0.17	0.87	0.87	0.87	0.87
NO4->NO3	-0.39	-0.38	-0.39	-0.42	1.01	1.01	1.02	1.03	2.70	2.70	2.70	2.74
NO3->SE2	-0.29	-0.29	-0.27	-0.31	1.07	1.07	1.06	1.08	4.15	4.15	4.14	4.17
SE2->NO3	-0.18	-0.18	-0.18	-0.19	0.64	0.64	0.64	0.64	2.49	2.49	2.49	2.50
NO4->SE1	-0.55	-0.55	-0.53	-0.64	1.78	1.78	1.77	1.82	4.86	4.85	4.84	4.91
SE1->NO4	-0.17	-0.17	-0.17	-0.17	0.60	0.60	0.60	0.61	2.52	2.52	2.52	2.53
DK2->SE4	-0.16	-0.16	-0.16	-0.18	1.23	1.23	1.23	1.24	5.07	5.07	5.06	5.10
SE4->DK2	-0.28	-0.28	-0.27	-0.31	1.65	1.65	1.64	1.67	5.04	5.03	5.02	5.08
SE1->SE2	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.19	0.19	0.19	0.19
SE2->SE1	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00
SE1->FI	-0.92	-0.92	-0.90	-1.18	4.53	4.53	4.52	4.65	10.22	10.21	10.20	10.33
FI->SE1	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.01	0.01	0.01	0.01
SE2->SE3	-0.20	-0.20	-0.19	-0.22	1.14	1.14	1.13	1.15	4.99	4.98	4.97	5.01
SE3->SE2	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00
SE3->SE4	-0.23	-0.23	-0.23	-0.26	1.50	1.50	1.50	1.52	4.70	4.70	4.69	4.74
SE4->SE3	-0.10	-0.10	-0.10	-0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00

Table 3.4.1 Mean error, mean absolute error and standard deviation in EUR for Nordic bidding zone borders when mark-up validity period of 1, 7 are 28 days are applied for historical time series of 30 days.

	Mean				Standard deviation			
	30d1d	30d7d	30d28d	30d1dpea	30d1d	30d7d	30d28d	30d1dpeal
NO1->NO2	-0.11	-0.11	-0.11	-0.11	0.23	0.23	0.23	0.23
NO2->NO1	-0.16	-0.16	-0.16	-0.17	3.5	3.5	3.5	3.51
NO1->NO5	-0.11	-0.11	-0.11	-0.11	0.18	0.18	0.18	0.18
NO5->NO1	-0.17	-0.17	-0.17	-0.17	3.74	3.74	3.74	3.74
NO1->SE3	-0.81	-0.81	-0.78	-0.9	6.39	6.39	6.37	6.44
SE3->NO1	-0.2	-0.19	-0.19	-0.21	2.52	2.52	2.52	2.54
NO2->NO5	-0.14	-0.14	-0.14	-0.14	0.7	0.7	0.69	0.7
NO5->NO2	-0.15	-0.15	-0.15	-0.15	1.45	1.45	1.45	1.45
NO3->NO4	-0.11	-0.11	-0.11	-0.11	0.87	0.87	0.87	0.87
NO4->NO3	-0.39	-0.38	-0.39	-0.42	2.7	2.7	2.7	2.74
NO3->SE2	-0.29	-0.29	-0.27	-0.31	4.15	4.15	4.14	4.17
SE2->NO3	-0.18	-0.18	-0.18	-0.19	2.49	2.49	2.49	2.5
NO4->SE1	-0.55	-0.55	-0.53	-0.64	4.86	4.85	4.84	4.91
SE1->NO4	-0.17	-0.17	-0.17	-0.17	2.52	2.52	2.52	2.53
DK2->SE4	-0.16	-0.16	-0.16	-0.18	5.07	5.07	5.06	5.1
SE4->DK2	-0.28	-0.28	-0.27	-0.31	5.04	5.03	5.02	5.08
SE1->SE2	-0.1	-0.1	-0.1	-0.1	0.19	0.19	0.19	0.19
SE2->SE1	-0.1	-0.1	-0.1	-0.1	0	0	0	0
SE1->FI	-0.92	-0.92	-0.9	-1.18	10.22	10.21	10.2	10.33
FI->SE1	-0.1	-0.1	-0.1	-0.1	0.01	0.01	0.01	0.01
SE2->SE3	-0.2	-0.2	-0.19	-0.22	4.99	4.98	4.97	5.01
SE3->SE2	-0.1	-0.1	-0.1	-0.1	0	0	0	0
SE3->SE4	-0.23	-0.23	-0.23	-0.26	4.7	4.7	4.69	4.74
SE4->SE3	-0.1	-0.1	-0.1	-0.1	0	0	0	0

Table 3.4.2 Mean error and standard deviation in EUR for Nordic bidding zone borders when two mark-up validity periods per day are applied (one for peak and one for off-peak hours) for historical time series of 30 days. Green colour indicates which period had the best forecast (mean and standard deviation closest to zero) for each border. Orange colour indicates the worst forecast for each bidding zone border.

3.5 Accuracy of the forecasted market value when applying different reference days

In this chapter it is investigated the impact of different reference days to the forecasted market value. Impact of different reference days is compared to the current methodology, where reference day is d-1, i.e., forecast for day d is equal to spread for d-1. The following alternative reference day models are studied:

- D-7
- Weighted (D-1 + D-7 - D-8)
- Custom (if Monday: D-3, if Tuesday, Wednesday, Thursday and Friday: D-1, if Saturday, Sunday: D-7)

In the calculation, 30 days historical calculation period and 1 mark-up per day has been applied.

The results show that the weighted reference day model and the D-7 method come out worse than the 30d1d ('proposed CZC' method) for most bidding zone borders, both for mean error and standard deviation calculations. The custom model is better than the 'proposed CZC' model for some bidding zone borders and worse for others. On average, these two models provide more or less same results when all bidding zone borders are considered.

	Mean				Standard deviation			
	30d1d	30d1dD-7	30d1dwei	30d1dcust	30d1d	30d1dD-7	30d1dwei	30d1dcust
NO1->NO2	-0.11	-0.11	-0.12	-0.11	0.23	0.27	0.28	0.24
NO2->NO1	-0.16	-0.16	-0.32	-0.16	3.50	3.51	4.08	3.46
NO1->NO5	-0.11	-0.11	-0.11	-0.11	0.18	0.29	0.23	0.21
NO5->NO1	-0.17	-0.17	-0.35	-0.17	3.74	3.88	4.37	3.69
NO1->SE3	-0.81	-0.92	-1.36	-0.79	6.39	7.59	7.24	6.13
SE3->NO1	-0.20	-0.21	-0.39	-0.20	2.52	2.87	3.05	2.69
NO2->NO5	-0.14	-0.14	-0.21	-0.14	0.70	0.82	0.88	0.71
NO5->NO2	-0.15	-0.15	-0.23	-0.15	1.45	1.79	1.75	1.45
NO3->NO4	-0.11	-0.11	-0.15	-0.11	0.87	1.20	1.08	1.03
NO4->NO3	-0.39	-0.50	-0.70	-0.42	2.70	3.52	3.28	2.80
NO3->SE2	-0.29	-0.34	-0.62	-0.30	4.15	5.01	5.09	4.12
SE2->NO3	-0.18	-0.19	-0.42	-0.18	2.49	2.84	2.97	2.66
NO4->SE1	-0.55	-0.74	-1.08	-0.60	4.86	6.09	5.95	4.86
SE1->NO4	-0.17	-0.18	-0.39	-0.17	2.52	2.93	2.99	2.72
DK2->SE4	-0.16	-0.17	-0.67	-0.16	5.07	5.67	6.10	5.47
SE4->DK2	-0.28	-0.34	-0.94	-0.30	5.04	5.87	6.09	5.21
SE1->SE2	-0.10	-0.10	-0.10	-0.10	0.19	0.22	0.23	0.19
SE2->SE1	-0.10	-0.10	-0.10	-0.10	0.00	0.00	0.00	0.00
SE1->FI	-0.92	-0.98	-1.92	-0.85	10.22	10.89	11.50	9.32
FI->SE1	-0.10	-0.10	-0.10	-0.10	0.01	0.01	0.01	0.01
SE2->SE3	-0.20	-0.22	-0.59	-0.19	4.99	5.94	5.88	4.91
SE3->SE2	-0.10	-0.10	-0.10	-0.10	0.00	0.00	0.00	0.00
SE3->SE4	-0.23	-0.25	-0.77	-0.23	4.70	5.45	5.52	4.71
SE4->SE3	-0.10	-0.10	-0.10	-0.10	0.00	0.00	0.00	0.00
avg	**-0.24**	**-0.27**	**-0.49**	**-0.24**	**2.77**	**3.19**	**3.27**	**2.77**

Table 3.5.1 Mean error and standard deviation in EUR for Nordic bidding zone borders for different reference days when 1 mark-up per day is applied for historical time series of 30 days. Green colour indicates which period had the best forecast (mean and standard deviation closest to zero) for each border. Orange colour indicates the worst forecast for each bidding zone border.

When errors per day are examined, the custom model produces substantially lower average errors for Monday and Saturdays (see Figure 3.5.1). This indicates that taking the weekly price structure into account could be beneficial for the CZC market value forecasting methodology, resulting in lower overall CZC cost errors.

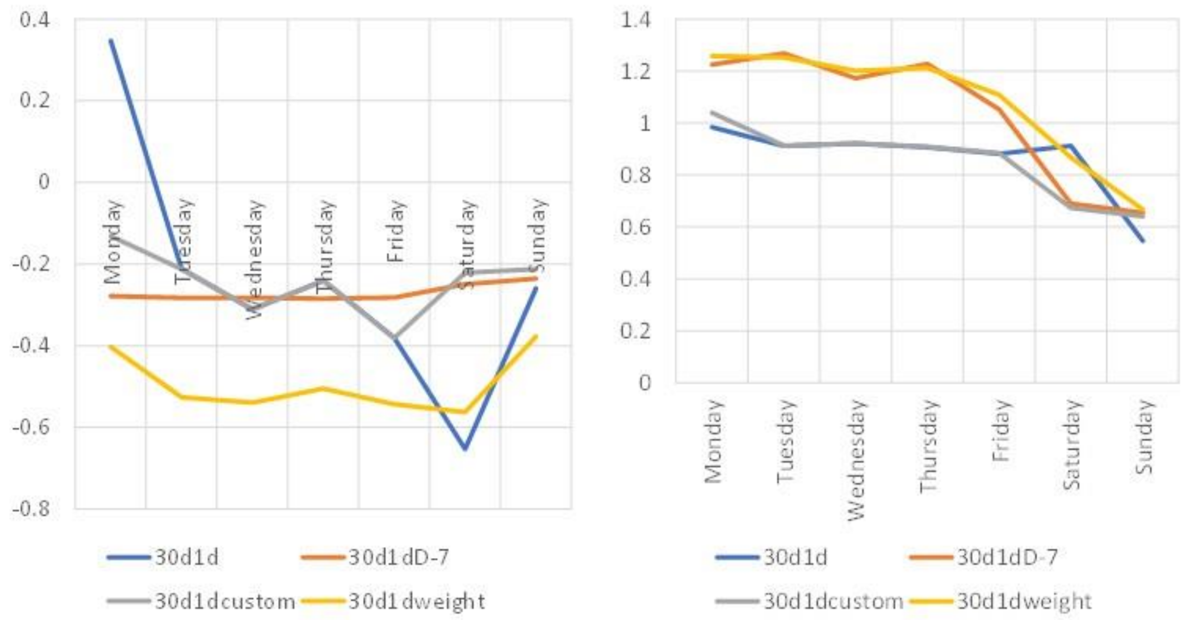

Figure 3.5.1 Mean error and absolute mean error in EUR for different reference days, when 1 mark-up per day are applied for historical time series of 30 days.

To investigate this further, the average error by day of the week over all bidding zone borders has been calculated. It is seen that Monday and Saturday CZC costs on average performs worse than the other days for the d-1 reference day method. This is as expected with the D-1 method as Monday will use Sunday and Saturday will use Friday prices.

The D-7 and the custom model show mean errors closer to zero for both these days. In terms of absolute errors, both the d-1 and the custom model perform best (with the custom model being better on Saturdays). The indication is, that both the weekly pattern and the day-to-day patterns should be incorporated in some form for reference day.

3.6 Summary from calculation and mark-up periods and reference day methods

Figure 3.6.1 shows a summary of calculations made for issues a, b and c of Article 6(4) of ACER decision No 22/2020, i.e., average error calculation periods, mark-up periods and reference day methods. Graphs in Figure 3.6.1 show the average values over all bidding zone borders for mean error, absolute mean error and standard deviation in EUR applying data between years 2013-2020.

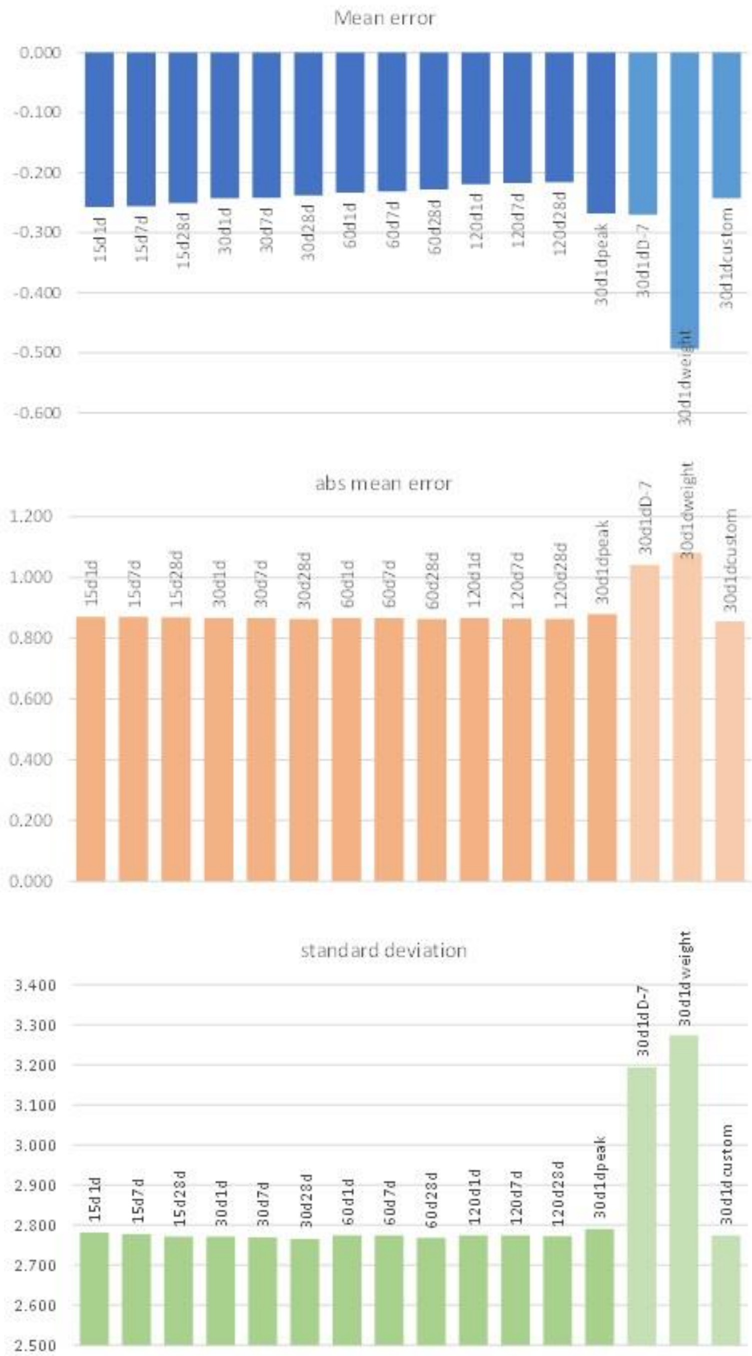

Figure 3.6.1 Average values in EUR over all bidding zone borders for mean error, absolute mean error and standard deviation applying data between years 2013-2020. Here the values for the mark-up methodology have darker colour than the values for the reference days. Note that the y-axis is truncated for standard deviation for visibility.

Overall, changes in CZC cost errors for the mark-up calculation scenarios are relatively low and for standard deviation and absolute mean error close to zero. For the reference day scenarios, the custom model is the best performer. As a summary, following conclusions can be made:

- For very simple models such as reference day of d-1, it is better to have invariant or slowly changing mark-ups; The error volatility means that reacting too quickly to recent changes seems to degrade performance; and

- Improving the model such as applying the custom reference day model, to take into account for more complex price and error patterns is beneficial. This seems to outweigh the impact of the average error calculation periods and the mark-up validity periods on performance.

In addition, CZC cost errors have been calculated without a mark-up. Table 3.6.1 compares the mean error, absolute error and standard deviation for current mark-up methodology and for no mark-up. The comparison shows that without mark-up the average standard deviation is about 3% lower than with current mark-up methodology. This result confirms the assumption that DA market will be favoured over the aFRR CM for CZC reservations.

Current mark-up

	Mean	Mean_abs	Median	Std dev
NO1->NO2	-0.11	0.12	-0.1	0.23
NO2->NO1	-0.16	0.47	-0.1	3.5
NO1->NO5	-0.11	0.11	-0.1	0.18
NO5->NO1	-0.17	0.52	-0.1	3.74
NO1->SE3	-0.81	2.63	-0.1	6.39
SE3->NO1	-0.2	0.63	-0.1	2.52
NO2->NO5	-0.14	0.22	-0.1	0.7
NO5->NO2	-0.15	0.27	-0.1	1.45
NO3->NO4	-0.11	0.17	-0.1	0.87
NO4->NO3	-0.39	1.01	-0.1	2.7
NO3->SE2	-0.29	1.07	-0.1	4.15
SE2->NO3	-0.18	0.64	-0.1	2.49
NO4->SE1	-0.55	1.78	-0.1	4.86
SE1->NO4	-0.17	0.6	-0.1	2.52
DK2->SE4	-0.16	1.23	-0.1	5.07
SE4->DK2	-0.28	1.65	-0.1	5.04
SE1->SE2	-0.1	0.1	-0.1	0.19
SE2->SE1	-0.1	0.1	-0.1	0
SE1->FI	-0.92	4.53	-0.1	10.22
FI->SE1	-0.1	0.1	-0.1	0.01
SE2->SE3	-0.2	1.14	-0.1	4.99
SE3->SE2	-0.1	0.1	-0.1	0
SE3->SE4	-0.23	1.5	-0.1	4.7
SE4->SE3	-0.1	0.1	-0.1	0

No mark-up

	Mean	Mean_abs	Median	Std dev
NO1->NO2	0	0.01	0	0.19
NO2->NO1	0	0.36	0	3.49
NO1->NO5	0	0.01	0	0.14
NO5->NO1	0	0.39	0	3.68
NO1->SE3	0.01	2.25	0	6.15
SE3->NO1	0	0.49	0	2.44
NO2->NO5	0	0.11	0	0.8
NO5->NO2	0	0.14	0	1.39
NO3->NO4	0	0.07	0	0.84
NO4->NO3	0	0.81	0	2.58
NO3->SE2	0.01	0.89	0	4.03
SE2->NO3	0	0.5	0	2.41
NO4->SE1	0.01	1.51	0	4.69
SE1->NO4	0	0.47	0	2.44
DK2->SE4	0	1.11	0	4.98
SE4->DK2	0	1.46	0	4.88
SE1->SE2	0	0	0	0.18
SE2->SE1	0	0	0	0
SE1->FI	0	4.12	0	9.87
FI->SE1	0	0	0	0.03
SE2->SE3	0	0.99	0	4.85
SE3->SE2	0	0	0	0
SE3->SE4	0	1.33	0	4.52
SE4->SE3	0	0	0	0

Table 3.6.1. CZC forecasting error (in EUR) calculated as mean error, mean absolute error, median error and standard deviation of the error for Nordic AC bidding zone borders for current mark-up methodology and without any mark-up. Red colour shows the bidding zone borders with largest standard deviations.

3.7 Accuracy of the forecasted market value when applying additional relevant factors influencing demand and generation patterns

In this chapter, a high-level ARIMA modelling[5] process has been applied to answer the following questions:

- Does alternative model architecture to the simple (previous day) forecast give improved results?
- Will the inclusion of additional information (e.g., demand forecasts) give improved forecasting results for market values?

The analysis presented here is a high level one and a fully optimised "best" model has not been developed. However, the analysis undertaken here is sufficient to make some broad conclusions

[5] Autoregressive integrated moving average (ARIMA) model fits the time series data either to better understand the data or to predict future points in the series for forecasting purposes.

regarding the quality of the simple forecasting approach and the possible development of improved approaches and methods.

3.7.1 Results from ARIMA modelling

A set of simple ARIMA architectures were developed for the analysis purposes. Details of applied architectures and results achieved with these architectures has been presented in Annex 1.

As presented in Annex 1, ARIMA models seem to have performance advantages over the current simple model in most situations. However, the advantages were not substantial. As the analysis is preliminary, and the models developed were not optimised, this suggests as conclusion that substantial improvements would require significant modelling development (for example the development of advanced machine learning models or ensembles of ARIMA models). Any improved forecasting ability of such models should be weighed against the substantially increased complexity and reduced transparency when compared to the current simple model.

The conclusion from the studies applying the ARIMA models is that the simple model is difficult to beat unless complex models and the model fitting techniques is employed, and/or other data, e.g., wind production or demand forecasts, are included. Usually, these forecasts are not publicly available and application on non-publicly available data would produce non-transparent model.

3.7.2 Application of additional data in forecasting models

The hypothesis for the analysis is that the use of additional data in the forecasting models will lead to improved forecasting accuracy. This follows from the assumption that price spread will be related to fundamental market drivers and predicting these drivers may allow better prediction of price spreads. These fundamental market drivers include such as wind generation, weather, demand, and production. Detailed assessment of these fundamental drivers will involve substantial data analysis, model development, data fitting and assessment and this is outside the scope of the current assessment. However, in this assessment a general analysis on demand as a predictor is undertaken.

Figure 3.7.1 shows price spread on FI-SE1 bidding zone border as a function demand in Finnish bidding zone and Table 3.7.1 correlation between FI-SE1 price spread and demand in Swedish and Finnish bidding zone for each hour.

Relationships may exist, but if they exist, they are complex and non-linear. Figure 3.7.1 and Table 3.7.1 indicate multiple drivers may be required to improve predictions and detailed data on these drivers will be required. Complex model architectures may be required to take advantage of the relationships that exist.

The conclusion is that such fundamental market drivers may be used to improve predictions. However, this will require significant modelling effort to develop and will result in substantially more complex models than the simple model.

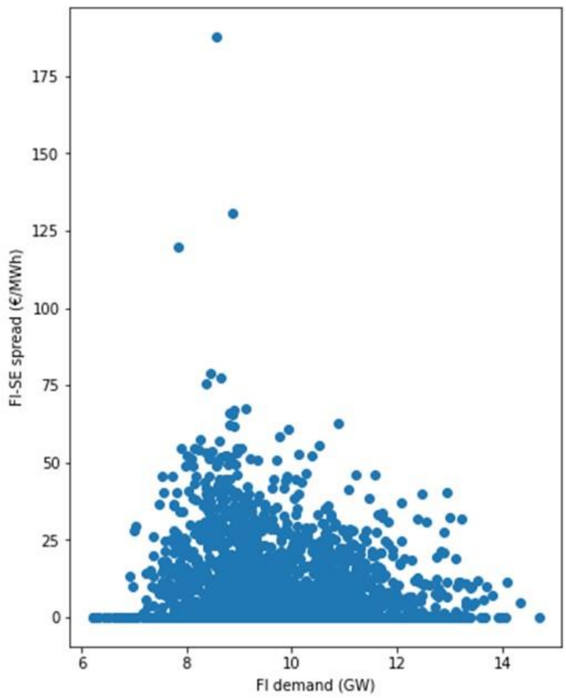

Figure 3.7.1. Price spread on FI-SE1 bidding zone border vs. demand in Finnish bidding zone.

	SE - correlation	SE - p-value	FI - correlation	FI - p-value	FI-SE - correlation	FI-SE - p-value
hr00	-0.07	0.00	-0.07	0.00	0.06	0.00
hr01	-0.03	0.09	-0.04	0.04	0.02	0.22
hr02	-0.02	0.25	-0.03	0.15	0.01	0.46
hr03	-0.01	0.65	-0.01	0.55	0.00	0.80
hr04	0.05	0.01	0.06	0.00	-0.04	0.07
hr05	0.12	0.00	0.13	0.00	-0.09	0.00
hr06	0.12	0.00	0.13	0.00	-0.10	0.00
hr07	0.10	0.00	0.09	0.00	-0.11	0.00
hr08	0.06	0.00	0.02	0.26	-0.08	0.00
hr09	0.01	0.50	-0.01	0.52	-0.03	0.12
hr10	-0.06	0.00	-0.07	0.00	0.04	0.02
hr11	-0.10	0.00	-0.10	0.00	0.09	0.00
hr12	-0.11	0.00	-0.11	0.00	0.10	0.00
hr13	-0.08	0.00	-0.08	0.00	0.07	0.00
hr14	-0.00	0.92	-0.01	0.58	-0.01	0.79
hr15	0.07	0.00	0.06	0.00	-0.07	0.00
hr16	0.11	0.00	0.10	0.00	-0.12	0.00
hr17	0.12	0.00	0.10	0.00	-0.13	0.00
hr18	0.04	0.04	0.03	0.10	-0.04	0.02
hr19	-0.11	0.00	-0.11	0.00	0.09	0.00
hr20	-0.14	0.00	-0.15	0.00	0.12	0.00
hr21	-0.17	0.00	-0.17	0.00	0.15	0.00
hr22	-0.17	0.00	-0.17	0.00	0.15	0.00
hr23	-0.12	0.00	-0.12	0.00	0.11	0.00

Table 3.7.1 Correlation between FI-SE1 price spread and demand Swedish and Finnish bidding zone border for each hour.

3.8 Estimated welfare effect for a range of confidence levels of the positive forecast errors

3.8.1 Calculation method

In this chapter it is investigated the welfare effects on the aFRR market and day-ahead market (DAM) emerging from errors in the CZC market value calculations. The analysis is based on two models: “Perfect foresight” and “Proposed model”. In “Perfect foresight” there are no errors in CZC market value forecast, i.e., the CZC costs used in the aFRR clearing process are equal to the price difference (spread) across the bidding zone border in the DAM solution for that period. This forecast is assumed to predict perfectly the actual CZC cost. In “Proposed model” the CZC costs for the aFRR clearing are calculated using the proposed CZC algorithm as defined in the ACER decision. In this model, the reserved CZC capacities from the aFRR clearing are used to determine available DAM cross-zonal capacities, with the daily mark-up calculated over a 30-day period (current method in the ACER decision). The simulations were made for the calendar year 2018 for both models.

The welfare effect of the proposed model has been calculated as:

CZC_effect = welfare(aFRR_proposed) – welfare(aFRR_perfectF) + welfare(DAM_proposed) – welfare(DAM_perfectF)

However, there are challenges for simulating the aFRR and DA markets as-if both had existed for year 2018. As the Nordic aFRR capacity market do not exist yet no precise bid or requirements data is not available. If the aFRR capacity market had existed, bids into the DAM would be expected to accepted bids into the aFRR capacity market, and potentially be different to the actual year 2018 bid curves. Similarly, the available CZC capacities in the DAM would be different – reduced – from the actual CZC capacities.

These challenges limit the ability to simulate precisely what would have occurred had the aFRR CM existed in year 2018, and thus the welfare effects of CZC model for forecasting the market value. Therefore, a heuristic approach will be adopted to estimate these effects. This heuristic approach estimates the clearing outcomes of both the aFRR CM and DAM in 2018 as follows:

- Both the bids and reserve requirements for the aFRR CM in year 2018 were estimated, based on inputs and requirements supplied by the TSOs for earlier market analysis. Expected reserve requirements for year 2018 were supplied by the TSOs, as was a set of estimated bids scaled up the bid set to match the reserve requirements.
- The aFRR CM was cleared against these estimated bids and requirements, and the resulting welfare from the aFRR CM and CZC reservations calculated.
- Duality theory has been used to estimate the impact on the DAM welfare in year 2018 if the aFRR CM had existed and the reserved cross-zonal capacity were removed from the DAM.
- Specifically, marginal CZC reservation on a given bidding zone border in the aFRR CM will reduce the DAM welfare from that observed in year 2018 by an amount equal to the DAM dual price on the bidding zone border.
- This insight will be used to estimate the change in DAM welfare with an aFRR CM clearing over that observed in year 2018 by calculating a welfare loss per bidding zone border (BZB):

  DAM_welfare_loss(BZB) =mgl_price(BZB)*(y + x – C)

  where y is BZB capacity used in the actual year 2018 cleared DAM, x is BZB capacity used in aFRR CM clearing and C is the total NTC capacity on the BZB

- Then the DAM welfare given in an aFRR CM clearing is estimated as

  Welfare(DAM_given_aFRR) = welfare(DAM_2018) - sum(l in BZB) (DAM_welfare_loss(l))

3.8.2 Results from welfare calculations

The simulations for the year 2018 show that in aFRR CM Norway is exporting at nearly full capacity to Sweden and further to Denmark and Finland for almost all days due to bids in Norway being priced relatively much lower than the other countries for aFFR CM. In general, the CZC cost is higher in “Proposed model” simulations than in “Perfect foresight” simulations due to the mark-up. This drives lower total aFRR CM exports from Norway, and total Nordic aFRR CM costs increase.

For the changes in DAM welfare, it should be expected that by reserving less transmission capacity on the bidding zone borders (“Proposed model” vs “Perfect foresight”), that the DAM welfare loss would be lower in the “Proposed model” scenario than in the “Perfect foresight” scenario. However, the opposite is seen because it is possible to forecast the price differences perfectly and the days and hours where the price differences (spreads) are underestimated have a larger impact on the DAM welfare than the days and hours where price differences are overestimated.

This leads to the summary from welfare calculations for the year 2018:

- Change in aFRR socio economic benefit: -708 000 EUR
- Change in DAM socio economic benefit: -1 035 000 EUR
- Total change from “Perfect foresight” to “Proposed model”: - 1 743 000 EUR

Figure 3.8.1 shows the difference between “Proposed model” and “Perfect foresight” in aFRR CM welfare for each Nordic bidding zone. As the CZC reservation cost is in general higher in the “Proposed model” scenario, there will be less CZC reservation from Norway to Sweden, Denmark and Finland and fewer Norwegian bids chosen than in the “Perfect foresight” scenario. This means also more expensive bids selected in Sweden, Denmark and Finland compared to the “Perfect foresight” scenario. This implies that total aFRR CM bid cost is higher in the “Proposed model” scenario than in the “Perfect foresight” scenario.

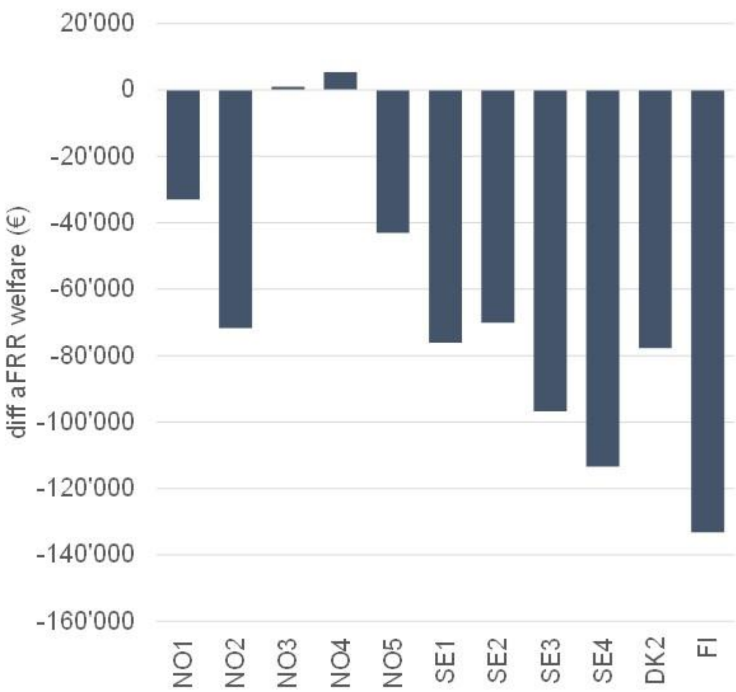

Figure 3.8.1 Difference in aFRR CM welfare for each Nordic bidding zone between the “Proposed model” and the “Perfect foresight”. Here minus sign means that “Perfect foresight” has higher welfare.

Figure 3.8.2 shows the difference in estimated DAM welfare between the “Proposed model” and the “Perfect foresight” calculations. Due to non-existent aFRR CM, in the calculations the approximate for “duality” theory was used to estimate welfare impact from CZC reservation on the DAM. Welfare changes were assigned to each bidding zone equally (50% to each bidding zone). Figure 3.8.2 shows that all bidding zones encounter a reduction in DAM welfare when using the “Proposed model” compared to “Perfect foresight” calculations. Even though the costs in the “Proposed model” scenario are higher and the total CZC reservation is lower, the days when the CZC cost (price differences) are underestimated have a disproportionally larger effect on the total DAM welfare.

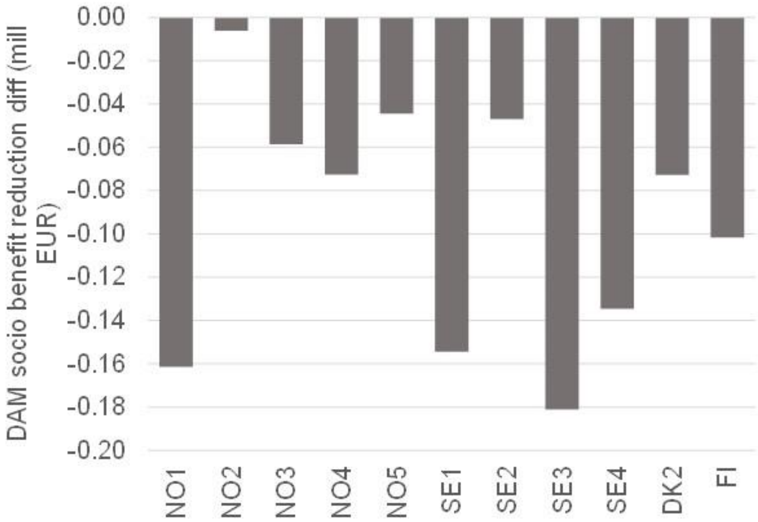

Figure 3.8.2 Difference in estimated DAM welfare for each Nordic bidding zone between the “Proposed model” and the “Perfect foresight”. Here minus sign means that “Perfect foresight has higher welfare.

Figure 3.8.3 shows the reduction in total welfare between the “Proposed model” and the “Perfect foresight” calculations. All Nordic bidding zones encounter a reduction in total welfare when DAM and aFRR CM are combined, with a sum per country:

- Norway: -485 000 € (0.29 EUR/MW demand)
- Sweden: -873 000 € (0.36 EUR/MW demand)
- Denmark: -150 000 € (0.43 EUR/MW demand)
- Finland: -235 000 € (0.30 EUR/MW demand)

Figures 3.8.4 and 3.8.5 shows the correlation between welfare effects and CZC cost for aFRR CM and DAM. Results show that when the price difference (and thus overestimate CZC costs) are overestimated, less CZC is reserved and the total bid costs increase, which gives a negative effect on the total welfare in the aFRR CM. The opposite is also true as seen from the Figure 3.8.4. Results for DAM show that when the CZC costs (negative CZC cost error) are overestimated, less CZC will be reserved. However, when the price difference is underestimated, more CZC is reserved and the welfare loss in DAM is high and even for some days very high.

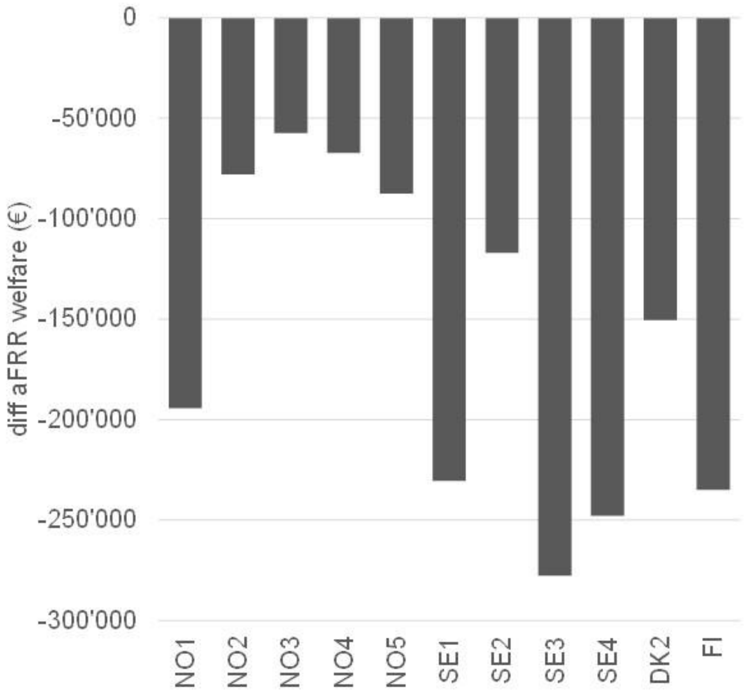

Figure 3.8.3 Reduction in total welfare between the “Proposed model” and the “Perfect foresight” calculations. Here the minus sign means that “Perfect foresight” has higher welfare.

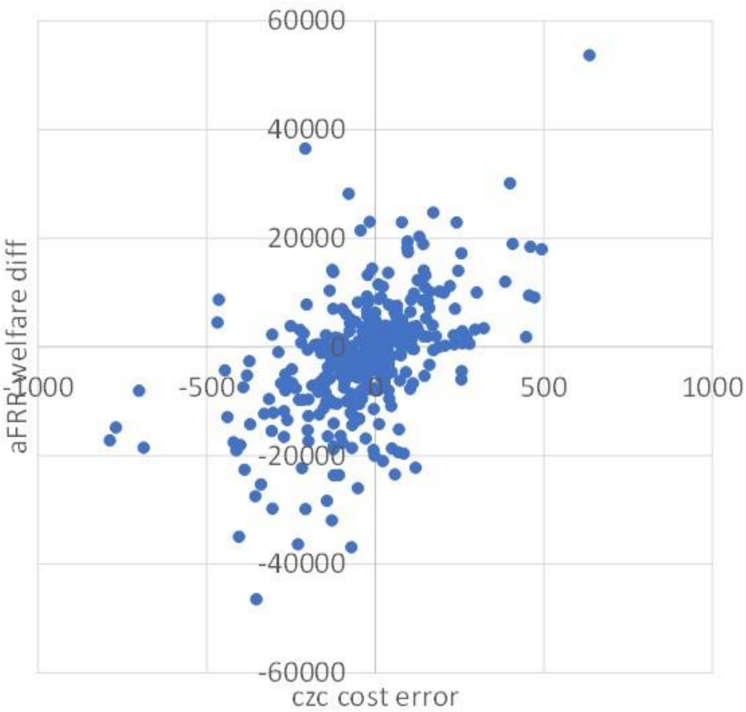

Figure 3.8.4 Sum of CZC cost error (negative is overestimating) and the sum of aFRR welfare difference per day between the “Proposed model” and the “Perfect foresight” calculation.

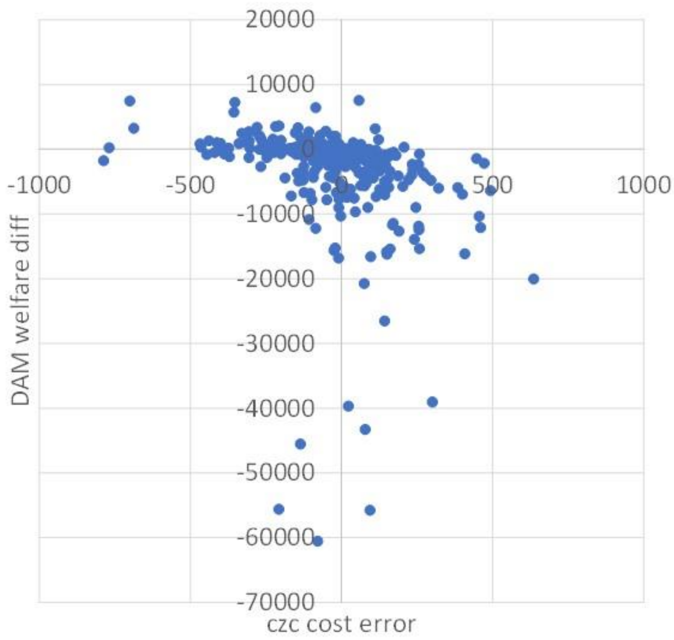

Figure 3.8.5 Sum of CZC cost error (negative error means overestimated CZC costs) and the change in DAM welfare between the “Proposed model” scenario and the “Perfect foresight” calculations.

In addition, Figure 3.8.6 shows duration curve for the change in DAM welfare effect. The figure shows the welfare effect is seen only in very few cases (about 3 % from all combinations of bidding zone border directions and hours). In most cases, the errors in CZC reservation costs have little to no effect on DAM welfare. The DAM welfare impact is concentrated in a small number of bidding zone borders and hours. The bidding zone border NO1->SE3 and NO4->SE1 have 30% of the total welfare impact in the year 2018 simulations. This indicates that any future improvements to the CZC market value forecasting methodology should concentrate on reducing extreme errors rather than on small(er) reductions in average error.

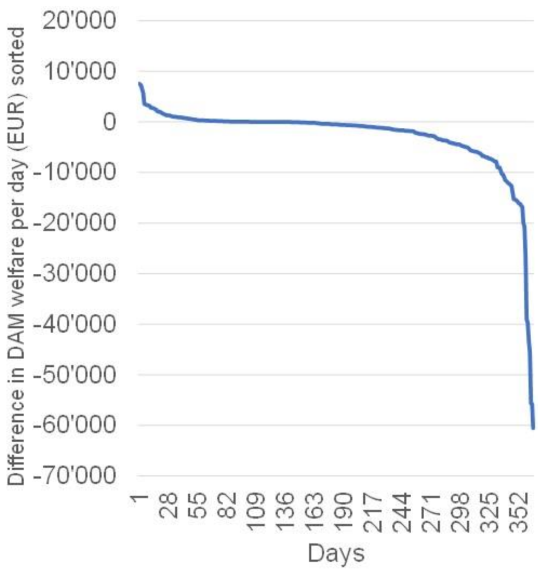

Figure 3.8.6 Change in the DAM welfare effect for year 2018.

3.8.3 Results from mark-up sensitivity calculations

To investigate how different mark-up definitions and confidence levels affects estimated welfare, the following seven mark-up options were studied and compared the current mark-up methodology:

- No mark-up: only market spread is applied in determination of CZC market value; mark-up is zero;
- No max: no maximum limit to mark-up, minimum limit is 1 EUR;
- Max 1: maximum/minimum limit to mark-up is 1 EUR;
- 25% sensitivity: current mark-up definition is applied, except 75% of hours with highest positive error are removed from calculation of mark-up instead of current 5% of hours;
- 50% sensitivity: current mark-up definition is applied, except 50% of hours with highest positive error are removed from calculation of mark-up instead of current 5% of hours;
- 75% sensitivity: current mark-up definition is applied except 25% of hours with highest positive error are removed from calculation of mark-up instead of current 5% of hours;
- 100% sensitivity: current mark-up definition is applied, except 0% of hours with highest positive error are removed from calculation of mark-up instead of current 5% of hours.

Table 3.8.1 shows the welfare effects calculated with these seven different mark-up options and current mark-up methodology (95% sensitivity option).

Mark-up option	total CZC cost (EUR)	aFRR welfare Diff. from perfect foresight (EUR)	DAM welfare Diff. from perfect foresight (EUR)	aFRR+DAM welfare Diff. from perfect foresight (EUR)
No mark-up	133 400	-144 000	-1 151 000	-1 295 000
No max	150 500	-708 000	-1 035 000	-1 743 000
Max 1	150 100	-655 000	-1 038 000	-1 693 000
25% sensitivity	150 100	-655 000	-1 038 000	-1 693 000
50% sensitivity	150 100	-655 000	-1 038 000	-1 693 000
75% sensitivity	150 100	-655 000	-1 038 000	-1 693 000
95% sensitivity	150 500	-708 000	-1 035 000	-1 743 000
100% sensitivity	155 800	-827 000	-975 000	-1 802 000

Table 3.8.1 Calculated welfare (in EUR) compared to perfect foresight with different mark-up options. 95% sensitivity options is current approach. Table includes also total CZC cost (in EUR) with these different mark-up options. Data from year 2018 was used.

Table 3.8.1 shows that the 'no mark-up' option gave lowest CZC cost for the year 2018 data set. Highest CZC cost were given by option with 100% sensitivity (i.e., when no forecast errors were moved in mark-up calculation). Options with 25%, 50% and 75% sensitivity and option with same min/max of 1 EUR gave same CZC cost for year 2018, which were slightly lower than CZC costs for current mark-up methodology (95% sensitivity option). 'No max' option (i.e., when maximum forecasting error was unlimited) gave same results as current mark-up methodology.

The reason why similar results for some of the mark-up options are received is because the current mark-up methodology (95% sensitivity option) has mark-ups between 1 and 2 EUR for the year 2018 and therefore changes in mark-up methodology have limited effects in CZC cost and welfare calculations.

Looking at the aFRR welfare, the options where CZC costs increase result in a larger welfare loss than the current approved methodology (95% sensitivity option), and the options where the CZC cost decrease result in a lower welfare loss. This is as expected as in general a higher CZC cost will lead to more expensive bids being chosen rather than transporting cheaper bids from neighbouring bidding zones. Thus the ‘no mark-up’ option has the largest improvement of over 0,5 million EUR over the current mark-up methodology.

Looking at the DAM welfare, the opposite effects are seen: the options where CZC costs increase, result in a lower welfare loss compared to the current mark-up methodology (95% sensitivity option), whilst options where the CZC costs decrease result in a higher welfare loss. The only option with improvement on DAM welfare (of 60 000 EUR) compared to the current mark-up methodology is the ‘100% sensitivity’ option, where all forecast errors are included in the mark-up calculation.

In total, it is seen that the changes related to the mark-up options are largest in the aFRR-market. The results from the year 2018 dataset show that a lower mark-up (‘No mark-up’ option) gives the best total welfare effects. However, it should be remembered that the DAM welfare effects are underestimated with the selected approach. The preliminary expectation is that a more accurate estimate of the DAM welfare effect would increase the estimated DAM welfare loss for low mark-up options, thus reducing the differences summed (aFRR+DAM) welfare loss on average over the mark-up methodologies. This means that with a better methodology for estimating DAM welfare, the DAM welfare loss would be higher for the no mark-up sensitivity and possibly even worse in total than the sensitivities with higher mark-ups.

4. Amendment proposal for mark-up methodology

The assessment of chapter 2 shows that application of different ranges of historical time series show that longer historical time series give marginally better results on average by reducing errors due to the short-term volatility. However, the improvement is marginal and does not support change in the mark-up methodology, where 30 days historical time series is applied to calculate forecasted market value of cross-zonal capacity.

Increase of the validity mark-up period results in slightly improved accuracy the longer the mark-up validity period. The change is very small as seen from chapter 3.4 and does not either support changing the mark-up validity time in the mark-up methodology, where one day validity period is used to define forecasted market value of cross-zonal capacity.

Application of different reference days shows that the custom model produces lower average errors for Monday and Saturdays compared to current reference day model. This indicates that taking the weekly price structure into account could be beneficial for the CZC market value forecasting methodology, resulting in lower overall CZC cost errors. Overall, the improvement by custom model is marginal and does not support change in the mark-up methodology, where the previous day is used as reference day in defining the forecasted market value of cross-zonal capacity.

Calculations made in chapter 3.7 show that it is difficult to beat the simple model unless complex models and model fitting is employed, e.g., applying machine learning and including wind production and demand forecasts. Usually, these forecasts are not publicly available and application on non-publicly available data would introduce a non-transparent model. The expectation is that substantial improvement will require significant modelling effort and will result in a complex model structure or – equivalently – a large set of models for different days and hours. The new models introduce substantially increased complexity compared to the current simple model. These new models include less transparency and more need for communication to the stakeholders compared to simple mark-up methodology approved within the ACER decision no 22-2020.

The overall conclusion from the assessment introduced in chapter 3 is, that studied changes in methodologies bring very small improvements. In majority of hours, the current mark-up methodology is good and transparent to the stakeholders. If removal of large forecasting errors within this methodology is needed, the possible next step in development of forecasting market value of cross-zonal capacity is machine learning, which will introduce more complexity and less transparency in forecasting the market value of cross-zonal capacity.

Due to reasons presented above and the assessment presented in chapter 3, Nordic TSOs will not change the current mark-up methodology as described in Article 6 of the ACER decision 22-2020. This implies that Nordic TSOs will propose only to delete Article 6(4) in the amendment proposal.

The assessment of welfare effects between aFRR CM and DAM has been based on certain assumptions as Nordic aFRR CM has not yet been implemented. Nordic TSOs will perform a new assessment, when the Nordic aFRR CM has been in operation for the time needed to withdraw necessary data to perform the new assessment. This will be part of the efficiency monitoring of the forecasting methodology as described in Article 12(5) of the current methodology for the market-based allocation process of cross-zonal capacity for the exchange of balancing capacity for the Nordic CCR.

ARIMA models

A1 General

An exhaustive model fitting process is outside of the scope of the analysis presented in this assessment. Rather, a set of simple ARIMA architectures were developed. These architectures were selected using preliminary analysis of auto- and partial auto-correlation diagnostics (example ACF and PACF curves for spread data on an example border are shown in Figure A1). The architectures used featured MA terms, with several also featuring AR and weekly seasonal AR terms.

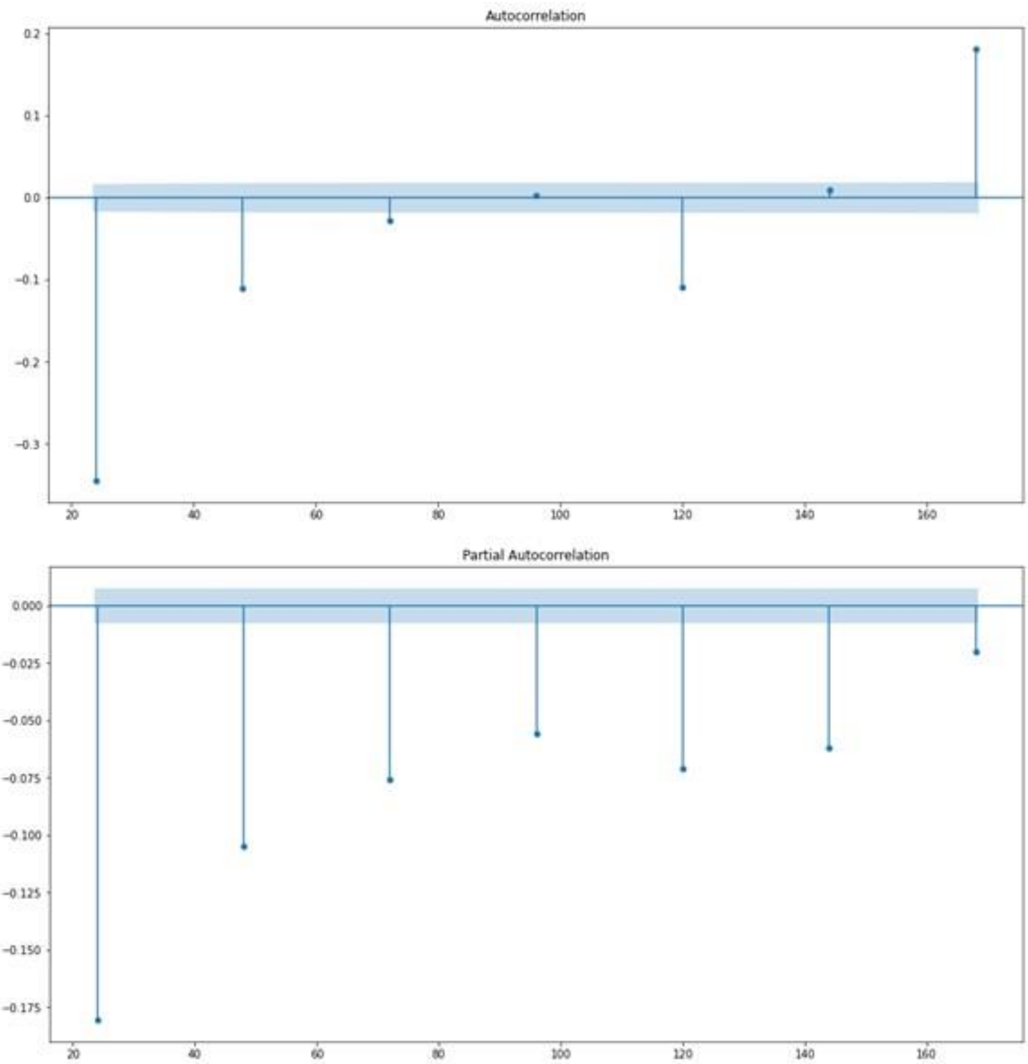

Figure A1. ACF and PACF applied to the analysed data. Note that the diagrams show lags 24, 48, 72 etc. This corresponds with the data from the same hour but d-1, d-2, d-3 etc.

In the analysis one independent ARIMA model was fitted for each hour (24 in total). Thus, for example an AR(2) model for hour 12 would use the data from hour 12, d-1 and d-2. The same architecture was used for each of the 24 models. The model parameters were fitted independently for each hour model. The same model was used for a given hour in each day; the same ARIMA model was used for forecasting for e.g., hour 12 on Friday and hour 12 on Saturday.

Two alternative approaches were investigated:

- Fitting a fixed model based on data from 2013 to 2016, and using it to predict 2017-2020
- Fitting a new model for each prediction year, based on the previous 12 months, e.g., the 2017 model was fitted on the 2016 data

The latter approach (annual model) performed slightly better, and the results presented in this document are based on this approach. For this approach architectures built around an MA(2) process seemed to perform best. AR and seasonal ARIMA components appeared to add some benefits, but with sometimes borderline statistical significance.

A2 Results from ARIMA modelling

The simple (naïve) and ARIMA models were used to forecast spreads for bidding zone borders applying data from 1.1.2014 to 30.9.2020. Forecasting errors for the SE1-FI bidding zone border are shown in Table A1 for the simple (naïve) model and two ARIMA models. The first model is fitted on the original data, the second on differenced data; otherwise, their architectures are the same. The results shown in Table A1 are typical for the bidding zone borders analysed.

From the analysis, it seems that the ARIMA model produced results which seemed to slightly sacrifice accuracy in low-spread periods, e.g., when spread is 0, with improved accuracy in higher-spread periods.

	Naive	ARIMA	ARIMA diff
count	59160.00	59160.00	59160.00
mean	0.00	-0.53	0.18
std	10.14	8.05	8.37
min	-174.40	-183.01	-176.29
25%	0.00	-0.76	-1.15
50%	0.00	0.13	0.01
75%	0.15	1.95	2.50
max	192.37	74.48	151.40

Table A1 Forecasting errors for the SE1-FI bidding zone border for simple (naïve), ARIMA and ARIMA differenced models.

As an example, Figure A2 shows results from analysis for SE1-FI bidding zone border between March-June 2019. The simple model will always miss a jump - up or down - in spread price and will lag spread change by one day. The ARIMA models will also typically lag spread price change by one day. Occasionally, the ARIMA models are able to predict a spread price change, although the magnitude will most likely be underestimated. Unlike the simple model, the ARIMA models will typically avoid predicting very high spreads. The ARIMA models will typically have small prediction errors in periods with zero price spreads.

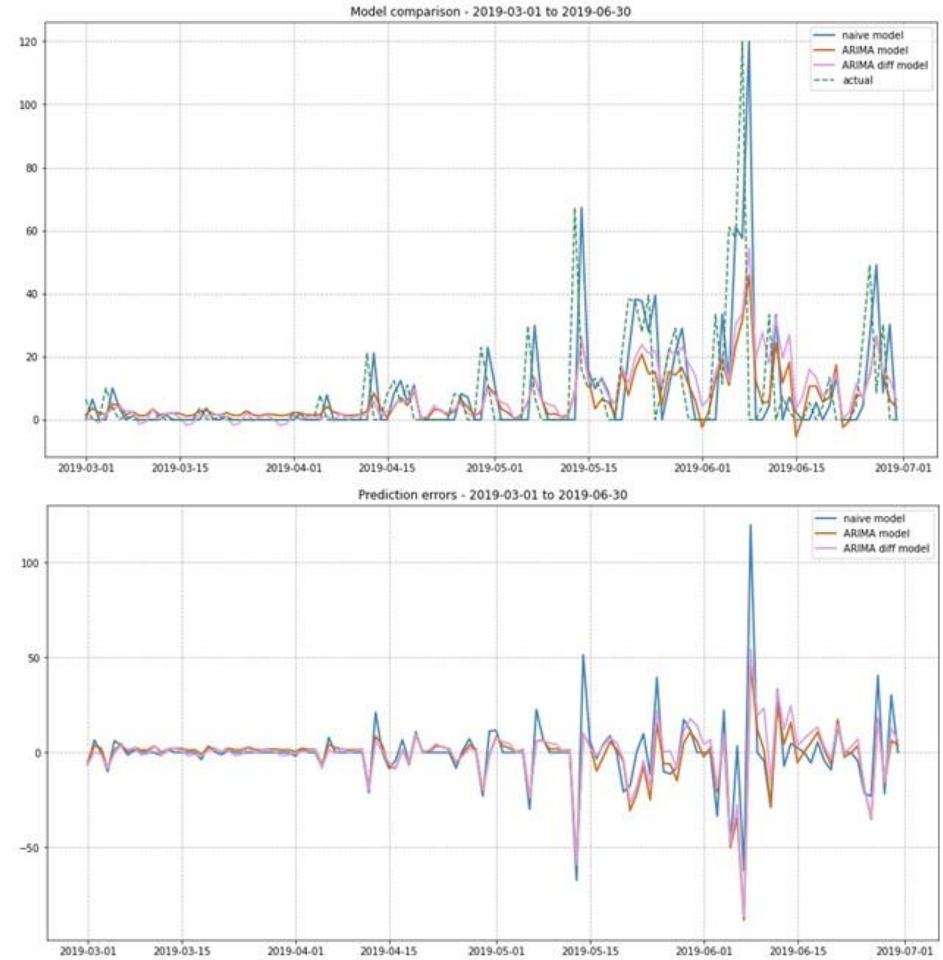

Figure A2 Comparison between models for SE1-FI bidding zone border during March-June 2019.

Figure A3 shows forecast error distribution to simple and ARIMA models. All models demonstrate kurtosis with long tails. Errors appear symmetric around zero with simple model. Errors appear to be negatively skewed with the ARIMA model, although skewedness disappear largely with the ARIMA differenced model.

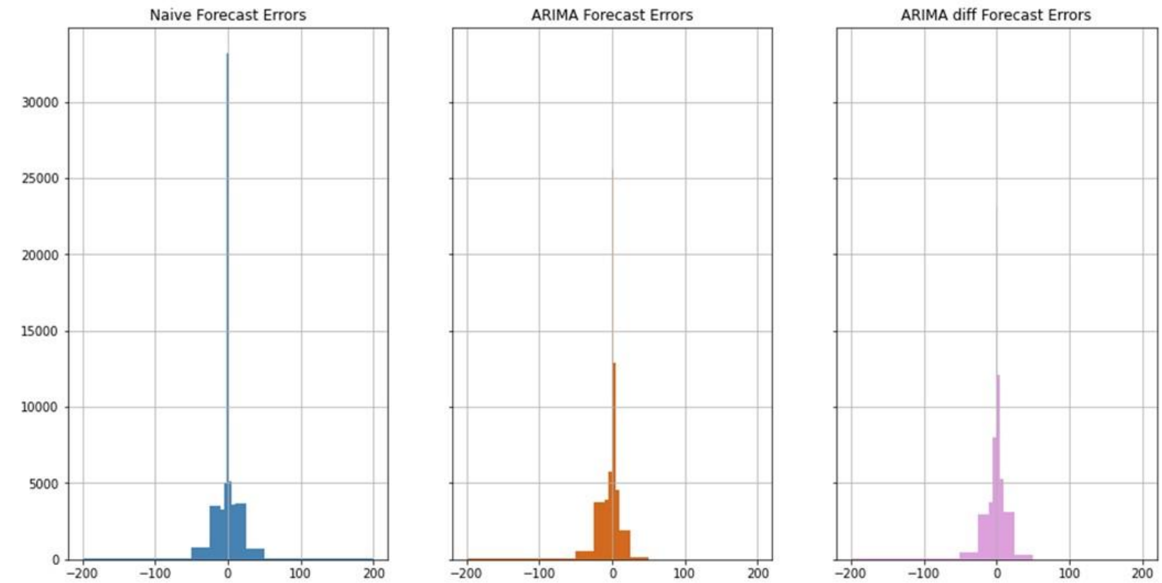

Figure A3 Distribution of forecast errors for simple and ARIMA models.

Broadly, the ARIMA models can be thought of as predicting based on “typical recent spread” levels, rather than the more volatile approach of the simple (naïve) model. This results in these models having a lower variation in predictions than the simple model, and also lower variations in predictions than the actual spreads themselves. By avoiding extreme predictions, the ARIMA models tend to reduce overall error levels, and result in fewer large prediction errors than the simple (naïve) method.

To illustrate, consider a sequence of actual spreads {0, 0, 20, 4}. The naive model will predict {0, 0, 20} for the last 3 periods, with prediction errors {0, -20, 16}. The ARMIA models, on the other hand, may typically predict something like {2, 6, 10}, resulting in errors {-2, -14, 6}. The “dampened predictions” of the ARIMA models helps them to avoid the large prediction errors of the simple (naïve) model during periods of spread volatility. In addition, examination of the ARIMA forecasts in our analysis shows that they are occasionally able to predict price spread changes, i.e., jumps, whereas the simple model will never do so (it will always be surprised).

The improvements come at the cost of slightly worse performance during periods of no or very low spread volatility, when the simple (naïve) model performs well as it always sets the spread now to be equal to the spread from the day before. If there is no or very little volatility in spreads, then this approach by definition will give more accurate forecasts.