Calculations for the evaluation of the functioning of the wholesale electricity markets on the Finnish bidding zone borders as required in the FCA GL

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1 Executive summary

This report conducts an assessment which shall identify whether the electricity derivative market provides sufficient hedging opportunities in the concerned bidding zone. The work is a requirement according to the Commission Regulation (EU) 2016/1719 of 26 September 2016 establishing a guideline on forward capacity allocation (“FCA GL”).

The concerned bidding zone in this study is Finland. The study also includes bidding zones interconnected to Finland, namely Stockholm (SE3), Luleå (SE1), Tromsø (NO4) and Tallinn (TAL). Where meaningful, also other bidding zones are included. All assessments cover time period from 2013 to 2016 and where data available also year 2012.

This work applies the methodology described in detail in a study commissioned by NordReg (2016) titled “Methods for evaluation of the Nordic forward market for electricity”. The analysis is structured around three groups of efficiency measures, namely descriptive measures (volume and open interest), price measures (ex-post risk premium), and transaction-cost measures (bid-ask spread). Additionally, the work conducts correlation analysis on single and combinations of derivative contracts with respect to the underlying spot prices (risks).

The main findings of the work are as follows:

- EPADs’ trading activity, measured by traded volumes, has been steadily increasing since 2012. The most actively traded contracts are the yearly contracts and the most active bidding zones are Stockholm and Helsinki. These two areas alone represent approximately 60% (30% each) of the total EPAD traded volumes out of which 60% is traded in yearly contracts.
- Open interest of EPADs has remained stable throughout the studied period and indicates that EPADs are primarily used for hedging rather than

trading/speculation. There is slightly more trading/speculation in Helsinki EPADs and more hedging with Stockholm EPADs.

- The steady increase in trading volumes implies greater trading activity and growing interest from market participants. This interest is confined to few bidding zones, such as Stockholm and Helsinki, where market participants attribute greater attention to transmission risk and its management. Greater trading activity typically positively contributes to liquidity, because “correct” prices can be discovered faster and more efficiently.
- Significant positive risk premia were found in monthly EPADs for Helsinki and Tallinn, but given the limited trading activity and usage of monthly EPADs for hedging, the economic impact of this finding may be limited.
- No significant risk premia were found in yearly EPADs which are the main trading and hedging vehicle.
- The average best-bid ask spreads in EPADs have been systematically decreasing from 2012 to 2016.
- Based on the analysis of “worst” bid-ask spreads, there seems to be no systematic high bid-ask spreads in any particular EPAD contract category.
- From the monthly correlation analysis it was shown that market participants in Estonia can use Finnish monthly EPADs for hedging Estonian spot price differences.
- The yearly correlation analysis showed that the combined yearly hedges seem to have lower fit relative to the monthly hedges, but the very small sample size and simplified hedging strategy are obvious explanations.

Recommendations for future analysis:

- Actual usage of hedging products by market participants should be always kept in mind when conducting historical analysis of derivatives markets. Hence, taking averages of untraded or recently introduced contracts can easily bias the findings.
- For instance, weekly EPADs can be added in the future analysis of bid-ask spread calculations, if they become more relevant to market participants, as visible from trading volumes and open interest, for example.
- For yearly correlation analysis, the sample should include many more years in order to make the correlations between spot and futures prices reliable.

The work is structured into the following parts. Chapter 2 briefly discusses the data used for the analysis. Chapter 3 presents descriptive measures, namely volumes traded and open interest. Chapter 4 quantifies ex-post risk premia for EPAD contracts, and chapter 5 presents bid-ask spreads as a measure of transaction costs. The work ends with correlation analysis between prices of selected derivatives, namely EPADs and system price futures, and their respective underlying spot prices.

2 Data summary

Three types of data on Nordic power market were provided by Nasdaq OMX and available to this analysis. First, daily aggregate data that presented the daily summaries of trading activity, including best ask, best bid, high price, low price, closing prices, number of contracts traded, and volume traded. Second type of data included anonymized intraday information on individual trades, which included deal source (on (OTC) or off (ETS) order book), deal price, number of contracts traded, contract size, and volume traded. Third type of data were displaying open interest of individual contracts, namely number of open contracts, volume of open contracts, and value of open contracts. Time period covered by all data sets was from 2nd January 2012 to 30th November, 2016, except the open interest data started from 4th March 2012.

Table 1 below presents the numbers of *unique* contracts included in the daily aggregate data and represents the structure and sample size available to this work.

Table 1 Summary of unique contracts included in the analysis

	Day	Month	Quarter	Week	Year	Grand Total
Base	**2**	**84**	**341**	**262**	**321**	**1010**
DSFutures		64	27		14	105
Futures	2	20	13	262	11	308
Options			301		296	597
BaseDay	**516**					**516**
Futures	516					516
Day	**1285**					**1285**
Futures	1285					1285
EPAD		**812**	**326**	**930**	**127**	**2195**
DSFutures		626	233		79	938
Futures		186	93	930	48	1257
Peak		**46**	**17**	**198**	**4**	**265**
DSFutures		46	17		4	67
Futures				198		198
Grand Total	**1803**	**942**	**684**	**1390**	**452**	**5271**

As a comment on the primary data - the daily aggregate data and some of the intraday yearly data files (2012 and 2013), included a minor technical error where some of the sub-category products (Base, EPAD, Peak, BaseDay or Day) were listed under the main category, which should be only “Power”. This mistake was, however, quickly recognized and corrected, after which the data did not display signs of inconsistency that could reduce the reliability of the analysis here conducted.

3 Descriptive measures

As described in detail in the methodological paper preceding this work, evaluation of the Nordic forward market for electricity is a complex and multifaceted exercise. As a starting point, traded volumes and open interest are presented as descriptive measures shedding light on market liquidity. The two metrics are useful for measuring market significance and market breadth, which represent the existence of numerous and large orders in volume with minimal transaction price impact.

3.1 Volumes traded

Traded volumes, representing number of MWh sold and bought for a given derivative during a specified period, provide information on liquidity and demand for a particular hedging instrument. Contracts in high demand are traded more and can be easily sold or bought whereas contracts with low traded volumes can be difficult to sell or buy. This metric is traditionally used to measure the existence of large number of transactions and market participants. Hence, trading volume is mostly linked to market breadth, i.e. orders are numerous and large in volume with minimal impact on prices.

Figure 1 shows the total traded volumes of EPAD contracts per year. Total trading volume of EPADs has been 5.8 times greater in 2016 than in 2012. The largest increase in trading volume have seen the yearly EPAD contracts, especially since June 2013 as visible from the more detailed Figure 3 in monthly frequency. Quarterly and monthly EPAD contracts have seen a slight increase in trading volumes throughout the studied time interval, whereas weekly EPAD remain negligible and hardly traded.

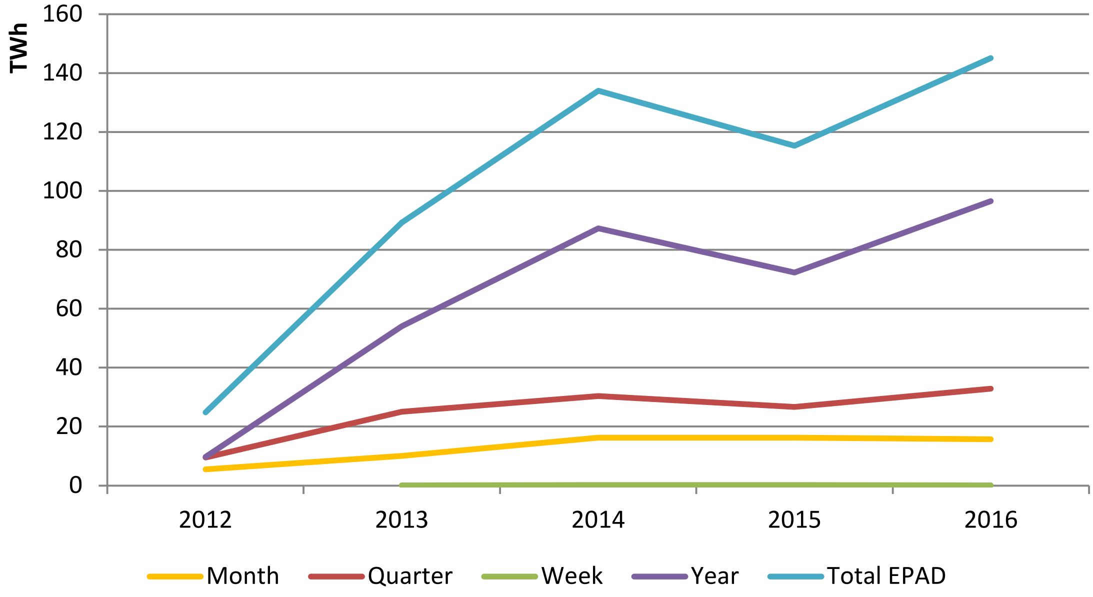

Figure 1 Yearly traded volumes (TWh) of EPADs for all bidding zones according to contract maturity

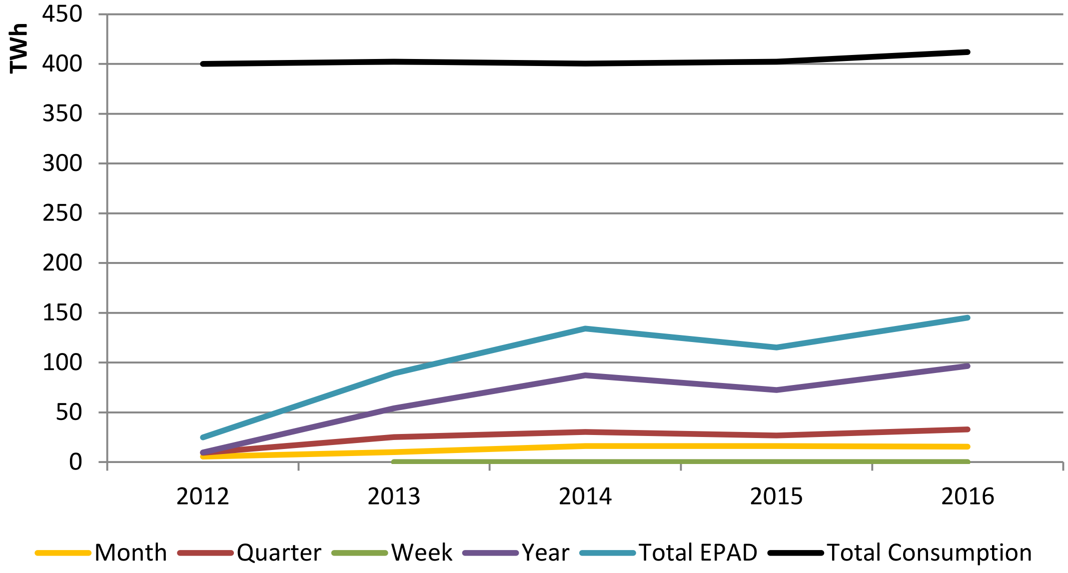

Figure 2 Yearly traded volumes (TWh) of EPADs for all bidding zones according to contract maturity with reference to total physical consumption in all bidding zones

Figure 2 and Figure 4 additionally display the yearly and monthly EPAD traded volumes with the reference to physical electricity consumption in all bidding zones. Typically, churn ratios could be constructed by comparing traded volumes to physical consumptions. Churn ratios indicate, how many times a contract is traded before it is physically delivered. However, EPAD contracts are used for hedging the local transmission congestion risk, which is only a part (if relevant in considered bidding zone) of total electricity price risk (risk in system price + risk in transmission). For this reason, calculating EPAD churn rates as ratios of EPAD traded volumes and total consumption does not provide appropriate measure for EPAD liquidity.

Nevertheless, with the caution for interpretation mentioned just above, Figure 2 and Figure 4 show that approximately every 4th physically consumed MWh among all bidding zones is traded with EPAD contract. This is given by approximately 0,25 EPAD churn ratios.

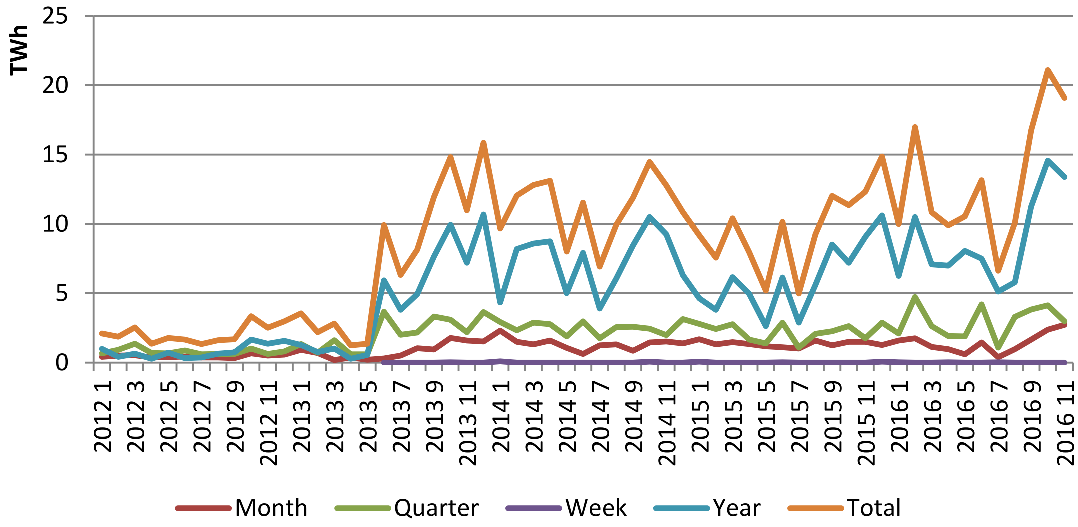

Figure 3 Monthly traded volumes (TWh) of EPADs in all bidding zones according to contract maturity

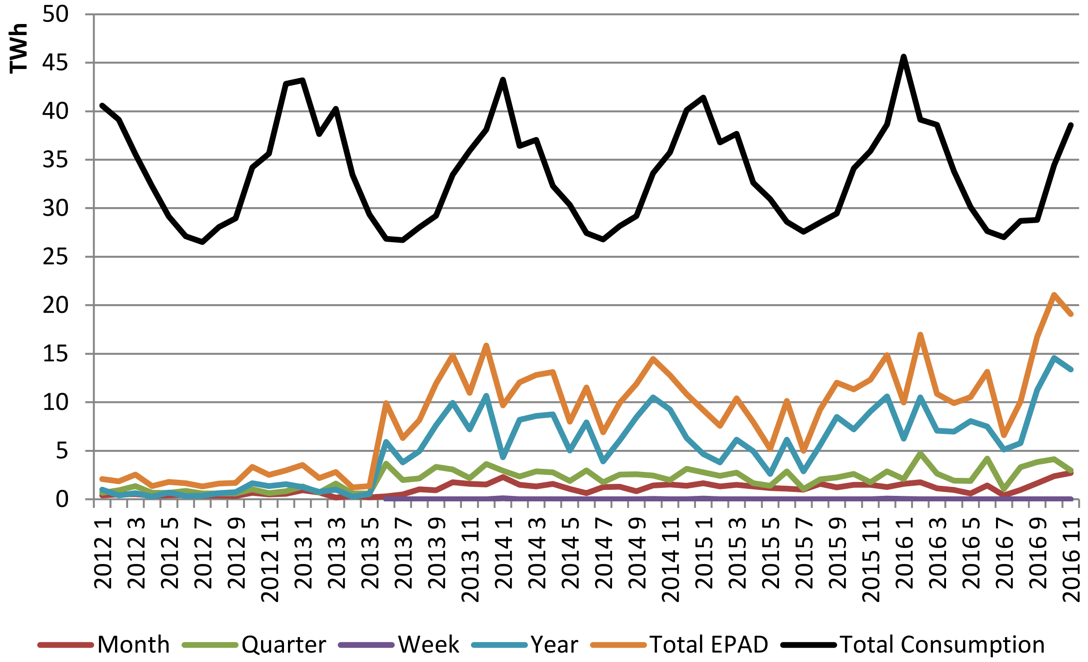

Figure 4 Monthly traded volumes (TWh) of EPADs for all bidding zones with reference to total physical consumption in all bidding zones

Figure 5 displays the traded EPAD volumes of *selected* bidding zones and for reference is added a total EPAD traded volume for *all* bidding zones. It can be seen that out of the total EPAD volume, clear majority of EPADs are traded for Helsinki and Stockholm bidding zones. Throughout the studied period on average 30% and 31% monthly traded EPAD volumes are for Stockholm and Helsinki, respectively.

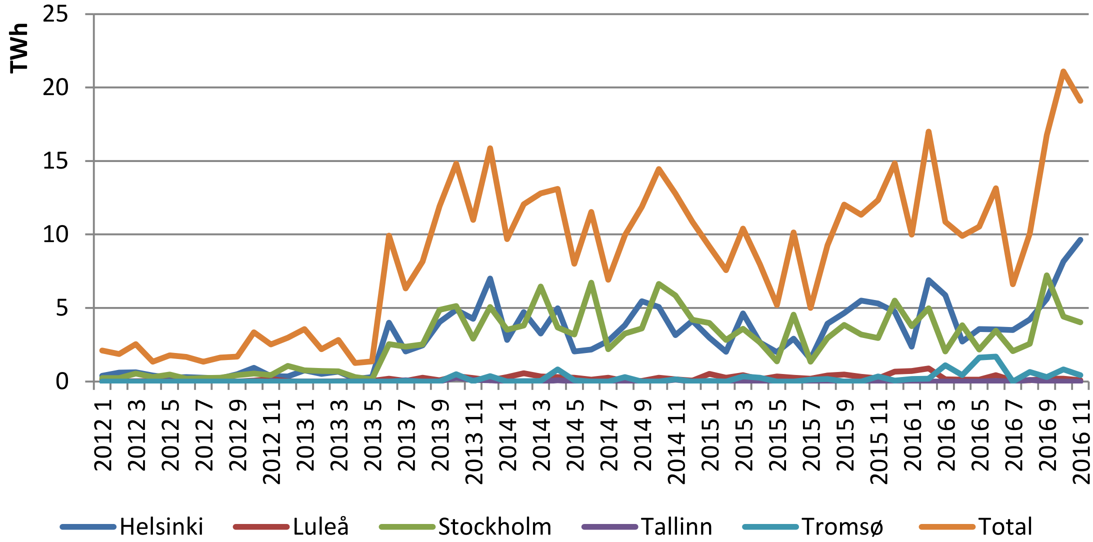

Figure 5 Monthly traded volumes (TWh) of EPADs for selected bidding zones with reference to total traded volumes of EPADs in all bidding zones (Total)

Figure 6 shows the same EPAD traded volumes for the same bidding zones as in Figure 5 but now displays the EPAD total volume *only for these bidding zones* as well as physical consumption for these zones. In this case the churn ratio from 2013 onwards is 0,46, meaning approximately every 2nd physically consumed MWh in this region is traded with EPADs.

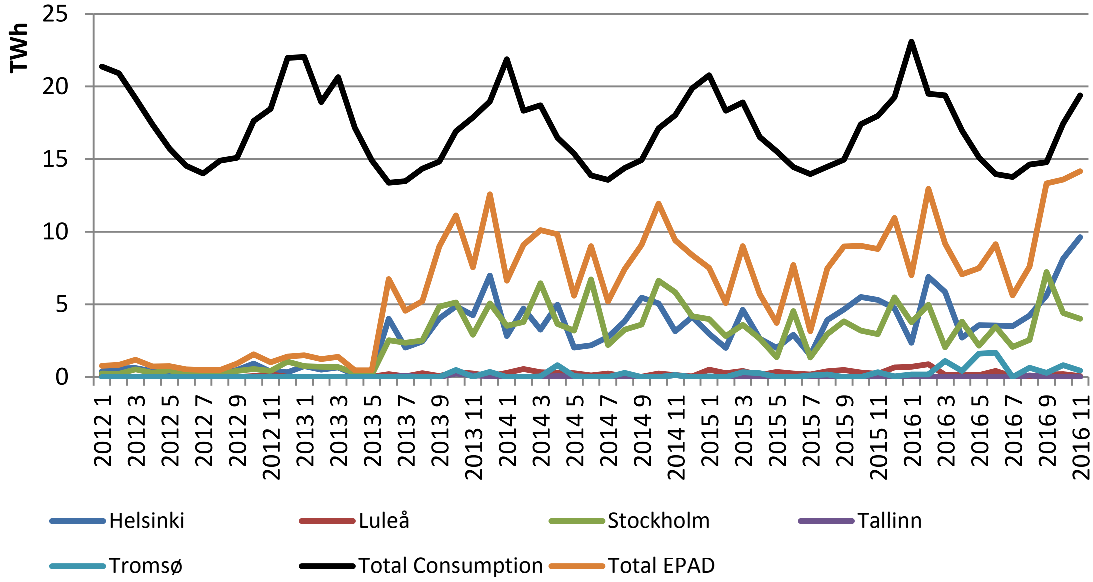

Figure 6 Monthly traded volumes (TWh) of EPADs for selected bidding zones with sum of only these EPADs (Total EPAD) and reference to the total physical consumption in these bidding zones (Total Consumption)

Figure 7 and Figure 9 show the monthly traded EPAD volumes according to contract maturity in bidding areas Finland and Stockholm, respectively. The most popular contracts are traded for yearly maturity in both bidding zones. On average, close to 60% of each of the bidding zone's traded volume originates from yearly contracts. Figure 8 and Figure 10 additionally display the total physical consumption in Helsinki and Stockholm, which imply churn rates of 0,55 and 0,49, respectively, since 2013 onwards.

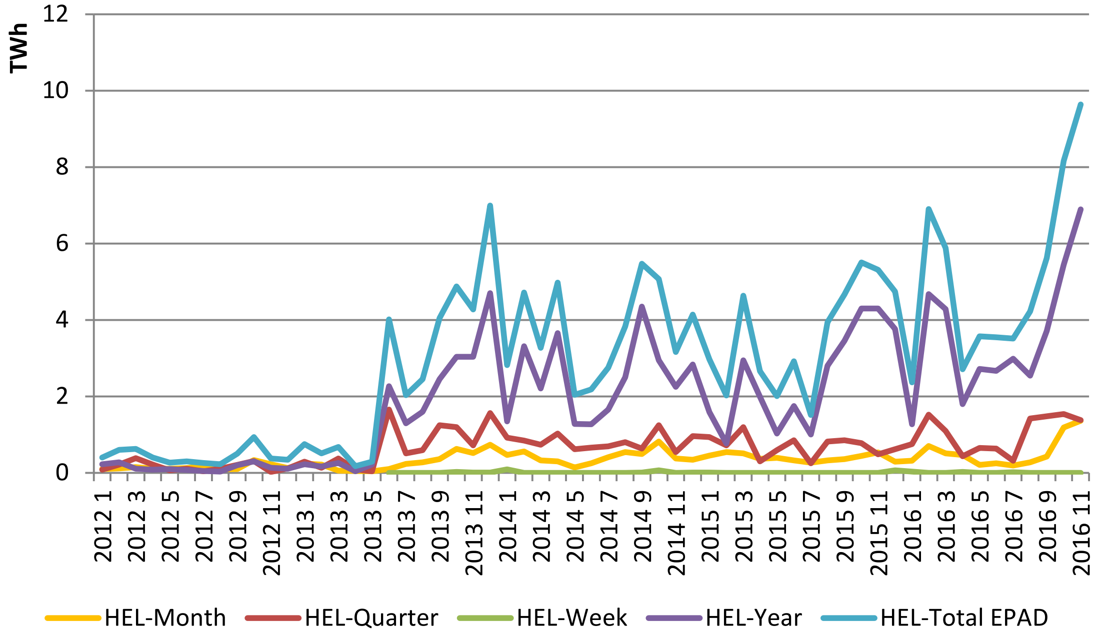

Figure 7 Monthly traded volumes (TWh) of EPADs in bidding zone Finland according to contract maturity

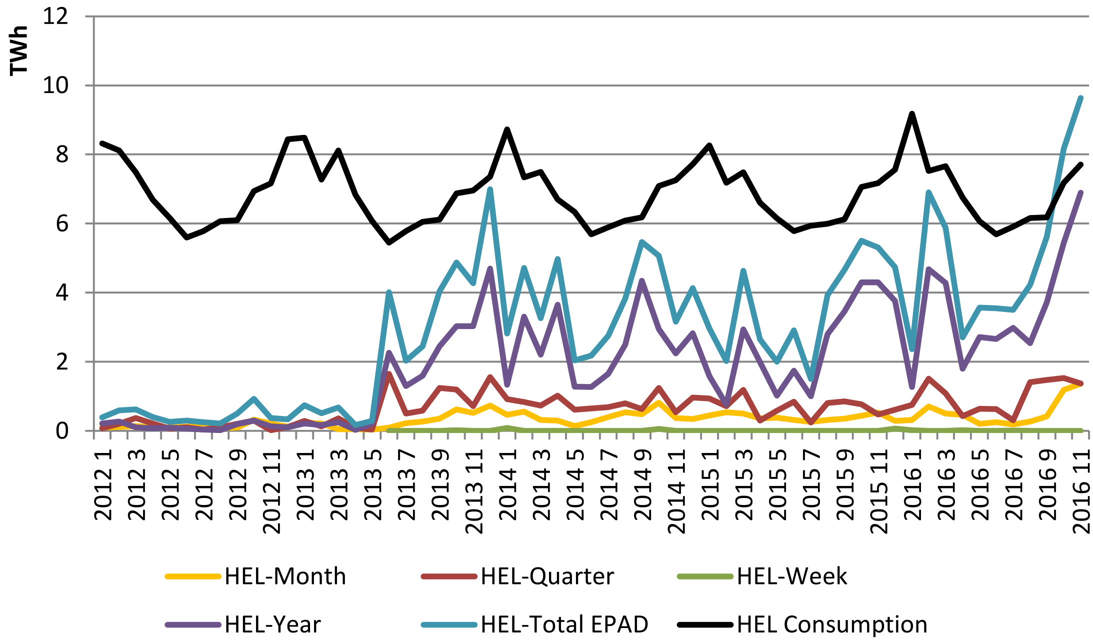

Figure 8 Monthly traded volumes (TWh) of EPADs in bidding zone Finland according to contract maturity with reference to physical consumption in Finnish bidding zone (HEL Consumption)

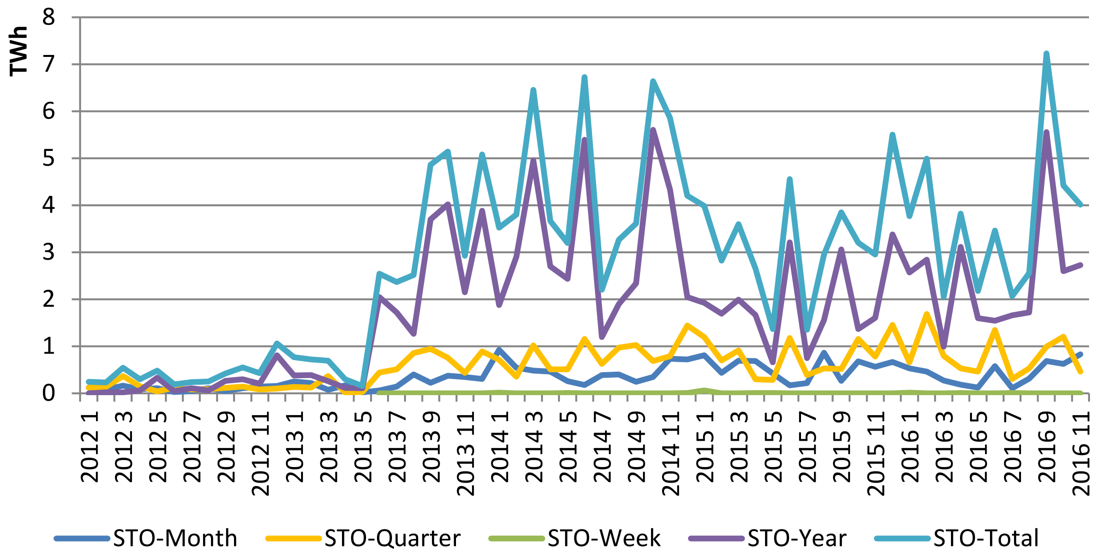

Figure 9 Monthly traded volumes (TWh) of EPADs in bidding zone Stockholm according to contract maturity

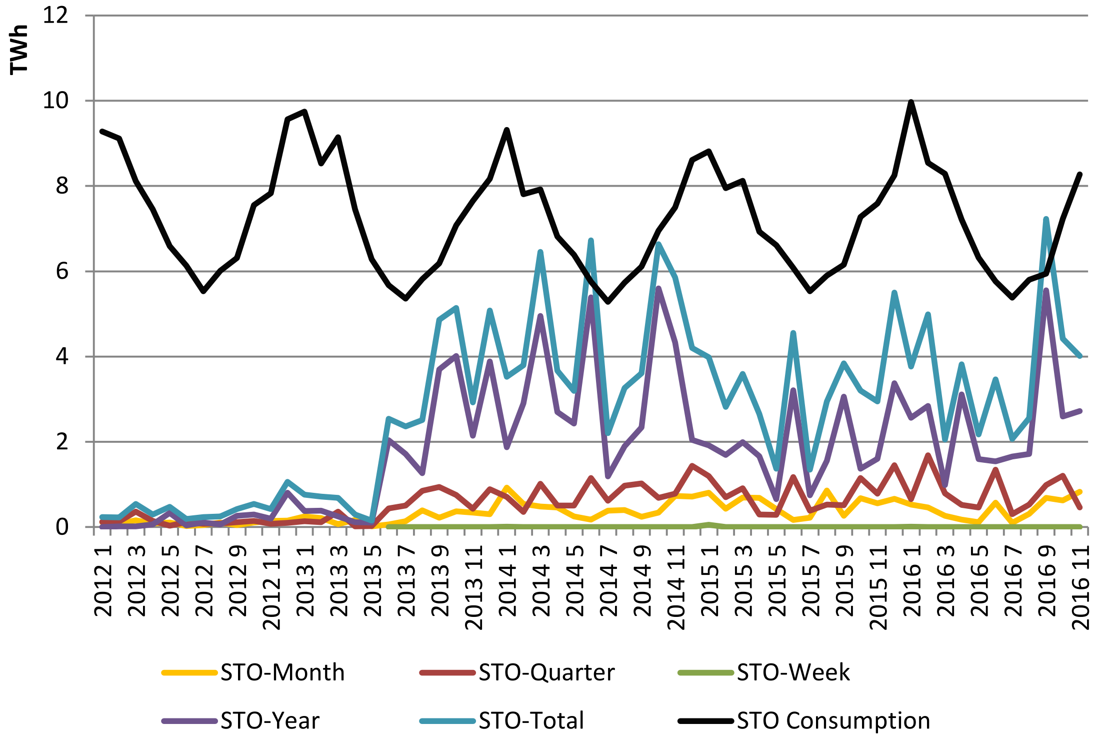

Figure 10 Monthly traded volumes (TWh) of EPADs in bidding zone Stockholm according to contract maturity with reference to physical consumption in Stockholm bidding zone (STO Consumption)

3.2 Open interest

Open interest refers to all open positions with a clearing house at a given point in time. An important metric to understand financial markets is the development of open interest. When a contract is bought or sold for hedging purposes, the intention is to keep the new position until the contract goes to delivery. If the contract is bought (sold) for trading purposes, the idea is most often to sell (buy) a similar contract for a higher (lower) price at a later point in time. The first of the trader's transaction will increase open interest, while the second will reduce open interest. Hence, the size of the open interest in a contract in relation to the traded volumes in the contract shows to what extent the contract is used primarily for hedging purposes or for trading.

Figure 11 presents end-of-month open interest (TWh) in EPAD contracts for all bidding zones during the time period included in the sample (4.3.2012 - 30.11.2016). The figure shows that the open interest for yearly contracts steadily builds up throughout the year. At the end of the trading period a yearly contract cascades into quarterly, which can be seen by the systematic increase in open interest of quarterly EPADs in the beginning of a year.

Total open interest has remained stable throughout the studied period, which implies that the interest of hedgers/risk managers in EPADs has remained unchanged. No large changes or fluctuations in open interest can be observed. In November 2016 the open interest of EPADs has for the first time crossed the 100 TWh line, specifically 102 TWh of open EPAD contracts.

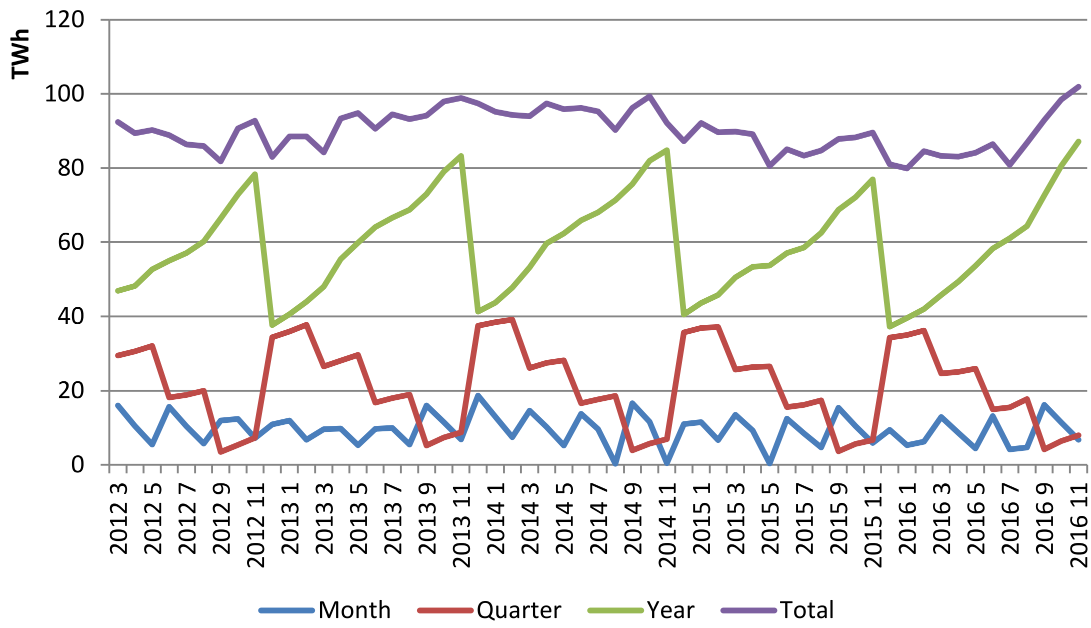

Figure 11 Open interest (TWh) of EPADs at the end of month for all bidding zones according to contract maturity

Figure 12 adds to the previous figure also the total physical consumption of electricity in all bidding zones. What can be seen is that on monthly basis there is approximately 2,8 times more open EPAD contracts than there is physical consumption. In general, when information on open interest is combined with information on traded volumes from the previous section, it can be seen that EPADs are mostly used for hedging purposes done especially via yearly contracts.

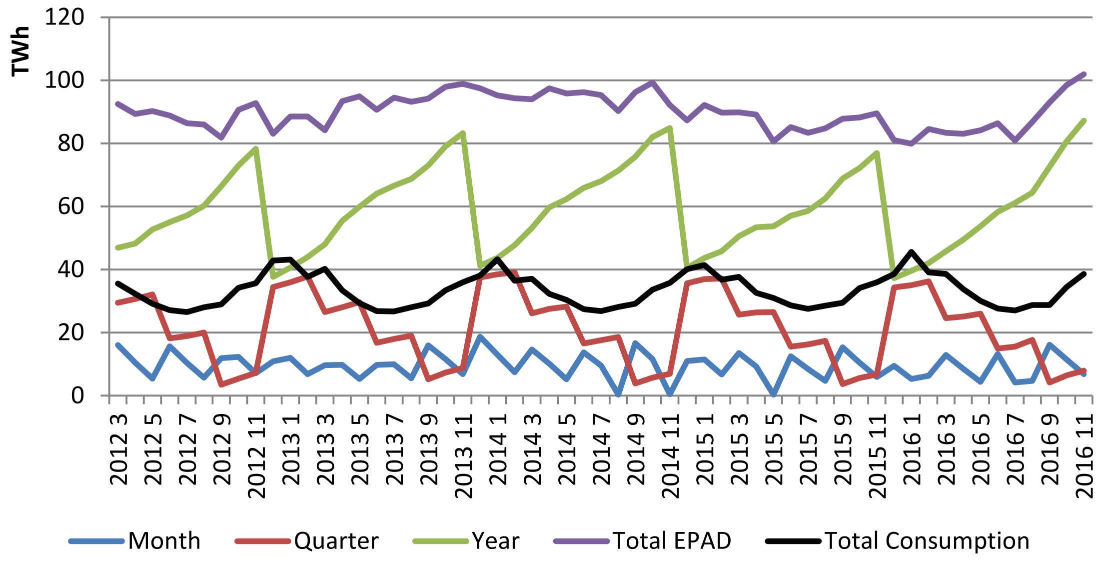

Figure 12 Open interest (TWh) of EPAD contracts at the end of each month for all bidding zones according to contract maturity and with reference to total physical consumption (Total Consumption) in all bidding zones

Figure 13 presents EPAD open interest for Stockholm and Helsinki showing that Stockholm has larger volume of open contracts in every contract maturity than Helsinki. Given the fact that both bidding zones have similar monthly traded volumes, the greater open interest in Stockholm implies that there is a slightly more trading/speculation activity in Helsinki EPADs compared to Stockholm's.

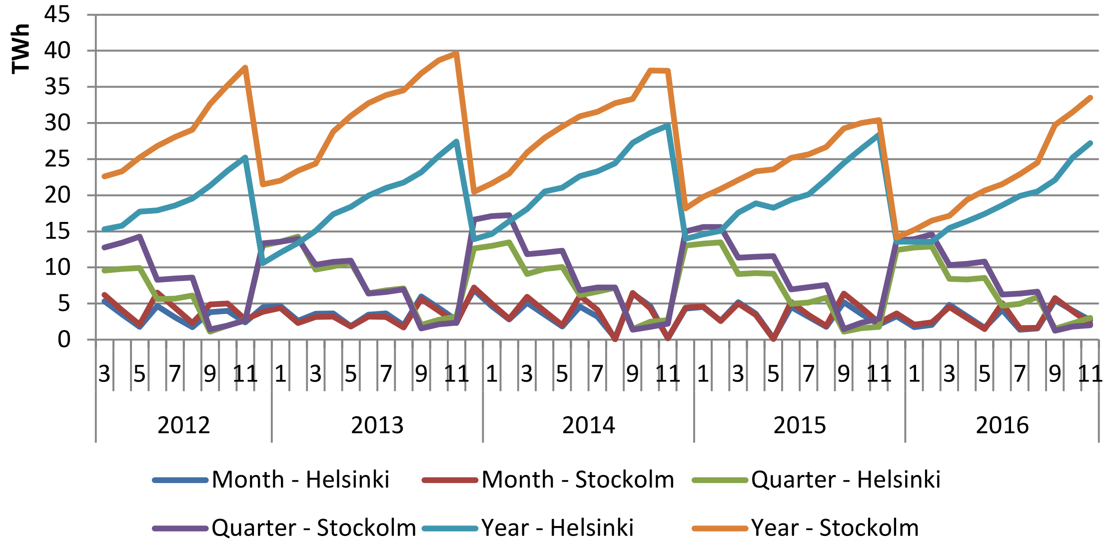

Figure 13 Open interest of EPAD contracts at the end of each month for Helsinki and Stockholm bidding zones (TWh) according to contract maturity

Figure 14 displays monthly open interest for all EPADs in Stockholm and Helsinki as well as the physical consumption in these areas. As was pointed out above, Stockholm bidding zone has greater EPAD open interest than Helsinki but the difference has been narrowing down since mid-2014. Actually, the narrowing down of the difference seems to be mainly driven by the drop in Stockholm's open interest from mid-2014 onwards while Helsinki EPAD open interest has remained rather stable. The drop in the combined open interest for Stockholm and Helsinki is visible from the green line (HEL+STO EPAD) but since July 2016 there is an increase in open contracts back towards 70TWh levels.

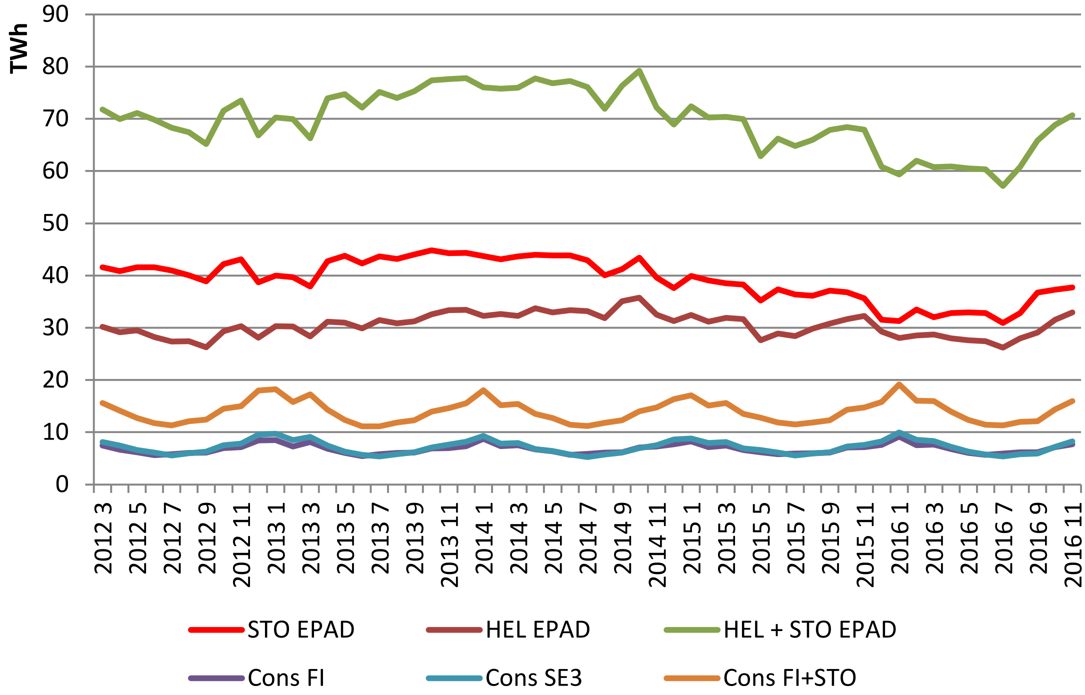

Figure 14 Open interest (TWh) of EPAD contracts at the end of each month for bidding zones Helsinki (HEL EPAD), Stockholm (STO EPAD) and their sum (HEL + STO EPAD) with reference to physical consumption in Helsinki (Cons FI), Stockholm (Cons STO) and their sum (Cons FI+STO)

Finally, from Figure 14 can be also seen that on monthly basis there is over 5 times more open EPAD contracts in Stockholm and Helsinki zones combined (HEL+STO EPAD) compared to their combined physical consumption (Cons FI+STO). This ratio is almost two times greater for this combined region than for the total market including all bidding zones (Figure 12), which again highlights the dominating hedging activity and EPAD market size in Stockholm and Helsinki compared to the overall EPAD market.

4 Price measures

This section presents ex-post calculations of risk premia (RP), which can be understood as mark-ups or compensations in a derivatives contract charged either by traders, suppliers or consumers for bearing the price risk for the underlying commodity. The ex-post risk premium serves as a measure of contract efficiency because greater insight on the market dynamics between buyers and sellers of derivatives can be gained. This section presents *magnitudes*, *directions*, and *significance* of ex-post risk premia for monthly and yearly EPAD contracts traded for Finnish bidding zone and its neighbours. Implications of possible systematic biases in the pricing of derivatives are discussed.

Detailed methodology on risk premia calculation is described in the previous report titled “Methods for evaluation of the Nordic forward market for electricity”. As a reminder, ex-post risk premium is here calculated by taking the closing prices of the last trading day before a derivative contract expires and enters the delivery phase. By taking into consideration only the front-contracts, i.e. contracts with closest delivery, the price should contain the market participants’ best estimate of the coming future, because it is the closest to delivery. The derivative’s last trading day closing price is then compared to the ex-post underlying spot price outcome. This approach assumes perfect information where we would expect zero difference only in a situation where market participants could perfectly forecast the future, not making mistakes and not having better information than others. In real markets, this is not the typical scenario.

However, by quantifying risk premia, we gain insights into whether derivatives prices are systematically under- or over-priced, by what quantity, and test whether the bias is systematically different from zero or just a random phenomenon.

4.1 Ex-post risk premia in monthly EPADs

Monthly EPAD contracts have been shown to have rather low traded volumes and open interest, which may reduce the information content and quality in their prices. However, since these contracts are only for 1 front-month period[1], market participants should be able to discover the “correct” prices efficiently.

Table 2 presents the summary of risk premia in monthly EPAD contracts for selected bidding areas in a given year. Each yearly value represents the average risk premia of twelve individual months in a given bidding zone. Positive values imply that EPADs’ price was higher than the realized spot price outcome during the delivery period of the contract. Most of the risk premia are positive (all for Finland-HEL and Estonia-TAL) and the highest positive value is 2.87 EUR/MWh. Negative risk premia are interpreted as EPADs being sold at discount compared to the realized spot price outcome during the delivery period. The negative risk premia are mostly present in Tromsø (NO4) and Luleå (SE1) with values close to -0.5 EUR/MWh.

Table 2 Risk premia in monthly EPADs by year (2013-2016)

year	HEL_RP	SE3_RP	SE1_RP	NO4_RP	TAL_RP
2013	1.083	0.287	-0.176	-0.234	1.907
2014	0.621	0.484	0.389	-0.233	1.017
2015	0.746	0.723	0.787	1.353	0.924
2016	1.237	-0.314	-0.602	-0.464	2.873
Total	0.922	0.295	0.099	0.105	1.680

[1] Front-contract refers to a contract with the closest maturity. For instance, last trading day price in January 2016 for a monthly EPAD for February 2016 would be used as the EPAD closing price in the ex-post calculation of the risk premia for February 2016 contract.

Figure 15 to Figure 19 graphically plot the ex-post risk premia in monthly EPADs for Helsinki, Stockholm, Luleå, Tromsø and Tallinn. Figure 20 combines the risk premia in monthly EPADs for the selected bidding zones. It can be seen that the risk premia fluctuate rather randomly from positive to negative which implies that no systematic over or under pricing in monthly EPADs has taken place during the studied period. Helsinki and Tallinn monthly EPADs contain more often positive risk premium than negative which is also proved statistically significant in Table 3 below.

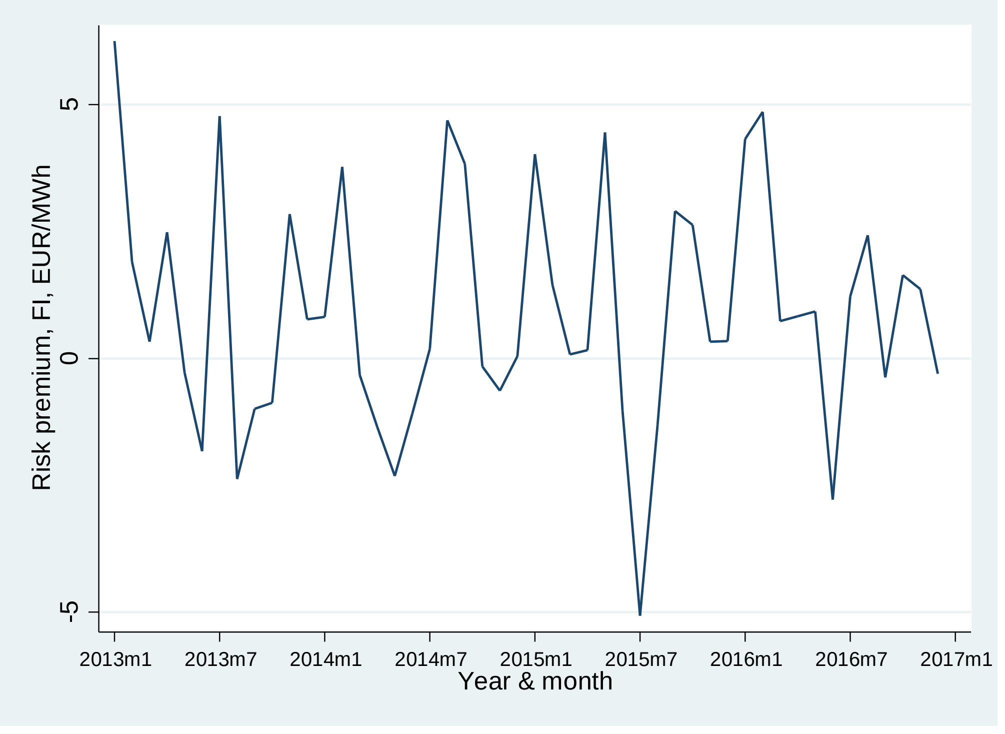

Figure 15 Risk premia in monthly Helsinki EPADs

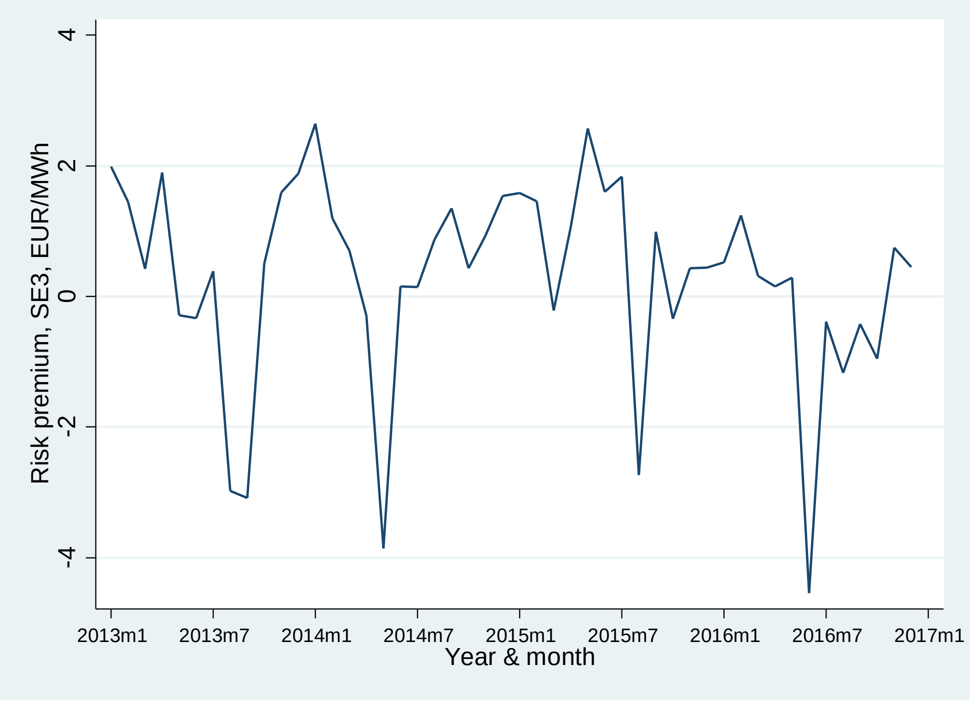

Figure 16 Risk premia in monthly Stockholm EPADs

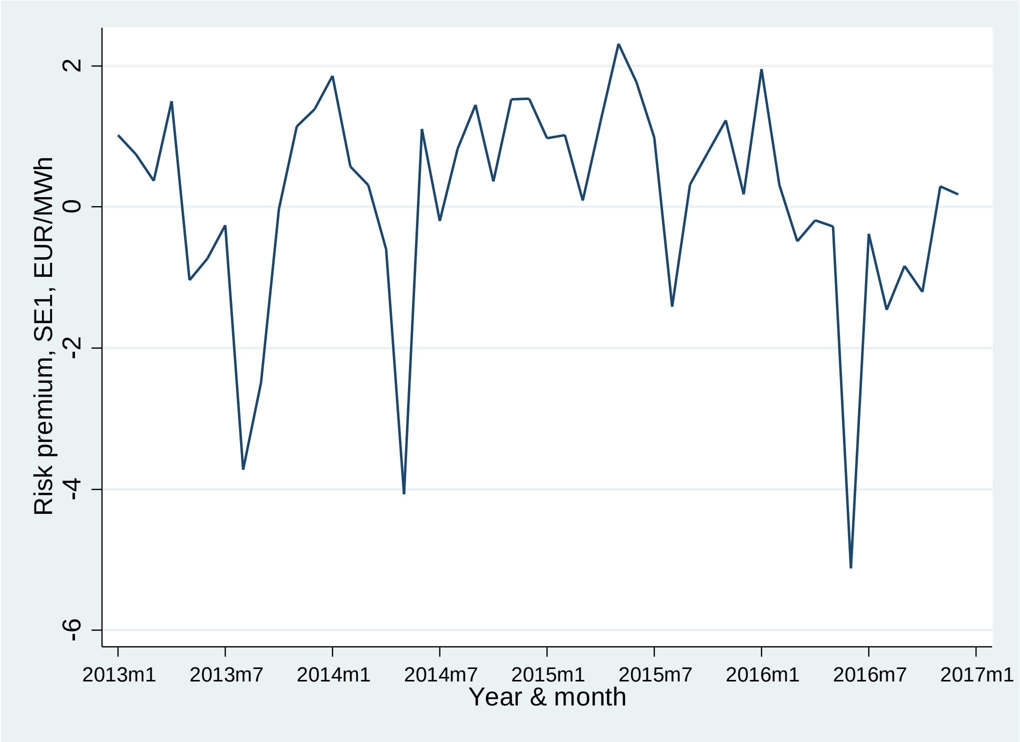

Figure 17 Risk premia in monthly Luleå EPADs

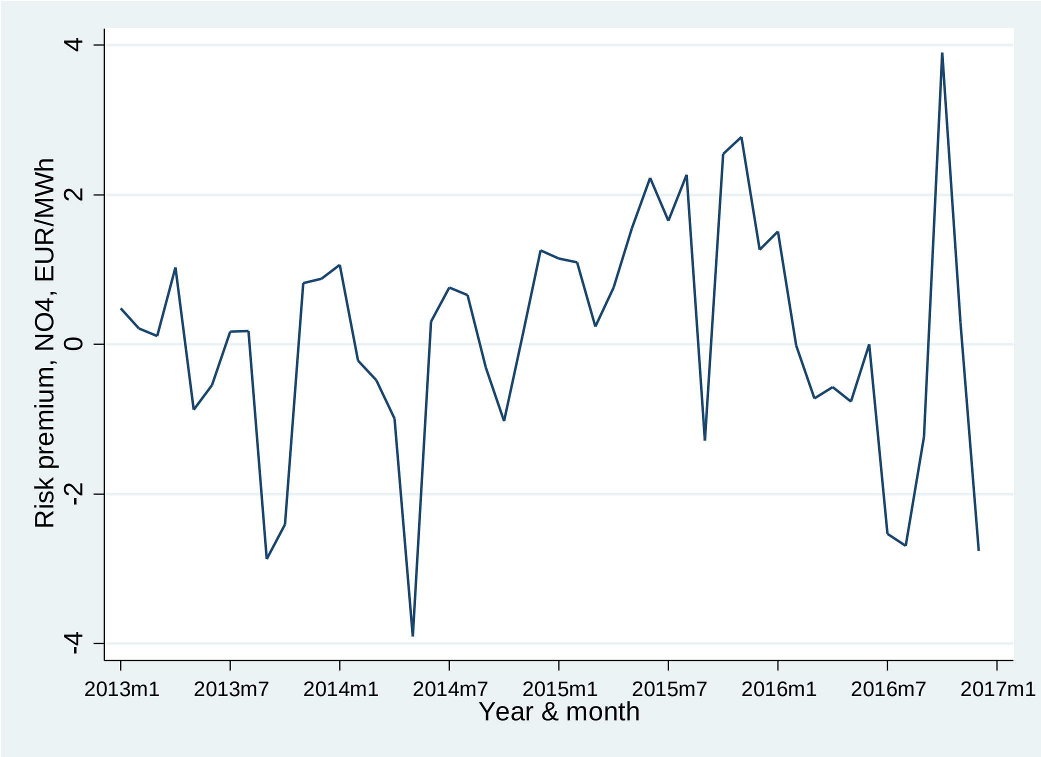

Figure 18 Risk premia in monthly Tromsø EPADs

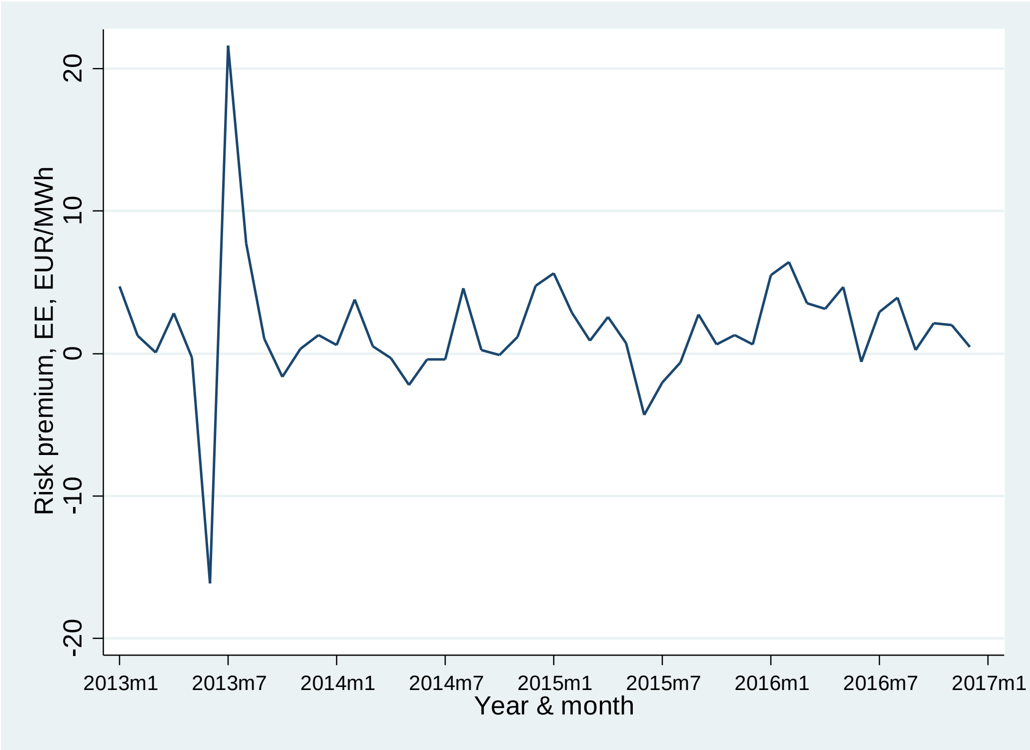

Figure 19 Risk premia in monthly Tallinn EPADs

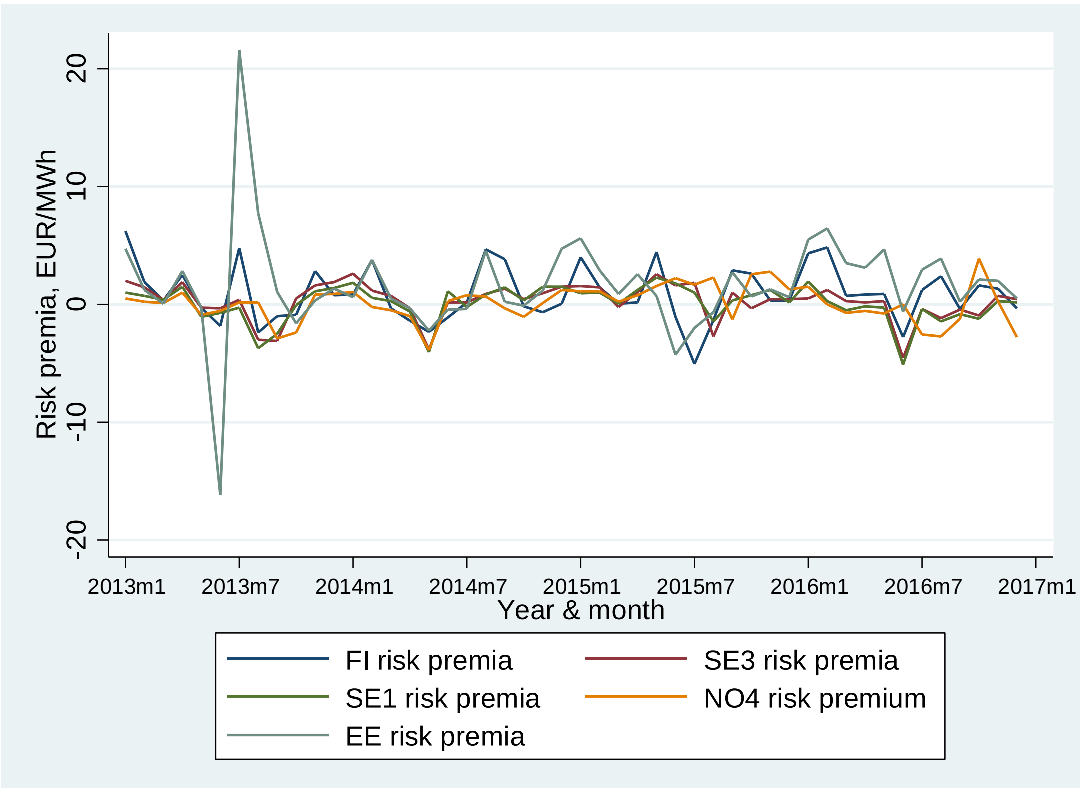

Figure 20 Risk premia in monthly EPADs, combined chart

Table 3 presents the risk premia in monthly EPADs over the four year period (2013-2016) and includes 48 single monthly EPADs for each bidding zone. We see that the mean risk premium values are close or below positive 1 EUR/MWh, except Tallinn's EPAD containing 1.68 EUR/MWh risk premia.

Statistical t-test is applied to find out whether the identified risk premia in each bidding zone are significantly different from zero or not. Helsinki and Tallinn monthly EPADs do contain statistically significant positive risk premia at 5 % significance level, whereas the other bidding areas do not provide a significant result.

Table 3 Risk premia in monthly EPAD contracts, summary (2013-2016)

	Obs	Mean	Std. Dev.	Min	Max	Std. Err.	[95% Conf.	Interval]	t	Sig.(2-tailed)
HEL_RP	48	0.922***	2.34	-5.07	6.25	0.34	0.24	1.60	2.728	0.008
SE3_RP	48	0.295	1.56	-4.55	2.64	0.23	-0.16	0.75	1.312	0.196
SE1_RP	48	0.099	1.53	-5.12	2.31	0.22	-0.35	0.54	0.449	0.655
NO4_RP	48	0.105	1.58	-3.91	3.90	0.23	-0.35	0.56	0.463	0.644
TAL_RP	48	1.680***	4.58	-16.14	21.61	0.66	0.35	3.01	2.542	0.014

***Mean risk premium is statistically different from zero at 5% significance level.

4.2 Ex-post Risk premia in yearly EPADs

Yearly EPAD contracts have been shown to have the highest trading volumes and open interest and are thus the most liquid contracts available on the market. The yearly EPAD prices should thus be rather reliable despite the fact that the market participants are hedging and thus forecasting a much longer time period compared to the monthly EPADs. Again, the front-contracts, in this case the front-year, are used in the risk premia calculation.

Table 4 presents the summary of risk premia in yearly EPAD contracts for selected bidding areas in a given year. Each yearly value represents the risk premia of a single yearly EPAD contract in a given bidding zone. The interpretation of the sign is the same as for the monthly EPAD risk premia - positive representing a mark-up and negative representing a discount on the price of derivative compared to the ex-post underlying outcome.

Table 4 Risk premia in yearly EPADs by year (2013-2016)

Year	HEL_RP	SE3_RP	SE1_RP	NO4_RP	TAL_RP
2013	2.648	0.536	-0.635	-0.748	-0.388
2014	0.515	0.787	-0.614	-1.783	-0.656
2015	-2.181	1.403	1.614	1.648	-2.027
2016	6.396	0.228	-1.240	1.082	7.418
Total	1.844	0.739	-0.219	0.050	1.087

The signs and magnitudes of yearly EPAD risk premia in Table 4 seem to vary from year to year with highest positive values in year 2016 for Helsinki and Tallinn bidding zones. However, when observing the statistical significance of the mean risk premia in all yearly EPADs in Table 5, we see that none of the bidding zones contain a significant risk premium that would be different from zero at 5% significance level.

Yearly EPADs for Stockholm contain positive risk premium 0.74 EUR/MWh which is significant at 10% level.

Table 5 Risk premia in yearly EPADs, summary (2013-2016)

	Obs	Mean	Std. Dev.	Min	Max	Std. Err.	[95% Conf.	Interval]	t	Sig.(2-tailed)
HEL_RP	4	1.84	3.62	-2.18	6.40	1.81	-3.92	7.61	1.019	0.383
SE3_RP	4	0.74*	0.50	0.23	1.40	0.25	-0.06	1.53	2.962	0.060
SE1_RP	4	-0.22	1.26	-1.24	1.61	0.63	-2.22	1.78	-0.35	0.751
NO4_RP	4	0.05	1.59	-1.78	1.65	0.80	-2.49	2.59	0.063	0.954
TAL_RP	4	1.09	4.28	-2.03	7.42	2.14	-5.73	7.90	0.507	0.647

*Mean risk premium is statistically different from zero at 10% significance level.

Figure 21 presents the visual summary of ex-post risk premia in yearly EPADs in selected bidding zones. Typically, yearly EPADs contained risk premium of +/- 2 EUR/MWh, however risk premia in yearly EPADs for Helsinki and Tallinn jumped to positive 6 and 7 EUR/MWh, respectively, in 2016. Further fundamental analysis would have to be carried out to understand the reasons for the large risk premia in 2016. Among the fundamental reasons can be faults in transmission lines, exceptional demand, and planned or unplanned power plant outages, for example.

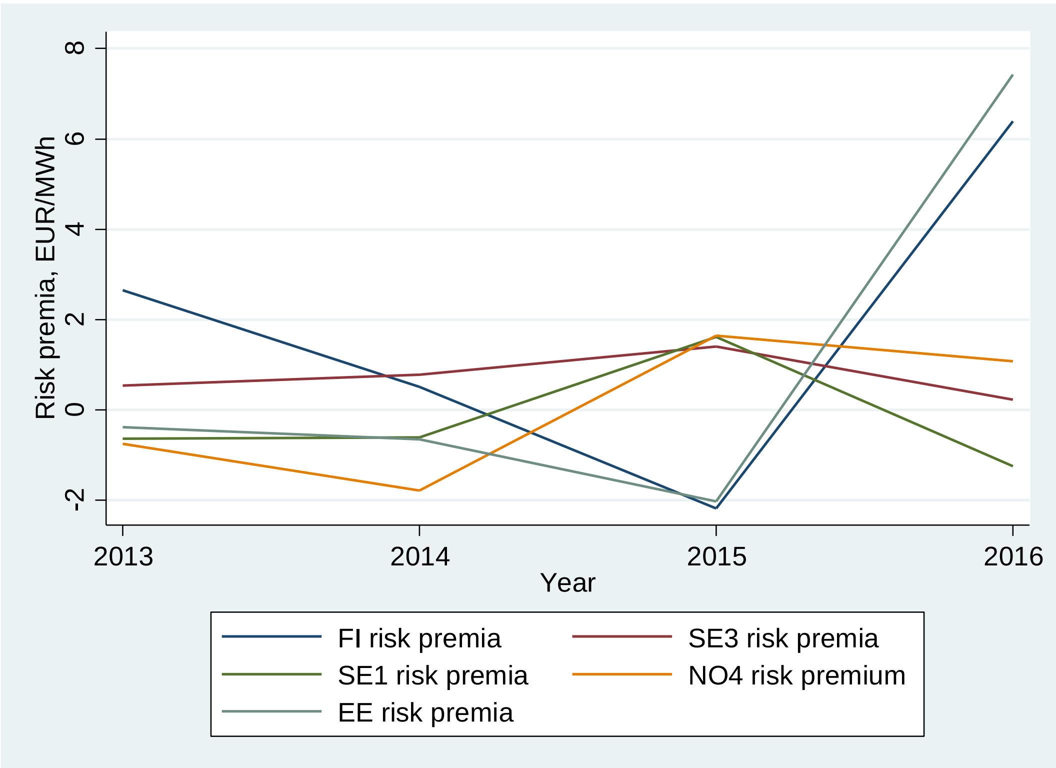

Figure 21 Risk premia in yearly EPADs, combined chart

5 Transaction cost measures

This section presents bid-ask spreads as one measure of transaction costs. The quoted spread is the difference between a market maker's bid and ask quotes. The best quoted bid-ask spread is the difference between the highest bidding (buying) price and the lowest asking (selling) price. The bid-ask spread is a direct measure of liquidity with more pronounced effects on transaction costs for market participants.

Bid-ask spreads answer the questions on the cost of hedging as well as the underlying liquidity. The magnitudes of the quoted bid-ask spreads reveal the transaction costs market participants face when participating in the power derivatives markets.

Bid-ask spreads are calculated for EPADs in Finnish and neighbouring bidding zones and presented on monthly, weekly, and daily frequency for the studied time interval. Additionally to average best bid-ask spreads also the worst bid-ask spreads, represented by the highest differences between absolute best bid and ask prices, are calculated for the same sample.

The bid-ask spreads are based on the daily aggregate data sample described in section 2 above. From the total sample of EPADs in this dataset (178484) in 11271 occasions best bid-ask spread could not be calculated, because either the best bid (1117), best ask quote (53), or both (10101) were missing. This phenomenon was present only for the years 2012 and 2013 and not observed then after. The summary of the events is present in Table 6.

Table 6 Counts of events where best bid, best-ask, or both were missing for EPADs in daily aggregate dataset

Year (month)	Count when NoBid and NoAsk	Count when NoBid but Ask present	Count when NoAsk but Bid present
2012	**6235**	**615**	**45**
1	201	38	17
2	171	102	12
3	488	77	
4	648	29	
5	782	21	2
6	557	72	2
7	613	46	
8	560	28	
9	417	14	5
10	399	71	
11	431	53	5
12	968	64	2
2013	**3866**	**502**	**8**
1	725	170	
2	691	83	3
3	639	114	2
4	725	79	2
5	1086	56	1
Grand Total	**10101**	**1117**	**53**

5.1 Average best bid-ask spreads for all EPADs

Figure 22 presents the monthly average best bid-ask spreads for all EPADs and bidding zones. The range is from approximately 1.8 to 0.2 EUR/MWh. Year 2014 was marked by unusually high best bid-ask spreads, however these have dropped quickly in 2015 and stabilized around 0.3 EUR/MWh. Value below 0.5 EUR/MWh could be seen as a positive and acceptable transaction cost.

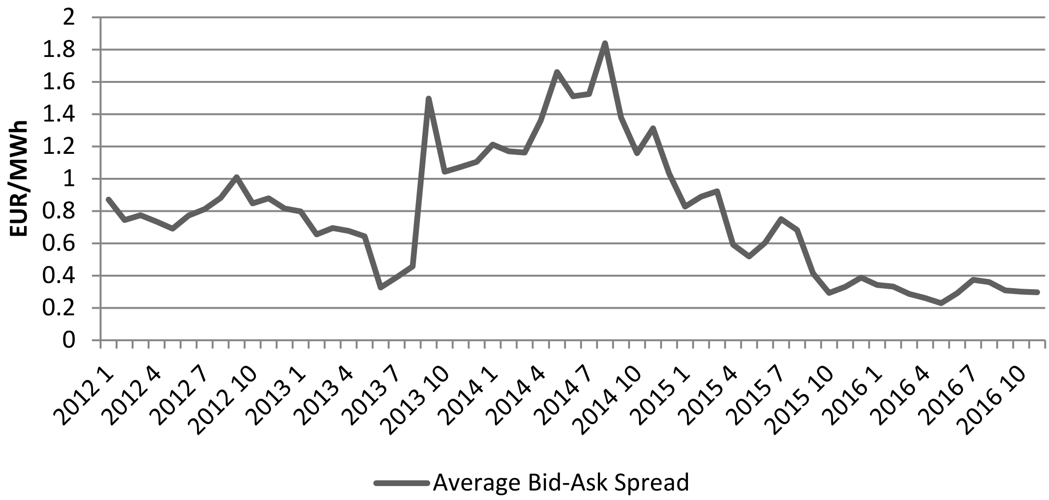

Figure 22 Monthly average best bid-ask spread for all EPADs and contract maturities

By visualizing the average best bid-ask spread according to a specific contract maturity, as shown in Figure 23, it can be clearly seen that the unusually high spread in 2013-2014 was caused by the weekly EPADs. As was discussed earlier, weekly EPADs are hardly traded and represent a product that has been introduced only recently. The market participants' and market makes' quotes for this product were thus exceptional during the introduction period but seemed to stabilize from mid-2015 onwards.

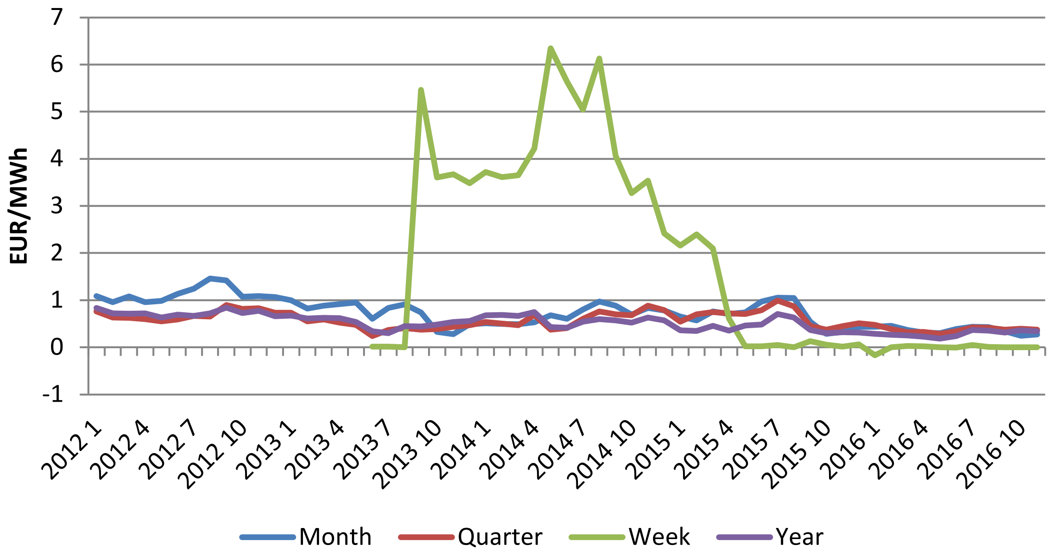

Figure 23 Monthly average best bid-ask spread for all EPADs according to contract maturity

Therefore, in order to represent an unbiased average best bid-ask spreads that is representative for EPAD traders and hedgers, weekly contracts have to be removed. This is shown in Figure 24 where monthly average best bid-ask spread for all bidding zones and monthly, quarterly, and yearly EPADs is present. The unusual spike in best bid ask spread is removed and is more representative of the real spreads faced by market participants.

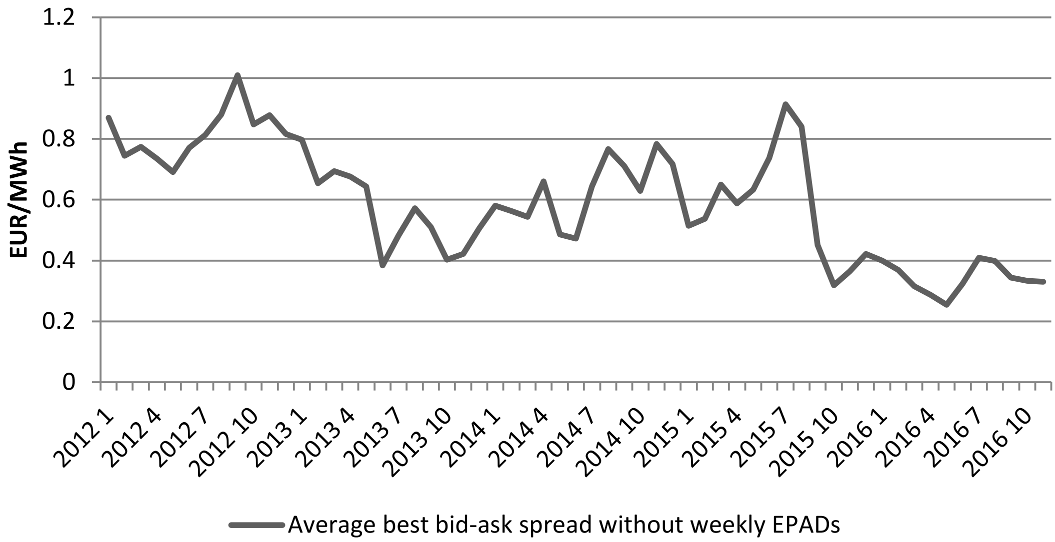

Figure 24 Monthly average best bid-ask spread for monthly, quarterly and yearly EPADs in all bidding zones

Figure 25 shows the monthly average best bid-ask spread for monthly, quarterly and yearly EPADs for all bidding zones structured around the individual contract maturities. It can be observed that on average, monthly EPAD bid-ask spreads are the highest and yearly are on average the lowest. This is a natural finding, since it was discussed that most of the trading and hedging is done in yearly contracts, which are thus the most liquid and having the tightest bid-ask spread, on average.

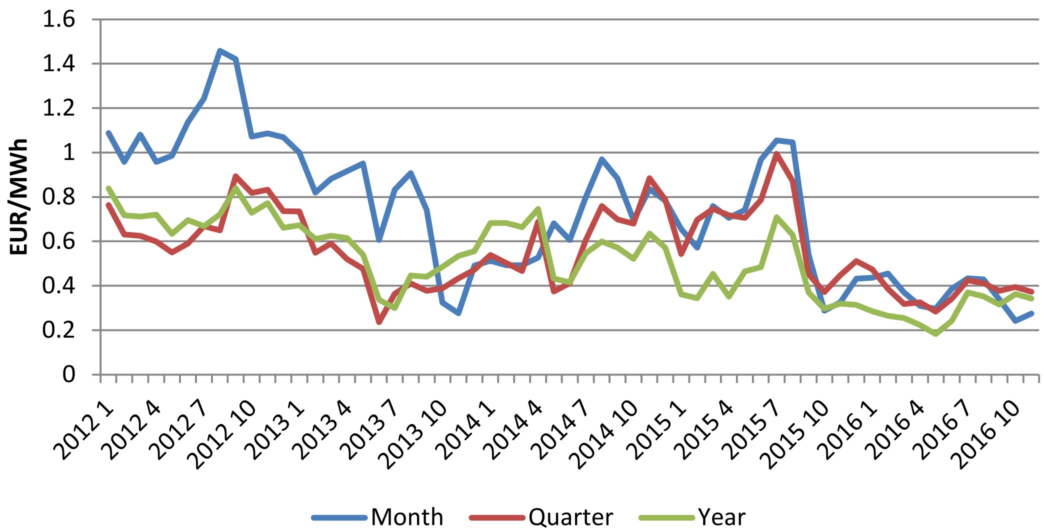

Figure 25 Monthly average best bid-ask spread for monthly, quarterly and yearly EPADs in all bidding zones

Figure 26 shows the average weekly best bid-ask spreads for all but weekly EPADs in all bidding zones and Figure 27 displays these weekly averages according to contract maturities. The same information as from the two previous charts is gained just in finer granularity. In general, the spreads between the three main EPAD contract maturities seem to converge and come closer, especially in year 2016, compared to the previous years.

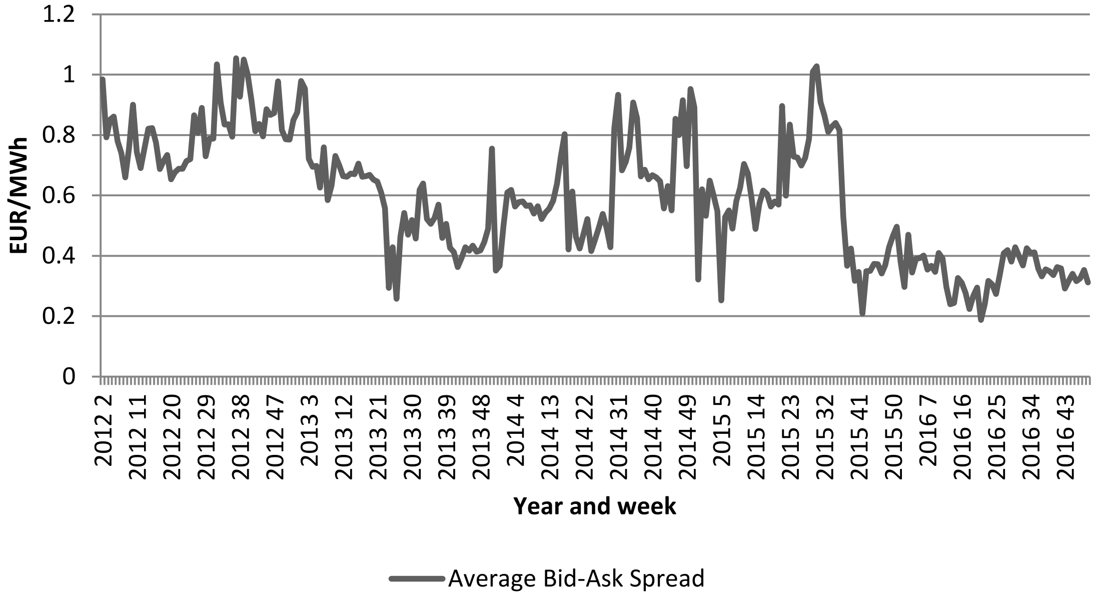

Figure 26 Weekly average best bid-ask spread for monthly, quarterly and yearly EPADs in all bidding zones

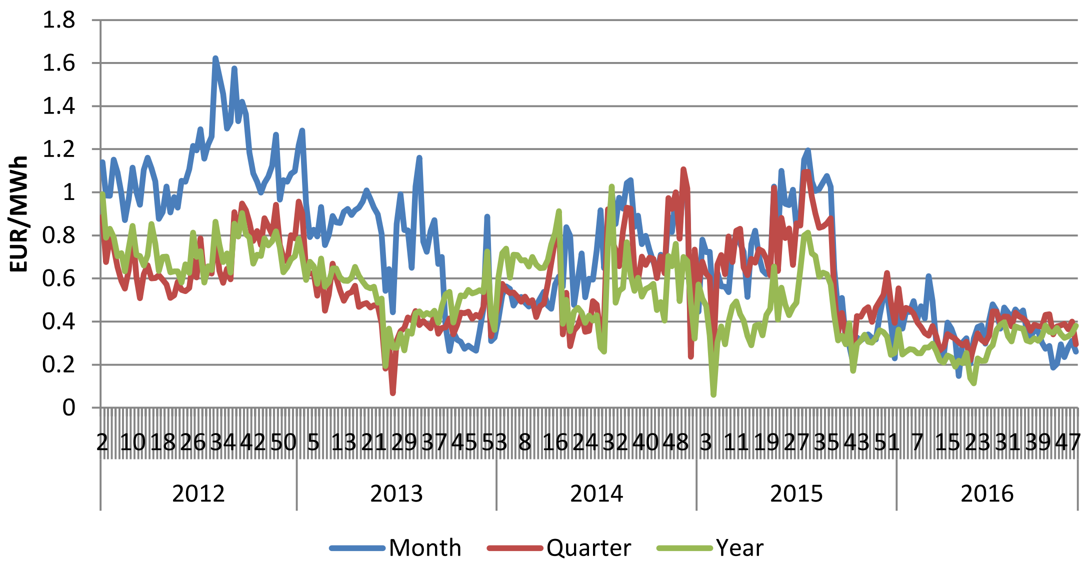

Figure 27 Weekly average best bid-ask spread for monthly, quarterly and yearly EPADs in all bidding zones

5.2 Average best bid-ask spreads for Finnish bidding zone and its neighbours

This sub-section presents detailed statistics on best bid-ask spreads for Finnish bidding zone and its neighbouring areas. For the sake of representativeness, weekly EPADs are again removed from the averages in order not to pollute the data with untraded contract that includes very high bid-ask spreads during its introductory phase in 2013-2014.

Table 7 shows the yearly average best bid-ask spread in EPADs for five years 2012-2016. In general, the bid-ask spreads in the selected bidding zones have been declining from year to year. Stockholm had the lowest average best-bid ask spread of 0.368 EUR/MWh and the others below 0.60 EUR/MWh.

Table 7 Yearly average best bid-ask spreads for monthly, quarterly and yearly EPADs in selected bidding zones

Year	Helsinki	Luleå	Stockolm	Tallinn	Tromsø	Average
2012	0.680	0.635	0.464	0.911	2.514	0.789
2013	0.638	0.625	0.476	0.670	0.837	0.627
2014	0.649	0.750	0.463	0.962	1.059	0.741
2015	0.634	0.516	0.318	0.807	0.174	0.490
2016	0.446	0.333	0.264	0.014	0.070	0.252
Average	**0.581**	**0.528**	**0.368**	**0.508**	**0.546**	**0.502**

Figure 28 shows the yearly average best bid-ask spreads for selected bidding zones. There is a clear downward trend in the average bid-ask spreads across the bidding zones.

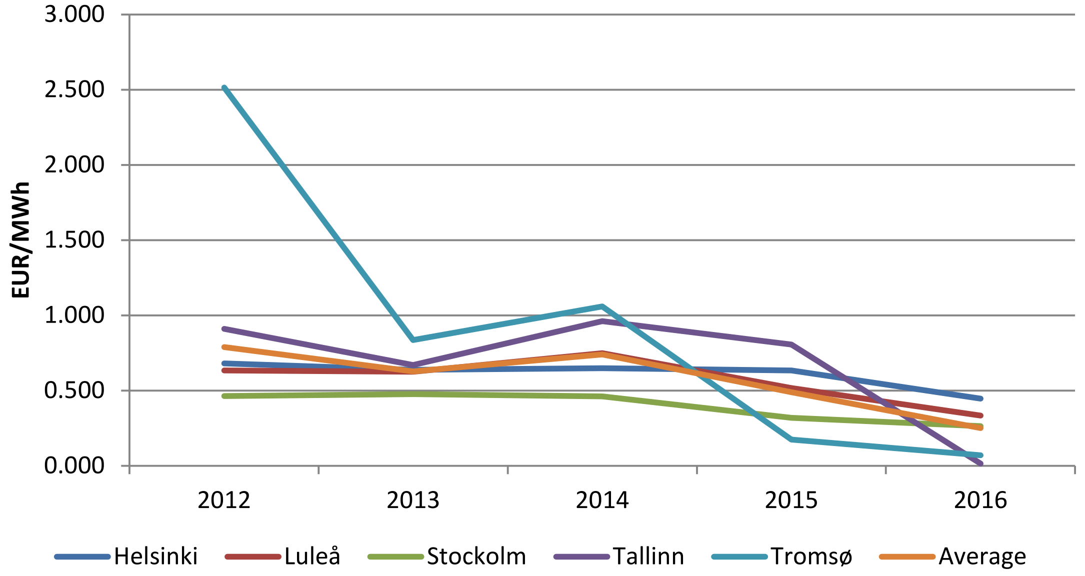

Figure 28 Yearly average best bid-ask spread for monthly, quarterly and yearly EPAD in selected bidding zones

Further granularity on the average best bid-ask spreads is gained by visualizing the data in monthly frequency, which is shown in Figure 29.

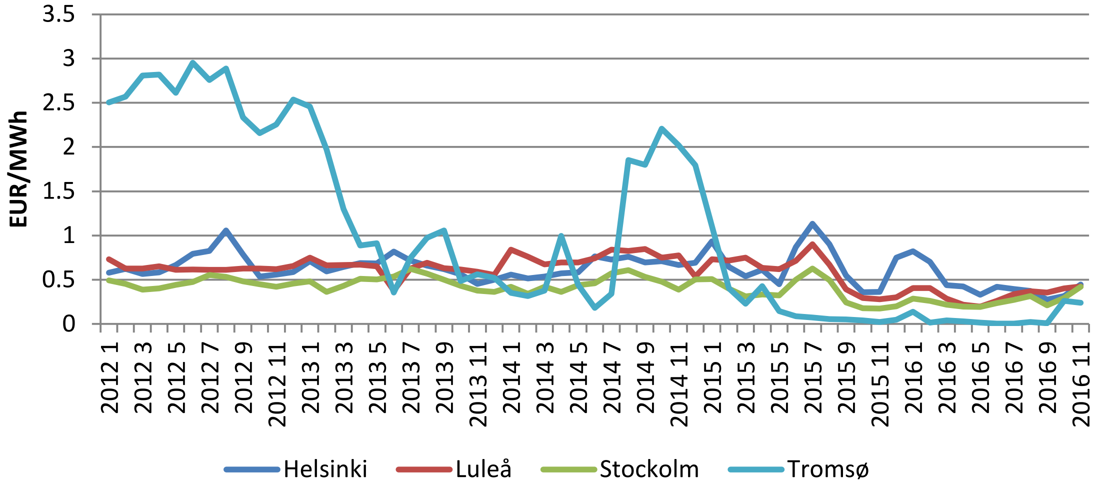

Figure 29 Monthly average best bid-ask spread for monthly, quarterly and yearly EPAD in selected bidding zones

Average weekly best bid-ask spreads are displayed for Helsinki bidding zone in Figure 30. Figure 31 additionally structures the Finnish best bid-ask spreads around the contract maturities and shows that the weekly spreads for monthly Finnish EPADs vary the most and yearly EPADs the least. Finally, Figure 32 shows the daily average best bid-ask spread for Finnish monthly, quarterly and yearly EPADs.

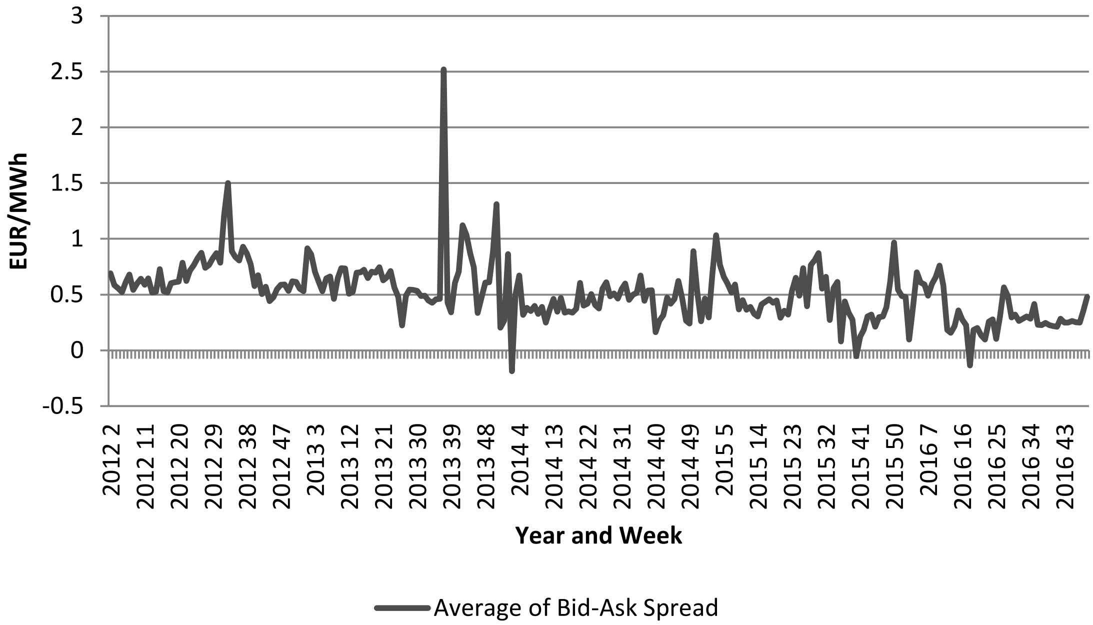

Figure 30 Weekly average best bid-ask spread for Helsinki monthly, quarterly and yearly EPAD

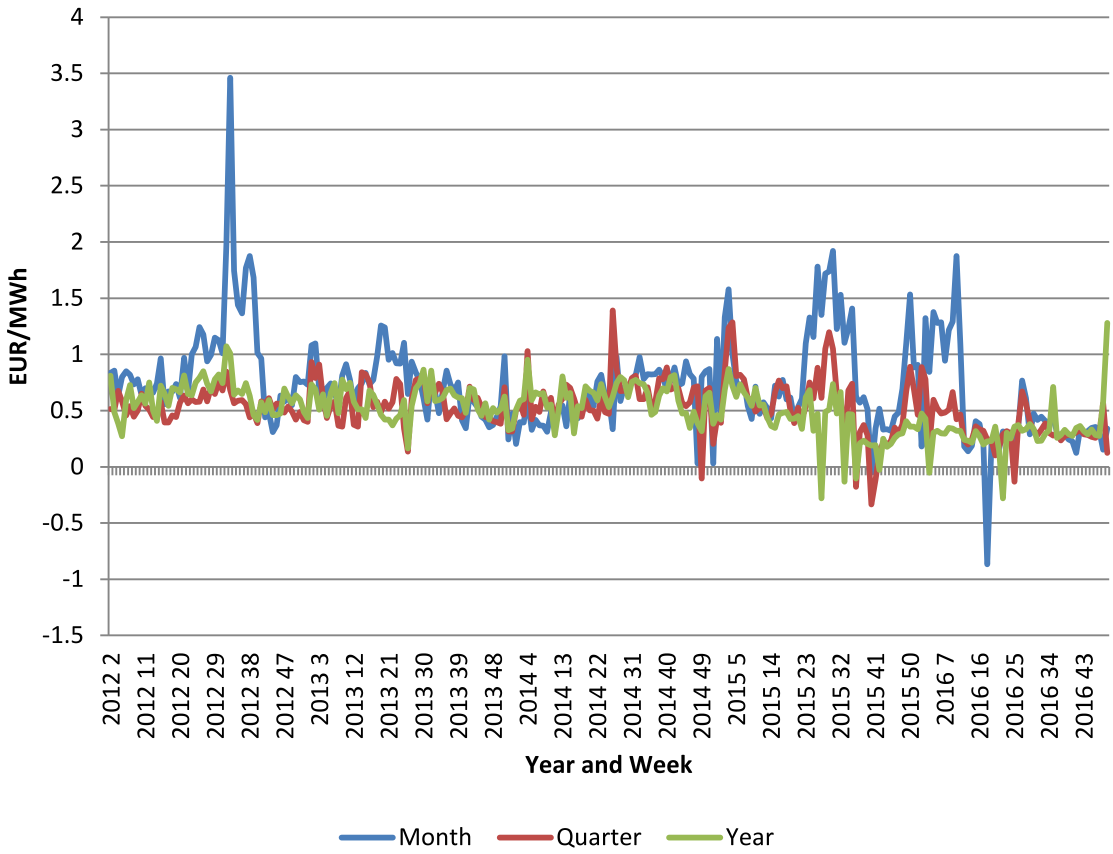

Figure 31 Weekly average best bid-ask spread for Helsinki monthly, quarterly and yearly EPAD according to contract maturity

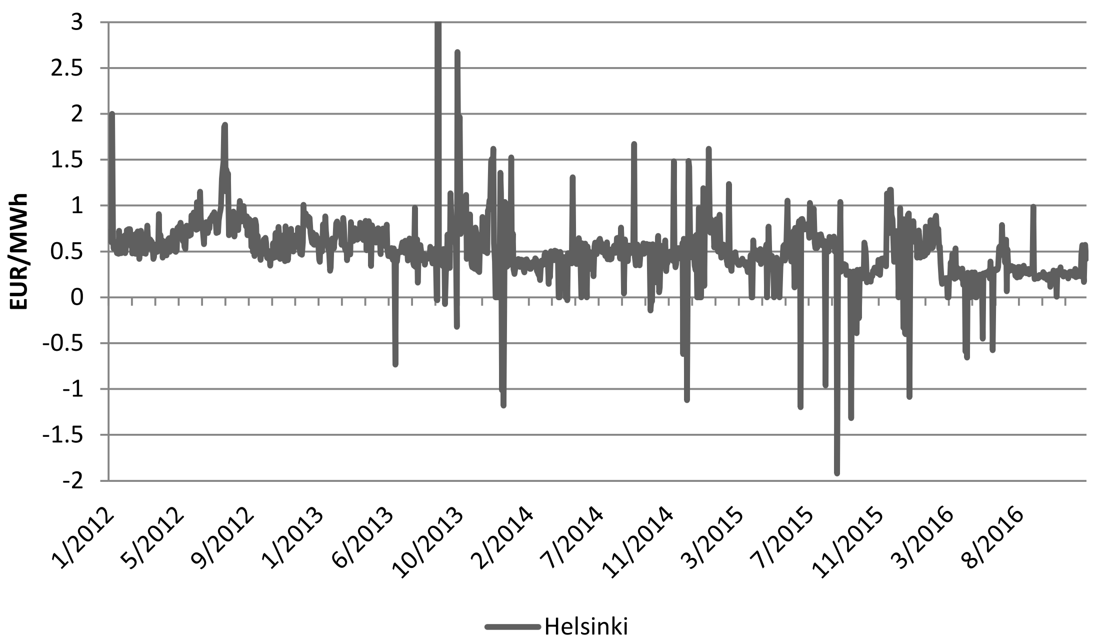

Figure 32 Daily average best bid-ask spread for monthly, quarterly and yearly EPAD in Helsinki bidding zone

5.3 Highest bid-ask spreads for all EPADs

To calculate the “worst” bid-ask spread, the highest absolute difference between best asking and best bidding price is summarized. Taking the absolute value of the best bid-ask spread allows to capture both negative and positive spreads and report their maximum distance in a given time interval. The interpretation of the “worst” best bid-ask spread is what was the highest price spread for a certain contract during a given time period. For the sake of representativeness, weekly EPADs are again removed from the spreads calculations.

Figure 33 and Figure 34 show that the highest monthly absolute best bid-ask spread among all bidding zones was approaching 30 EUR/MWh in mid-2014 quoted for a monthly EPAD contract. In general, there seems to be no systematic high bid-ask spreads in any particular EPAD contract category (maturity). Figure 35 adds finer granularity and shows the highest bid-ask spreads in weekly frequency.

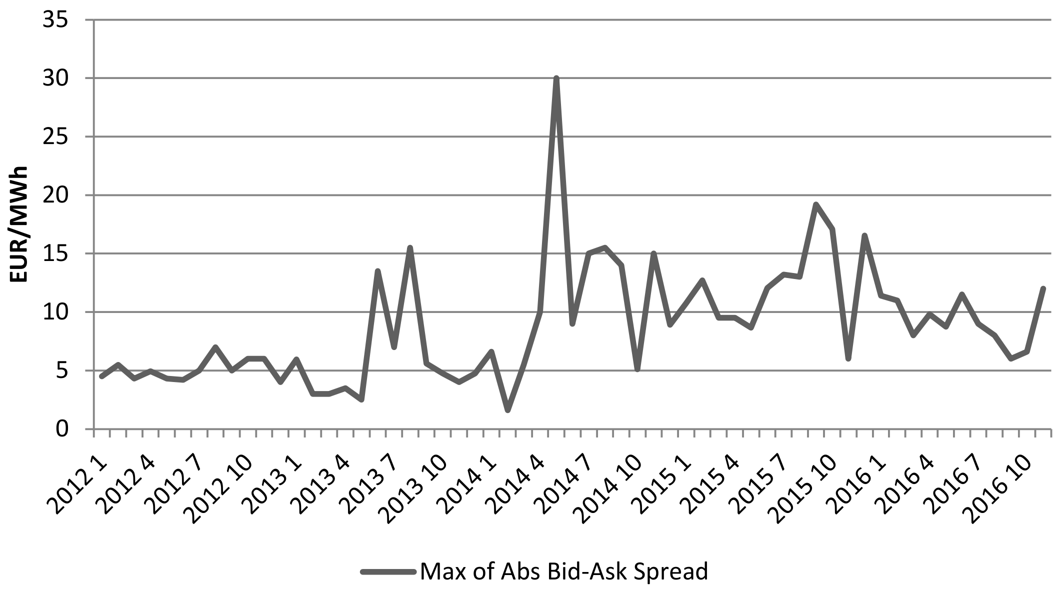

Figure 33 Highest absolute monthly best bid-ask spread in monthly, quarterly and yearly EPADs in all bidding zones

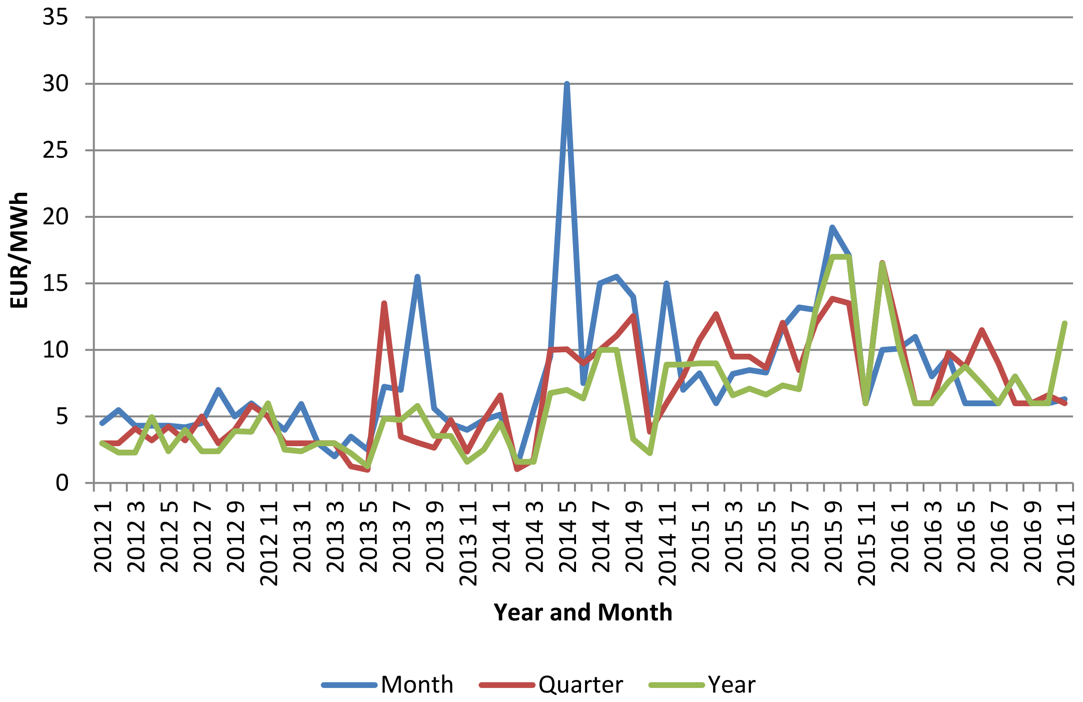

Figure 34 Highest monthly best bid-ask spread for monthly, quarterly and yearly EPADs in all bidding zones

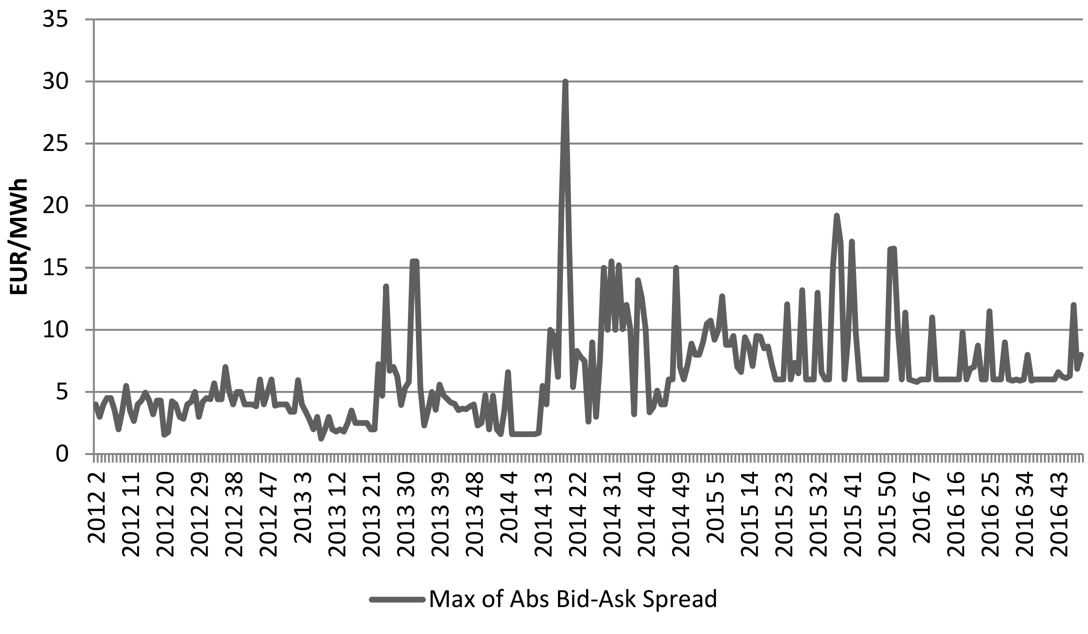

Figure 35 Highest weekly best bid-ask spread for monthly, quarterly, and yearly EPADs in all bidding zones

5.4 Highest bid-ask spreads for Finnish EPADs

This sub-section briefly presents the highest absolute best bid-ask spreads for the Finnish bidding zone. Again, weekly EPADs are omitted from the analysis in order to keep the results consistent with the previous sections.

Figure 36 presents the highest absolute best bid-ask spread for Finnish EPADs, excluding weekly contracts. The highest spread reached 11 EUR/MWh in the beginning of 2016 and can be attributed to a quote in quarterly EPAD, as seen from Figure 37.

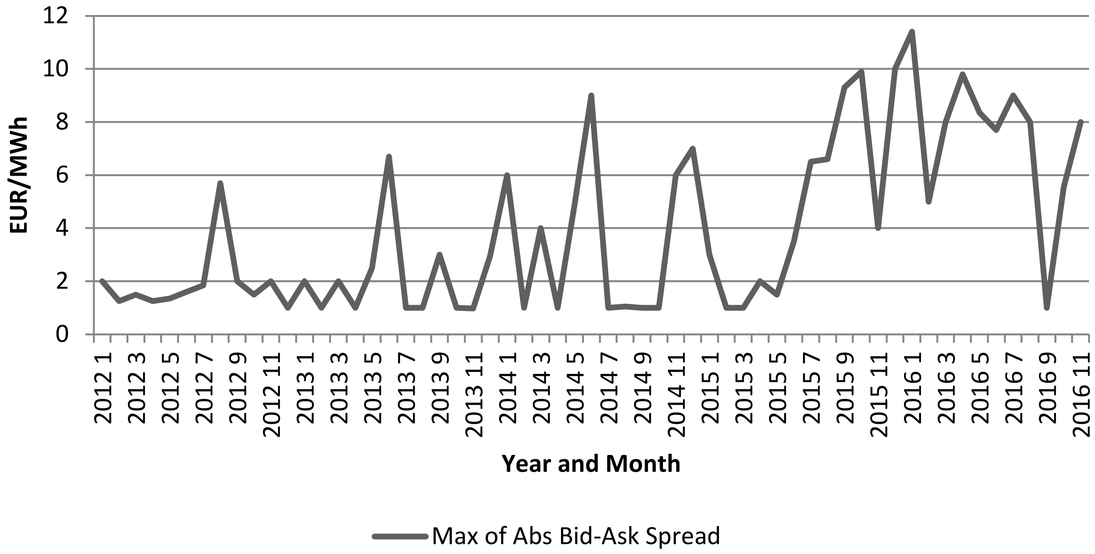

Figure 36 Highest monthly best bid-ask spread for Finnish yearly, quarterly and monthly EPADs

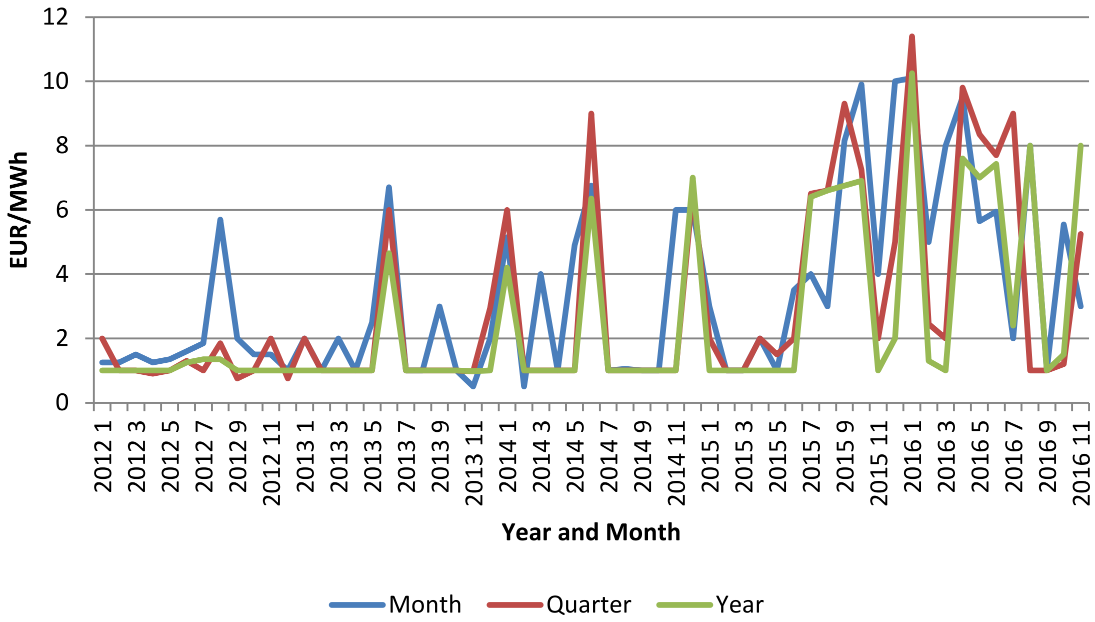

Figure 37 Highest monthly best bid-ask spreads for Finnish monthly, quarterly and yearly EPADs according to contract type

6 Correlation analysis

This section presents correlation analysis of area spot prices and combination of derivatives for the same underlying period. Last trading day closing prices of EPADs and futures contracts for system price are used in the analysis.

Correlation analysis is considered to both directions on the Finnish borders, for example Estonian participants using Finnish EPADs and vice versa. The discussion in the following two sub-chapters is structured according to:

1. Hedges and correlations of the spread between area spot price and system price with EPADs, and
2. Hedges and correlations of area spot prices with combinations of EPADs and futures for system price.

Monthly and yearly correlation analysis for the time period between 2013 and 2016 follows next.

6.1 Monthly average correlations

System futures used for the monthly correlation analysis are based on last trading day of monthly deferred settlement futures ENOJAN,FEB,MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC 13-16.

As a background, it is necessary to know the monthly spot price dynamics over the studied time interval, in order to match the market risks with hedging needs of market participants. Table 8 presents the monthly average spot prices for 2013-2016 and shows that Helsinki (FI) and Tallinn (EE) bidding zones had the highest area prices relative to the system reference price. Tromsø (NO4) had monthly average area spot price slightly below the reference system price. Area prices above the reference system spot price increase the hedging need of market participants to manage the local area price risk with EPADs.

Table 8 Monthly average spot prices (2013-2016)

Area	Obs	Mean	Std. Dev.	Min	Max
SYS	48	28.913	7.875	9.548	45.906
FI	48	34.814	5.737	21.518	47.763
SE1	48	30.189	8.178	9.067	44.612
SE3	48	30.584	8.043	9.067	45.705
NO4	48	28.890	8.194	8.797	44.477
EE	48	36.221	6.051	26.723	53.356

Table 9 shows the monthly average of area spot price differences (area price minus system price) and the underlying monthly EPADs. The sample includes 48 observations, as there are 4 years and the frequency is monthly. It can be seen that on average, the highest discrepancy between the two is in Helsinki bidding zone, but there is also the greatest deviation in the values, as shown by standard deviation value of 4.059.

Table 9 Monthly average spot price differences (spot area price-system price) and monthly EPADs (2013-2016)

Area	Obs	Mean	Std. Dev.	Min	Max
FI-SYS	48	5.901	4.059	-1.991	18.068
FI_EPAD	48	6.823	3.666	0.200	17.200
SE3-SYS	48	1.671	2.381	-1.998	8.806
SE3_EPAD	48	1.965	1.512	-0.300	7.250
SE1-SYS	48	1.276	2.413	-1.998	8.806
SE1_EPAD	48	1.375	1.633	-1.050	7.380
NO4-SYS	48	-0.023	2.296	-6.885	8.158
NO4_EPAD	48	0.083	1.986	-6.600	5.130
EE-SYS	48	7.308	4.740	-2.598	19.893
EE_EPAD	48	8.988	5.077	0.000	28.000

Table 10 presents the monthly average correlations and cross-correlations between area spot price differences (indexed by area code and – SYS) and monthly EPADs (indexed by area code and _EPAD). Correlations between area's own area spot price difference and its EPAD are highlighted by rectangular boxes in Table 10. Own price correlations range between 0.821 for Helsinki to 0.567 for Tallinn.

The table also shows that, for example, that market participants in Estonia can use Finnish monthly EPADs for hedging Estonian spot price difference. The correlation between Finnish EPADs and Estonian spot price difference between area and system price is greater (0.666) than direct correlation of Estonian EPADs with Estonian underlying spot price differences (0.567). These relationships are also shown in Figure 38 and Figure 39.

Also, market participants in Luleå (SE1) can use own area's EPADs or Stockholm's (SE3) EPADs for managing local area price risk, because their correlations are almost identical (0.779 with own EPAD and 0.774 with Stockholm's EPAD).

Table 10 Monthly average correlations of spot price differences (area price – system price) and monthly EPADs (2013-2016)

	FI-SYS	FI_EPAD	SE1-SYS	SE1_EPAD	SE3-SYS	SE3_EPAD	NO4-SYS	NO4_EPAD	EE-SYS	EE_EPAD
FI-SYS	1.000									
FI_EPAD	0.821	1.000								
SE1-SYS	0.365	0.181	1.000							
SE1_EPAD	0.283	0.256	0.779	1.000						
SE3-SYS	0.469	0.301	0.966	0.767	1.000					
SE3_EPAD	0.327	0.334	0.744	0.959	0.768	1.000				
NO4-SYS	0.229	0.144	0.463	0.492	0.442	0.471	1.000			
NO4_EPAD	0.308	0.303	0.130	0.302	0.176	0.300	0.739	1.000		
EE-SYS	0.825	0.666	0.233	0.182	0.293	0.185	0.236	0.352	1.000	
EE_EPAD	0.612	0.752	0.122	0.068	0.176	0.110	0.106	0.241	0.567	1.000

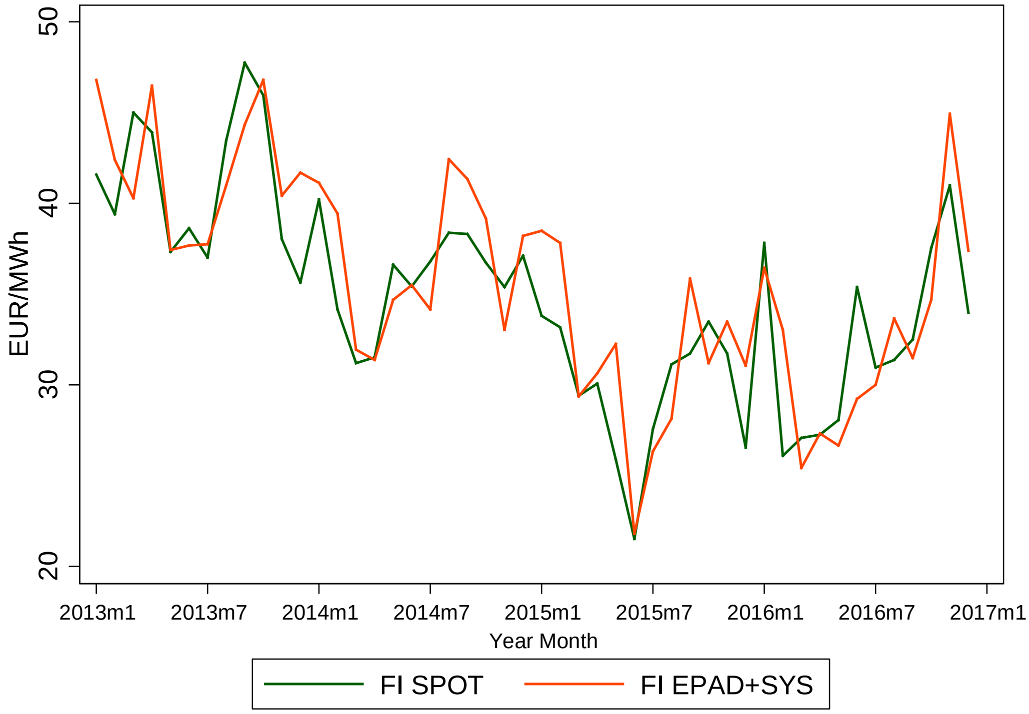

Figure 38 Relationship between Finnish spot area price (FI SPOT) and combination of derivative contracts on monthly system price and monthly Finnish EPAD (FI EPAD+SYS)

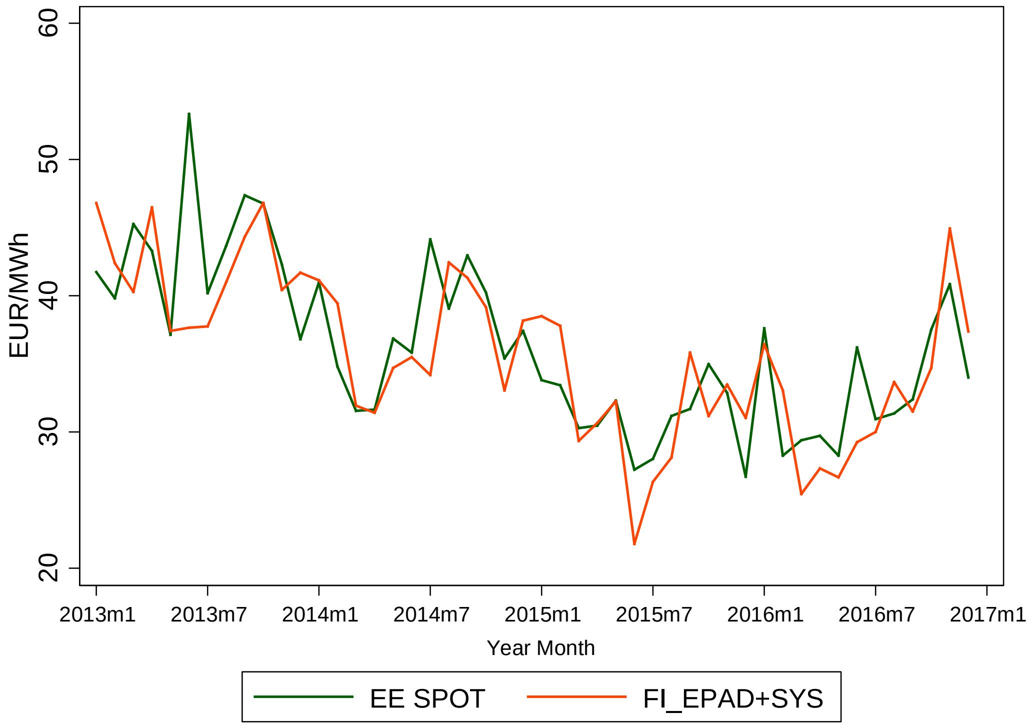

Figure 39 Relationship between Estonian spot area price (EE SPOT) and combination of derivative contracts on monthly system price and monthly Finnish EPAD (FI EPAD+SYS)

Hedging by combination of monthly system futures contracts and monthly EPADs is presented next. Table 11 presents the monthly average of area spot prices (indexed by area code and _SYS) and the prices of combined hedge from monthly system futures and local monthly EPAD (indexed by area code and _EPAD+SYS). The combined hedges match relatively well for all the bidding areas. The least tight/fit is seen in Tallinn where the combined hedge is slightly higher than the realized spot area price.

Table 11 Monthly averages of area spot prices and combination of monthly system futures and monthly EPADs (2013-2016)

	Obs	Mean	Std. Dev.	Min	Max
FI_EPAD+SYS	48	35.680	6.027	21.8	46.8
FI_SPOT	48	34.814	5.737	21.518	47.763
SE3_EPAD+SYS	48	30.823	7.997	12.3	45.9
SE3_SPOT	48	30.584	8.043	9.067	45.705
SE1_EPAD+SYS	48	30.232	8.002	11.35	45.5
SE1_SPOT	48	30.189	8.178	9.067	44.612
NO4_EPAD+SYS	48	28.940	7.839	12.3	45.6
NO4_SPOT	48	28.890	8.194	8.797	44.477
EE_EPAD+SYS	48	37.845	6.442	24.28	57.75
EE_SPOT	48	36.221	6.051	26.723	53.356

Table 12 presents the monthly average correlations and cross-correlations between spot area spot prices (indexed by area code and _SYS) and the prices of combined hedge from monthly system futures and local EPAD (indexed by area code and _EPAD+SYS). Correlations between area's own area spot prices and its combined hedge are highlighted by rectangular boxes. Own price correlations range between 0.940 for Tromsø (NO4) to 0.727 for Tallinn.

Table 12 Monthly average correlations of area spot prices and combination of monthly system futures and monthly EPADs (2013-2016)

	FI_EPAD+SYS	FI_SPOT	SE3_EPAD+SYS	SE3_SPOT	SE1_EPAD+SYS	SE1_SPOT	NO4_EPAD+SYS	NO4_SPOT	EE_EPAD+SYS	EE_SPOT
FI_EPAD+SYS	1.000									
FI_SPOT	0.864	1.000								
SE3_EPAD+SYS	0.916	0.813	1.000							
SE3_SPOT	0.841	0.916	0.911	1.000						
SE1_EPAD+SYS	0.905	0.813	0.998	0.916	1.000					
SE1_SPOT	0.832	0.902	0.914	0.997	0.921	1.000				
NO4_EPAD+SYS	0.898	0.805	0.965	0.873	0.963	0.874	1.000			
NO4_SPOT	0.853	0.878	0.919	0.954	0.924	0.956	0.940	1.000		
EE_EPAD+SYS	0.857	0.765	0.768	0.739	0.759	0.738	0.773	0.761	1.000	
EE_SPOT	0.775	0.898	0.737	0.820	0.741	0.814	0.760	0.818	0.727	1.000

6.2 Yearly average correlations

System futures used in the correlation analysis are based on last trading day of yearly deferred settlement futures ENOYR-13, 14, 15, and 16.

As a background again, it is necessary to know the yearly spot price dynamics over the studied time interval, in order to match the market risks with hedging needs of market participants. Table 13 presents the yearly average spot prices for 2013-2016 and shows that Helsinki (FI) and Tallinn (EE) bidding zones are typically the most distant from the reference system price throughout the years and Tromsø (NO4) is the closest to the system spot price.

Table 13 Yearly average spot prices by year (2013-2016)

Year	SYS_SPOT	FI_SPOT	SE3_SPOT	SE1_SPOT	NO4_SPOT	EE_SPOT
2013	38.104	41.156	39.448	39.190	38.602	43.142
2014	29.607	36.023	31.620	31.422	31.440	37.613
2015	20.978	29.659	22.004	21.164	20.429	31.085
2016	26.911	32.445	29.233	28.951	25.049	33.063
Total	28.900	34.821	30.576	30.181	28.880	36.226

Table 14 shows the yearly average of area spot price differences and the underlying yearly EPADs. The sample includes only 4 observations, as there are 4 years and the frequency is yearly. Because of the small number of years and hence sample size, correlations between the spot and derivatives are not recommended, because the results can be very biased.

Table 14 shows that some discrepancy exists between EPADs and the underlying area spot price differences, especially for Helsinki, Stockholm and Tallinn bidding zones. Table 15 shows the same information by individual years and highlights that the average discrepancy was mainly driven by year 2016, at least for Helsinki and Tallinn.

Table 14 Yearly average spot price differences (spot area price-system price) and yearly EPADs (2013-2016)

	Obs	Mean	Std. Dev.	Min	Max
FI-SYS	4	5.921	2.327	3.052	8.681
FI_EPAD	4	7.765	2.823	5.700	11.930
SE1-SYS	4	1.281	0.836	0.186	2.040
SE1_EPAD	4	1.063	0.579	0.450	1.800
SE3-SYS	4	1.676	0.595	1.027	2.322
SE3_EPAD	4	2.415	0.389	1.880	2.800
NO4-SYS	4	-0.020	1.568	-1.862	1.833
NO4_EPAD	4	0.030	0.792	-0.780	1.100
EE-SYS	4	7.326	2.222	5.038	10.107
EE_EPAD	4	8.413	3.741	4.650	13.570

Table 15 Yearly average spot price differences (spot area price-system price) and yearly EPADs by year (2013-2016)

	2013	2014	2015	2016	Total
FI-SYS	3.052	6.415	8.681	5.534	5.921
FI_EPAD	5.700	6.930	6.500	11.930	7.765
SE1-SYS	1.085	1.814	0.186	2.040	1.281
SE1_EPAD	0.450	1.200	1.800	0.800	1.063
SE3-SYS	1.344	2.013	1.027	2.322	1.676
SE3_EPAD	1.880	2.800	2.430	2.550	2.415
NO4-SYS	0.498	1.833	-0.548	-1.862	-0.020
NO4_EPAD	-0.250	0.050	1.100	-0.780	0.030
EE-SYS	5.038	8.006	10.107	6.152	7.326
EE_EPAD	4.650	7.350	8.080	13.570	8.413

Hedging by combination of yearly system futures contracts and yearly EPADs is presented next.

Table 16 presents the yearly average of area spot prices (indexed by area code and _SYS) and the prices of combined hedge from yearly system futures and local yearly EPAD (indexed by area code and _EPAD+SYS). The combined yearly hedges seem to have lower fit relative to the monthly hedges. The discrepancy between the spot and the hedged item is largest for Helsinki and Tallinn and smallest for Luleå (SE1). Table 17 presents the same information for individual years. The larger discrepancy between the hedging instruments and the spot prices stems from the limited number of years covered by this analysis and also by a simplified hedging strategy.

Table 16 Yearly averages of area spot prices and combination of yearly system futures and yearly EPADs (2013-2016)

	Obs	Mean	Std. Dev.	Min	Max
FI_EPAD+SYS	4	37.890	5.565	30.680	44.200
FI_SPOT	4	34.821	4.962	29.659	41.156
SE3_EPAD+SYS	4	32.540	8.046	21.300	40.380
SE3_SPOT	4	30.576	7.190	22.004	39.448
SE1_EPAD+SYS	4	31.188	8.230	19.550	38.950
SE1_SPOT	4	30.181	7.428	21.164	39.190
NO4_EPAD+SYS	4	30.155	8.610	17.970	38.250
NO4_SPOT	4	28.880	7.899	20.429	38.602
EE_EPAD+SYS	4	38.538	4.517	32.320	43.150
EE_SPOT	4	36.226	5.360	31.085	43.142

Table 17 Yearly averages of area spot prices and combination of yearly system futures and yearly EPADs by year (2013-2016)

	2013	2014	2015	2016	Total
FI_EPAD+SYS	44.200	38.930	37.750	30.680	37.890
FI_SPOT	41.156	36.023	29.659	32.445	34.821
SE3_EPAD+SYS	40.380	34.800	33.680	21.300	32.540
SE3_SPOT	39.448	31.620	22.004	29.233	30.576
SE1_EPAD+SYS	38.950	33.200	33.050	19.550	31.188
SE1_SPOT	39.190	31.422	21.164	28.951	30.181
NO4_EPAD+SYS	38.250	32.050	32.350	17.970	30.155
NO4_SPOT	38.602	31.440	20.429	25.049	28.880
EE_EPAD+SYS	43.150	39.350	39.330	32.320	38.538
EE_SPOT	43.142	37.613	31.085	33.063	36.226