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DERIVATIVE PRICING PREMIUMS AND RISK MANAGEMENT IN THE NORDIC POWER MARKET

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Abstract

The primary purpose of this thesis was to investigate pricing premiums for derivatives with Nordic power as the underlying asset and to outline whether such premiums influenced hedging strategies. The time period chosen was January 2013 to December 2019, and the financial derivatives analysed were options on futures and weekly-, monthly-, quarterly- and yearly futures contracts. This thesis found that futures prices are biased predictors of the corresponding spot prices, and that significant forward premiums are present in the financial market for Nordic power. Additionally, it was uncovered that the European Market Infrastructure Regulation enforced in 2016 eliminated the use of deferred settlement futures, which ultimately led to many foreign participants leaving the market, overall decreasing the liquidity. This, in combination with the high implied volatility of the underlying asset, caused options to cease trading in a meaningful volume, which ultimately led to their exclusion from future hedging strategies. Hedging strategies for power producers and -suppliers were presented where it was identified that 14 out of 40 offsetting hedging strategies yielded a lower standard deviation and a higher return than the baseline of zero hedging. Finally, as many market participants employ speculation alongside their risk management, speculative investment strategies were presented within the framework of Markowitz' mean-variance portfolio theory.

Acknowledgements

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1. Introduction & Motivation

After its initial liberalization in 1991, the Nordic power market is one of the most liberal and competitive power markets in the world of finance (Nord Pool, 2020a). This market supplements a highly volatile *physical* market by offering a wide array of financial instruments that enable risk management or speculation. Futures contracts and options on futures are the main derivatives traded on the Nordic power exchange, Nasdaq OMX Commodities Europe.

Consistent with the laws of energy conservation, large quantities of electrical energy cannot be stored economically. This is the reason why power trading is different in nature from traditional commodity trading. Some energy conservation projects are based on pumping water into higher altitude reservoirs when the spot price of electricity is low and producing electricity by letting the water flow through a hydro power turbine when the spot price is high. This has primarily been done as price arbitrage exploitation, rather than ensuring capacity for future delivery (Lie, 2014). As a result, all futures contracts traded are being settled financially, which entails there is no physical delivery of power, but rather a settlement based upon the spread between the futures price and the spot price.

When trading power derivatives, it is crucial that the market is both liquid and efficient, or the trades executed will leave money on the table due to market inefficiencies. This thesis hypothesizes that there might exist a forward premium on futures contracts as well as a volatility premium on the futures options. If these hypotheses are correct, it would raise questions for market participants as to which instruments to utilize when implementing a hedging strategy.

Initial research revealed that the financial instruments being traded as of 2020 are different compared to just five years ago. The main difference is the elimination of forward contracts, due to market regulations introduced in 2012 and coming into effect in 2016. This resulted in futures contracts being the main derivative currently traded. Interestingly, the authors of this thesis have been unable to find academic literature analysing options on the Nordic power market post 2015. The authors are therefore curious as to whether the 2012 market regulations altered the market dynamics with regard to which instruments are now being actively traded.

Parallel to the development of a functioning financial power trading market, the renewable energy sector has experienced a transition where merchant risk is becoming ever more present. Historically, renewable projects have relied upon governmental subsidies to become economically viable. Regulators introduced auctions in the tendering process whereby the bidder with the lowest quoted electricity price won the right to develop the project. However, as renewable technology has become both cheaper and more energy efficient, some regulators are introducing 'zero bids' in their auctioning schemes (Guillet, 2017). In such schemes, the developer is no longer guaranteed a minimum electricity price. This mechanism radically changes the risk factors in renewable projects. Historically, the main risks have been related to capital overexpenditure and project delays. With no floor for the electricity price, a significant additional commercial risk is introduced. To mitigate this risk, developers are looking to the derivatives markets to hedge their future production (McKinsey, 2018). As renewable energy developers turn to the futures market to hedge their production, the power derivatives market will experience increased market participation, thus highlighting the importance of an efficient market.

Should a forward premium be present in the data period, it would raise questions on how and when to hedge power production. Hedging the price of a commodity is the act of securing a future price of a given commodity, in this case the power delivered into a specified power-grid over a specific time-period. As electricity demand fluctuates throughout the day, the derivatives traded on the Nordic power market secures the price for the minimum power needed throughout the day, referred to as *base load* (Meredith, 2016). A hedger can lock in the future price of power delivered through either; a futures contract with power as the underlying asset, or through options with a futures contract as the underlying asset. Due to inherent future market uncertainty, the most commonly traded expirations are day-ahead, the following week, month and quarter (Appendix 2). This has led many market participants to employ a 'stack and roll' hedging strategy whereby the hedger purchases a futures contract on the near-term delivery date. When the contract expires, the hedger 'roll over' the initial exposure, less the power delivered in the expired period, into another set of near-term futures contracts. This suggests that the most interesting contracts to consider in a hedging strategy context are; following week, month and quarter, as these closely resemble prevailing market behaviour.

Additionally, it is currently not clear whether one should purchase the futures contracts or the options on the underlying contracts to optimally hedge future prices.

The two main topics of this thesis; the forward premium on the Nordic power market and the related hedging strategies, have been researched individually. To the best of our abilities, we have been unable to identify any academic research linking these two topics. Current research on the futures market of the Nordic power market has to date been somewhat limited, providing the authors with additional motivation for contributing to expanding the academic field.

2. Literary review on Nordic power derivatives and hedging strategies

The following literary review provides a context and theoretical framework for the academic field related to Nordic power futures and options, forward premiums, and hedging strategies. In order for the reader to better understand the findings of this thesis, it is useful to consider relevant, prior academic studies which highlight how theories and market dynamics might have shifted.

The structure of the literary review follows the framework of Saunders et al. *Research Methods for Business Students* (2016), which categorizes the review held as a hybrid between a historical review and a theoretical review (Saunders, et al., 2019, p. 74). The historical review examines the evolution on a particular topic over a period of time, whereas the theoretical review examines the body of theory that has accumulated with regard to a phenomenon (Saunders, et al., 2019, p. 74). This thesis' literary review assesses both the academic research on the field of Nordic power derivatives, and further how it might have changed over time. Ultimately, this thesis´ findings will outline a hedging strategy, thus the authors find it advantageous to review a case study of hedging strategies implemented.

2.1 Data collection

In order to provide transparency to the literary review process, the data collection, i.e. the search for relevant literary works, is outlined in detail. The authors first became aware of the notion that there might exist a form of pricing premium on the Nordic market for power derivatives by reading an article from the journal *Energy Economics* where Birkelund et al. (2015) presented their article '*A comparison* *of implied and realized volatility in the Nordic power forward market'*. This stimulated the authors' interest for the subject and triggered a thorough review of their citations, which again lead to the discovery of the article '*The Forward Premium in the Nord Pool Power Market'* by Haugom et al. (2018). As it became apparent that Eirik Haugom was knowledgeable within the field of Nordic power derivatives, his other works were also studied in order to gain a better understanding of the academic field.

In addition to searching for specific articles and academic scholars, data gathering has also been performed through Google and Copenhagen Business School's academic databases.

2.2 Literature on the market conditions for Nordic power derivatives[1]

2.2.1 *Market power in the expanding Nordic power market* – Bask, Lundgren and Rudholm (2011)

In their article published in Applied Economics, Bask et al. (2011) are evaluating the market power in the Nordic market for electric power. Market power is defined as a company's relative ability to influence the price of a commodity in the marketplace by altering supply, demand or both (Kenton, 2019a). Their context is centered around the transition from national markets to multi-national and largely deregulated markets, and how this might have affected the market power. The authors of the article are meticulous when presenting their data, how they process it and furthermore how they present their results. Their findings further underline previous research concluding that the transition from national markets to multi-national and deregulated markets has had an overall positive effect on market power.

In the context of this thesis, Bask, Lundgren and Rudholm's article provide a thorough understanding on how the market dynamics of Nordic power have developed. They provide validity to potential findings of forward premiums, as their conclusion, that market power has declined after the deregulation, would prohibit a single market participant manipulating the market. This suggests that

[1] For good measures, the authors of the thesis would like to state that the literary review is performed, to the best of our knowledge, without any inherent biases or self-interest towards the researchers and/or academic field.

the possible forward premiums are a natural occurrence, and not caused by market manipulation by one or more participants.

2.3 Literature regarding forward & futures premiums on the Nordic Power Market

2.3.1 *The Forward Premium in the Nord Pool Power Market* – Haugom et al. (2018)

In their article published in *Emerging Markets Finance,* Haugom et al. (2018) assess the forward premium in the Nord Pool power market[2] in the period 2004 throughout 2013. The notion of forward premium was first introduced to the world of academia by Kaldor (1939), Working (1948) and Brennan (1958), but Haugom et al. (2018) utilize the definition of a forward premium synthesized by Eugene F. Fama and Kenneth R. French in 1987. Their findings indicate that there is a forward premium on the Nordic market for power. They further test various models to predict future system prices, with inputs such as wind production, electricity consumption, reservoir levels and inflow.

It is without a doubt that the article *The Forward Premium in the Nord Pool Power Market* provide an interesting insight to the topic of this thesis, as it closely relates to the research question. However, our readers should note, there are some areas where the article differs significantly from this thesis. Firstly, Haugom et al. (2018) utilize weekly futures, and they do not comment on whether a similar pattern of forward premium is, or could be, present in futures with other delivery periods. Secondly, the notion of seasonality is discussed in the article, but the authors do not present whether the forward premium seasonality is stable or evolving over time. Thirdly, it is somewhat unclear which financial derivative is the basis for the research.

Addressing the first issue; this thesis hypothesizes that monthly futures have a higher open interest than weekly futures, thus making findings associated with monthly futures even more important when assessing whether a forward premium exists in the market. Additionally, even though an analysis of weekly futures will generate significantly more data points compared to monthly futures, there is a

[2] The futures trading exchange for Nordic power, currently owned by Nasdaq OMX

possibility that the results' reliability is poorer due to the lower liquidity. Furthermore, the practical implications of a forward premium being present in monthly futures will have a greater financial impact. Regarding seasonality it must be noted that, should one be able to identify a development in seasonality in the forward premium, this development might be exploitable when implementing a hedging strategy. Lastly, as mentioned in *Chapter 1. Introduction & Motivation*, and which will be further discussed in *Chapter 6. Theories*, due to new market regulations, the financial instruments traded with Nordic electric power as the underlying asset have experienced a shift from a de-facto forward contract to futures contracts. The time period Haugom et al. (2018) analyzes covers trading periods prior to new regulations being introduced and enforced, so it might not be possible to interpolate their results in the data period used in this thesis.

2.4 Literature regarding volatility premiums in the Nordic power market

2.4.1 *A Comparison of Implied and Realized Volatility in the Nordic Power Forward Market* – Birkelund et al. (2015)

In their article published in *Energy Economics*, Birkelund et al. (2015) present their study of implied and realized volatility on options in the Nordic power forward market. The authors of the article were the first to successfully create an implied volatility index on the Nordic forward market. Their findings suggested that, since the implied volatility consistently on average was higher than the realized volatility in the time period 2005 to 2011, a volatility risk premium might be present. This suggestion is furthermore consistent with related research of a positive volatility risk premium present in other, more traditional financial markets, enhancing the reliability of their findings.

As will be discussed in *Chapter 8. Liquidity analysis*, due to limited remaining, knowledgeable market participants and unfavourable capital requirements compliant with new market regulations, options on forwards have nearly disappeared from the market. This implies that the findings of Birkelund et al. (2015) relate to a severely illiquid financial market. However, their findings of a volatility risk premium in the time period of 2005 to 2011 serves as a proxy for pricing premiums in general, which adds to the hypothesis that there exists a forward premium on the Nordic financial market for electric power. Finally, their article illustrates that historically there existed a liquid market for options in the Nordic market for electric power. This raises the question whether the *European market infrastructure* *regulation* in its aim to regulate the OTC-market, essentially removed an entire array of financial derivatives available to market participants.

2.5 Literature on power & commodity hedging

2.5.1 *Using electricity options to hedge against financial risks of power producers* - Pineda and Conejo (2013)

In their article published in *Journal of Modern Power Systems and Clean Energy*, Pineda and Conejo (2013) outline how options can serve as an integral part of hedging strategies for power producers. The authors highlight mainly two scenarios where options reduce either the price- or availability risks by purchasing a put or a call option. In the first scenario, the power producer purchases a put option to ensure that they are guaranteed a minimum price they will achieve for the power produced. In their second scenario, Pineda and Conejo (2013) suggests purchasing a call option, which gives the power producer the right to purchase power at a given price. They stipulate that many power producers rely on power producing units that may fail, and to mitigate the risk of needing to buy power in the spot market, power producers should purchase call options to ensure they fulfil their obligations.

In the context of this thesis, Pineda and Conejo's article provide an interesting insight into the possibilities options on power represents. However, the reader should note that it is unclear which market the authors are analyzing in their article.

Coherent with established academia within the field of financial derivatives, Pineda and Conejo highlight the value of having the option to postpone decision-making to a later period in which uncertainty is lower, i.e. whether to exercise an option or not. Both the options and forwards described in their article refer to financial derivatives that have physical settlement. As the reader recalls, the financial derivatives in the Nordic financial market for power are *financially* settled, which means there is no physical delivery of power. This removes possibility to directly hedge against availability risks, as the power producer will fall short of supply no matter which financial instruments are bought if a power producing unit fails. However, the power producer can turn to the spot market to buy the electricity needed and offset potential losses with financial gains on derivatives bought and exercised.

Thus, the rationale for buying the options still holds, as the financial flexibility this offers would be valued with power producers.

Relating the findings from Pineda and Conejo's (2013) article to Birkelund et al. (2015), the thesis authors see a paradox in that options have disappeared from the spectrum of financial instruments in the Nordic market. A discussion presenting our hypothesis will be held in *Chapter 11. Discussion: Where are the options?* where the possible explanations will be assessed.

2.5.2 *The Collapse of Metallgesellschaft: Unhedgeable Risks, Poor Hedging Strategy, or Just Bad Luck?* - Edwards and Canter (1995)

In their article published in *Journal of Futures Markets*, Edwards and Canter (1995) thoroughly evaluate the hedging strategy of MG Corporation, the US subsidiary of Metallgesellschaft A.G. (MG). The hedging strategy employed by MG during the mid-90's left the company, at the time the 14th largest industrial company in Germany, with staggering losses on its positions in energy futures and swaps. Only a $1.9 billion bailout from over 150 German and international banks kept the industry giant from bankrupting due to massive margin calls. To better understand what brought Metallgesellschaft to its knees, Edwards and Canter meticulously walk their readers through which future contractual obligations MG entered, and which financial derivatives they subsequently bought to *hedge* their position, with the goal of mitigating price risk of said obligations. They further describe which characteristics of the energy markets that, in combination with a poorly executed hedging strategy, inflicted massive losses on MG.

In the context of this thesis, the findings of Edwards and Canter (1995) highlight the importance of a well-executed hedging strategy where the underlying asset is of a volatile nature. Furthermore, as illustrated in the MG case, a vital aspect to consider when implementing a hedging strategy is the hedging ratio, defined as the value protected by the hedge divided by the total value of the position (Kenton, 2019b). Furthermore, the financial market characteristics for oil futures described by Edwards and Canter (1995) share many similarities as described by Haugom et al. (2019) for the Nordic power futures market. This enables the thesis authors to interpolate the findings of Edwards and Canter to assess how one can learn from the mistakes made by MG in the 90's when creating a hedging strategy.

An important aspect to note is that Saunders et al. (2016) in their book *Research Methods for Business Students* highlight a possible bias represented by reduced relevance if the article being reviewed is 'older' (Saunders, et al., 2019, p. 105). This might seem the case, as the article in question is over 25 years old. However, Saunders et al. (2016) present a checklist of criteria, that if met, also ensures relevance. Measured against these criteria, the article adequately meets every one of them. Additionally, the thesis authors view the findings of Edwards and Canter (1995) to be of relevance today as (1) the financial futures markets described exhibits similar characteristics to the ones observable today, (2) the hedging strategies described are possible to recreate today, and (3) to this date, vital findings from MGs hedging strategy are still important to note when creating a hedging strategy.

These literature sources pertaining to the Nordic power derivatives, the futures market, and hedging strategies, enables the reader of this thesis to better understand the framework in which the research question presented in the following chapter is framed and responded to.

3. Approach to research question

A research question is, according to Ib Andersen, developed to optimize a projects progress towards a more precise answer (Andersen, 2013, p. 49). It should be complex, thus require the use of academic literature and theories to optimally investigate the problem properly. The research question in this thesis is designed using the *research question model*, where factors such as motivation, empirics, perspective, objective and theories are considered (Ankersborg, 2011). This will be further elaborated in the following paragraphs.

3.1 Motivation for research question

The research question in this thesis should be designed so that it is interesting for the participants and stakeholders in the Nordic power derivatives market. In other words, the research question should be designed so that banks, market makers, speculators and hedgers all view its findings unbiased and interesting. Existing and relevant research about the Nordic market for power derivatives is limited. This entails an increased motivation for designing a research question that will have practical value and be relevant today and in the future.

3.2 Empirics

The research question should be designed so that quantitative and qualitative empirics must be employed for investigating the research question. Quantitative empirics mainly origin from Nasdaq, Bloomberg, and Montel, whereas qualitative empirics origin from interviews and past research within the field. Due to limited field research and the market's complexity and distinctiveness, the research question should be designed to have an inductive empirical- rather than a deductive empirical approach. The likelihood of finding applicable theories in a distinct market such as the Nordic power market is considered to be low. Thus, designing and testing theoretical hypotheses is challenging, and the likelihood of falsely rejecting or accepting hypotheses are high. With an inductive empirical approach, theories will instead be used to analyze observed data. This makes it easier to draw reliable conclusions from the thesis' investigations (Andersen, 2013, p. 31).

3.3 Perspective

It is important that the thesis perspective and the research design are consistent with the research question. The research question sets the foundation of the thesis and indicates whether the thesis should be subjective or objective, and with an exploratory-, descriptive-, explanatory- or normative design (Ankersborg, 2011). The complexity of the Nordic market for power derivatives indicates that the thesis should have a descriptive research design in order to be able to describe market characteristics. Given the lack of existing clarifying field studies, the thesis should apply an exploratory research design, as one of the research objectives, entail investigating a lesser known market (Andersen, 2013, p. 20). Finally, the thesis will have an objective quantitative design as most of the empirics originates from reliable quantitative sources. In other words, by considering the discussed perspectives, the research question should be designed to support an objective and explorative thesis with a descriptive quantitative research design (Ankersborg, 2011).

3.4 Objective & Theories

When investigating the research question, the main objective is to explore and develop a practical-, technical-, and financial understanding of the market for Nordic power derivatives. Furthermore, this understanding is used to optimize power hedging strategies and to understand how different strategies are affected by market premiums. These objectives are fulfilled by applying theories such as *Fisher*

Blacks model for valuing options, futures- and forward pricing models, as well as econometric- and statistical theory.

3.5 Presentation of research question

Based on the above discussion of the research question model, the following research question has been formulated for this thesis:

"Are derivative pricing premiums present in the Nordic power market, and how do these influence hedging strategies?"

The following sub-questions are designed to answer the research question methodically:

1. *Which theories are used to research derivative pricing premiums and hedging strategies?*
2. *How is the market for Nordic power derivatives structured, and which market concepts and mechanisms are important?*
3. *Which Nordic power derivatives are suitable to be included in hedging strategies today and in the future?*
4. *How has the Nordic system price and futures prices developed historically and is seasonality present in prices?*
5. *Are historical premiums present in liquid Nordic power derivatives?*
6. *How can a hedging strategy be structured using the findings about derivative pricing premiums in the market?*

4. Topic delimitations

When investigating the research question a clear and detailed topic delimitation is important. Most analyses in this thesis are based on quantitative data, thus most delimitations are based on data limitation boundaries. All delimitations are explicitly stated below.

Topic delimitations

General delimitations	
Market	This thesis is exclusively a study limited to the Nordic power market and its market participants. Other markets are not taken into consideration.
Data period	Futures trading data are gathered from 1st of January 2013 to 31st of December 2019. Option trading data extends to 28th of February 2020. There is no period limitations on qualitatitve data.
Market premium	Market premiums are denoted by volatility risk premiums on options and forward premiums on futures.
Forward Premium analysis	
Data frequency on system price	The system price is recorded at a 30-minute basis.
Data frequency on derivatives	Futures and option trading data are collected on a daily basis.
Open Interest on options	The liquidity analysis on options are solely based on available trading data on Nasdaqomx.com per 28th of February 2020. Due to limited availability of up to date option data, the thesis assumes this data returns a correct representation of Nordic power option liquidity.
Futures settlement structure	Settlement structure of Nordic power futures vary depending on futures being average rate futures or standard futures. To decrease complexity, all futures are assumed to have settlements equal to the ex-post difference in the average futures price and the average system price in current period.
Hedging	
Locational Marginal Pricing	The system price is used as a proxy for all locational prices on physical power within the Nordic countries.
Offset hedging and market positions	Optimal hedging strategies are based upon the assumption of both suppliers and producers aiming for offset hedges. Furthermore, it is assumed that producers (suppliers) continuously hold a long (short) position in the system price.

5. Method

5.1 Research design

Chapter 3. Approach to research question stated that the research question is designed to support the use of both quantitative and qualitative data collection techniques. According to Saunders et al. (2019) a research paper based on multiple research methods have a *mixed methods research design*. Furthermore, the thesis is categorized as having a multiple-phase structure. First, qualitative sources, such as past literature and interviews, are assessed to understand the market and what to expect when conducting quantitative analyses in the subsequent phase. The following phase evaluates hedging strategies based on qualitative data before the final quantitative analysis is conducted. In other words, the thesis has a structure based on multiple phases of data collection and analyses defined as a *sequential multi-phase research design* to better support quantitative findings with qualitative findings and vice versa (Saunders, et al., 2019, p. 170) (Andersen, 2013).

Pragmatism and *critical realism* are two research philosophies often linked with the *mixed methods research design*. According to pragmatists, research starts with a defined problem where the findings will contribute to practical solutions in the future. Theories and concepts are not considered in its abstract form, but *"in terms of the roles they play as instruments of thoughts and action, and in terms of their practical consequences in specific contexts"* (Saunders, et al., 2019, p. 143). Pragmatism is a philosophy suitable for developing deep understandings of historical events and make the understanding beneficial in the future. The philosophy has especially been important when interpreting forward premium findings in *Chapter 10. Forward premium analysis* and to exploit these findings constructing hedging strategies in *Chapter 12. Hedging*. Critical realism, on the other hand, is a philosophy that views reality as external and independent, and everything that can be experienced are only manifestations of the real world. Researchers employing critical realism aim to be as objective as possible and highlights the importance of viewing the larger picture (Saunders, et al., 2019, p. 138). The fact that researchers within critical realism focus on providing explanations for observable events looking at underlying causes, makes the critical realism philosophy applicable to this thesis as observable samples are used to obtain an impression of the reality. Thus, the thesis is based both on pragmatism and critical realism to obtain findings that are objective, practical and applicable in the future.

5.2 Data collection

This thesis is based on quantitative and qualitative data gathered from both primary- and secondary sources. The use of secondary sources is done with a critical view to increase reliability and validity (Andersen, 2013, p. 84). The secondary sources used in the thesis mainly origin from large market participants, market makers and market analysts such as Nasdaq, Bloomberg, Montel, Nord Pool and

Markedskraft. Furthermore, secondary literature such as articles, research papers, and books are used to complement the secondary sources collected from mentioned participants. Additionally, primary data has been collected by conducting research interviews with market experts, aiming to support, complement, and fulfill findings from secondary data. Finally, hedging optimization based on qualitative and quantitative findings are conducted in *Chapter 12. Hedging* to assess which hedging strategies that are most optimal.

5.2.1 Quantitative data

Quantitative trading data on futures are collected from Montel, a European information provider for power markets (Montel, 2020). Data points collected from Montel are *Open*, *High*, *Low*, *Close*, *Volume* and *Open Interest* on futures, quoted daily in from January 2013 to December 2019.

Nasdaq OMX Commodities are used for data collection on options on futures. However, due to limited publicly available information, data regarding options on futures only consist of publicly available data collected on the 28th of February 2020. In other words, option data only consist of *Volume*, *Daily Fix*, *Open Interest,* and contract size in a three-month perspective. The quantitative data collected from Nasdaq are assumed to be highly relevant as they are up to date, and the patterns they exhibit are confirmed by industry experts at Nasdaq (Appendix 5). Therefore, as stated in *Chapter 4. Topic delimitations*, it is assumed that option trading analysis can be completed studying the data set at hand.

The period chosen when collecting data on futures range from 2013 throughout 2019. Research that consider several observations for many years are defined as longitudinal and results in a powerful insight of development throughout time (Saunders, et al., 2019, p. 148). As the thesis aims to use historical data to investigate whether a forward premium exist and to use findings to optimize hedging strategies in the future, longitudinal studies are assumed to be optimal. Furthermore, seven years of historical data are collected for the analyses to diminish non-recurring events' impact on findings and conclusions. As mentioned in *Chapter 1. Introduction and Motivation*, market regulations affecting trading of OTC derivatives on Nordic power were introduced in 2016. A data period lasting from 2013 to 2020 is chosen to obtain sufficient data points before and after the regulation change. Three years of trading data before the change in trading regulations are assumed to be sufficient to develop understandings of how the market functioned before the change. Furthermore, the market is assumed to have stabilized three years after the introduction of new regulations, thus data collected from 2016 to 2020 are representative for how the market has developed and functioned after regulations.

5.2.2 Qualitative data

Qualitative data are collected from past literature and research in the field, observations of the market, as well as from conducted interviews. The type of interviews conducted vary with the interviewee and the purpose of the interview.

Two of the interviews in the thesis are conducted with the industry expert Torbjørn Haugen (LinkedIn, 2020). The first interview was conducted in the early stages of the thesis with an exploratory intent. Saunders et. al (2019) states that exploratory interviews in an early phase of the research should be non-standardized and semi-structured. In other words, the first interview with Mr. Haugen were based on an interview guide consisting of a predetermined list of themes, with sub-question aimed at guiding the interviewee within the phases. The interview themes and the transcribed interview are found in Appendix 1 and 2, respectively.

The second interview with Mr. Haugen was more structured, as questions were more specific and based on the authors qualitative and quantitative findings. Interviews that evolve from being explorative to more concrete is by Saunders et. al (2019) defined as convergent interviews. One advantage of conducting convergent interviews is that it is an efficient way of converging on important aspects in a research process. Interview themes and the transcribed interview are found in Appendix 3 and 4.

The second interviewee was derivatives expert Knut Rabbe. Mr. Rabbe's interview was of a structured nature, as questions were specific and based on the authors qualitative and quantitative findings. Additionally, mail correspondence with Mr. Rabbe prior and after the interview was conducted to clarify key elements. Mail correspondence and the transcribed interview is found in Appendix 5.

5.3 Data quality issues

Data quality needs to be considered when collecting data from primary- and secondary sources. On the next page is a table containing various issues related to data used in the thesis.

Figure 5.1: Data quality issues

Data type	Threat	Impact
Quantitative data		
• Montel • Nasdaq • Nord Pool	Researcher error	Reliability
	Researcher bias	Reliability
	Past events	Validity
	Instrumentation	Validity
Qualitative Data		
• Interviews	Time of interview	Reliability
	Interviewer bias	Reliability
	Interviewee bias	Reliability

Source: Authors' own creation

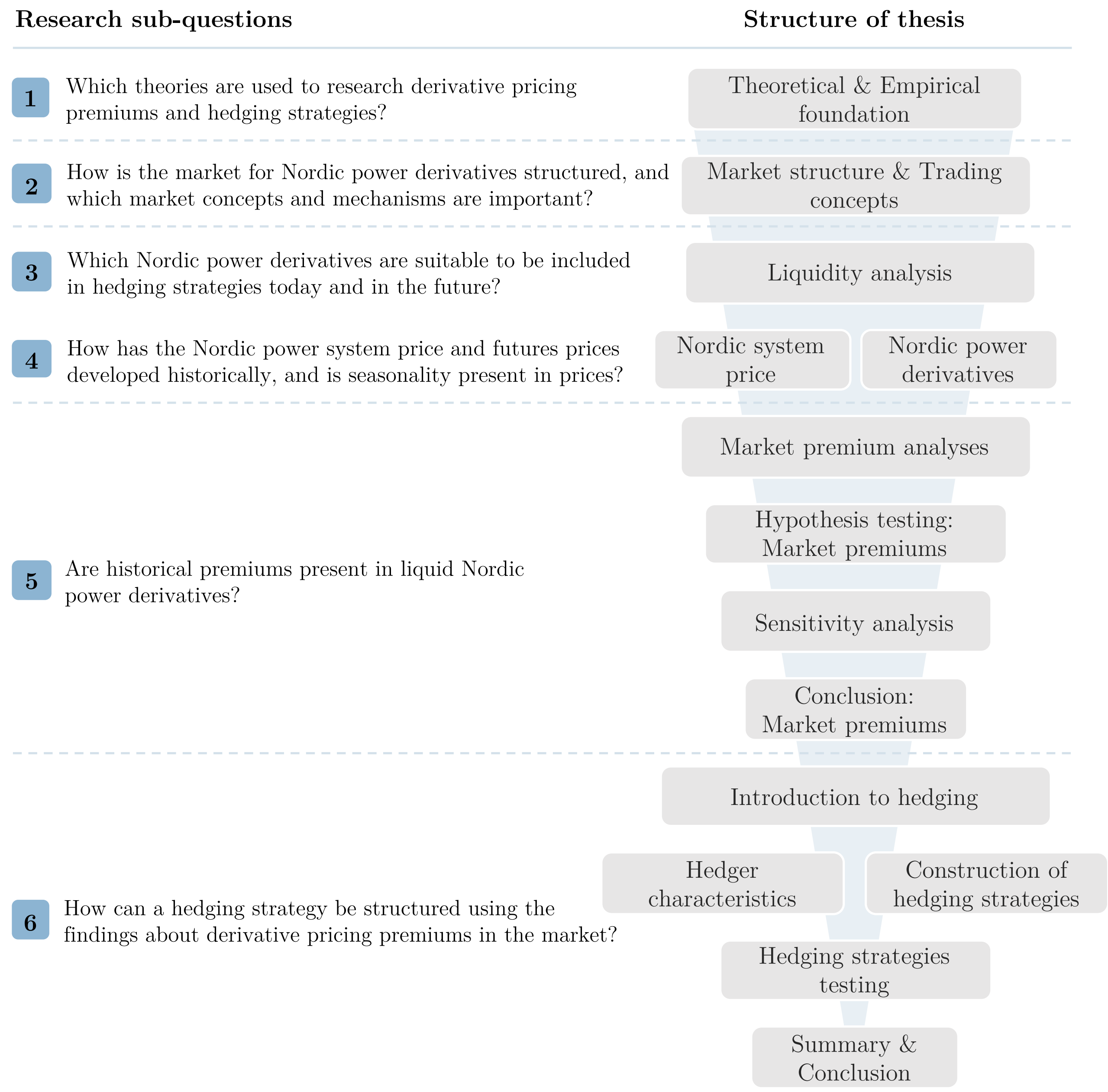
Quantitative data may have reliability and validity issues. Data interpretations may be influenced by researcher errors, i.e. misunderstandings, and researcher biases, i.e. subjectivity, which in turn may influence the data analyses. The quantitative data validity may be affected by past events and fundamental changes in financial instruments (Saunders, et al., 2019, p. 204). To limit these issues, findings and calculations are closely monitored, and in-depth research and interviews are conducted to identify negative data impacts such as regulatory changes and delisting of derivatives.

Qualitative data may be affected by reliability issues. The timing of interviews has an impact on later interview replications as markets develop, and interviewer- and interviewee biases may impact information gathered from interviews (Saunders, et al., 2019). This especially holds true for semi-structured interviews, and the authors have chosen to conduct all interviews together consequently to decrease the probability of interview biases.

5.4 Thesis structure

One of the most important attributes of the method section in a thesis is to have a clear approach, thus, give other researchers the possibility of constructing similar research and/or test findings in the future (Andersen, 2013, p. 16). Research design, data collection and issues regarding the data collection have been presented, and findings on how to limit data quality issues have been discussed. In addition, the research question clearly states the purpose of the thesis. In other words, to complete the method section it is important to design a clearly and defined structure of the research. Below is a figure visualizing the structure of the thesis which is designed to optimally answer sub-questions and the research question stated in *Chapter 3. Approach to research question*. Each chapter is structured with an introduction explaining which sub-question will be answered, followed by subsequent analyses and summaries.

Figure 5.2: Structure of Thesis



Source: Authors' own creation

6. Theories

It is important to establish a broad and concise theoretical basis to successfully investigate the research question. By answering the sub-question *"Which theories are used to research derivative pricing premiums and hedging strategies?"* readers are provided with a theoretical foundation to better understand conducted data processing, analyses and conclusions in this thesis.

6.1 Options explained

Options are a subset of financial derivatives that gives the option holder the right, but not the obligation to purchase or sell the underlying asset at an agreed upon price. Dependent upon the market view of the market participant, a long or short position in the underlying asset can be achieved by either buying or issuing various styles of options. In the following paragraphs, the most common types of options used on the power market will be explained both in theory and practice.

Options can either be American or European, which refers to when an option can be exercised. American options can be exercised at any time up to its expiration date, whereas a European option is exercisable only on its expiration date (Hull, 2018, p. 235). Options traded with power futures as the underlying asset are exercised as European styled options (Nasdaq, 2018). European style options are further divided into put and call options[3]. A call option is defined as *the right, but not the obligation to buy the underlying asset*, in other words, the investor buying a call-option has a market view that the underlying asset will increase its intrinsic value. A put option is defined as *the right, but not the obligation to sell the underlying asset*, which entails the investor buying a put option is betting on a decrease in value of the underlying asset (Hull, 2018, p. 235).

In addition to European options, a common type of options traded with power are called Asian options, a subset of *exotic options*. The payoff from an Asian option is determined by the average price of the underlying asset over a pre-determined time period (Chen, 2018). Asian options are often used when the underlying asset is highly volatile and is thus a good fit for electricity due to its intrinsic volatility.

[3] The same holds true for American options, however, they are not traded in relation to Nordic power.

In order to purchase either a put or call option, the investor requires a counterparty to issue the options, often referred to as the *option writer*. The writer of an option receives cash up front for the option but is potentially liable at the exercise date should the option purchaser chose to exercise their right to either buy or sell the underlying asset (Hull, 2018, p. 237). This entails that there are four types of option positions: (1) a long position in a call option, (2) a long position in a put option, (3) a short position in a call option and, (4) a short position in a put option.

It is often useful to characterize a European option in terms of payoff to the purchaser of the option, in which the initial cost of the option is excluded. If K is the options' strike price and S_T the price of the underlying asset at expiration, the payoff from a long position in a European call option is expressed as

$$max(S_T - K, 0) \qquad \textit{Equation 1}$$

This reflects the underlying rational mechanism that the option will only be exercised if $S_T > K$ and will not be exercised if $S_T \leq K$. The payoff from a short position in the European call option is

$$-\max(S_T - K, 0) = \min(K - S_T, 0) \qquad \textit{Equation 2}$$

The payoff from a long position in a European put option is

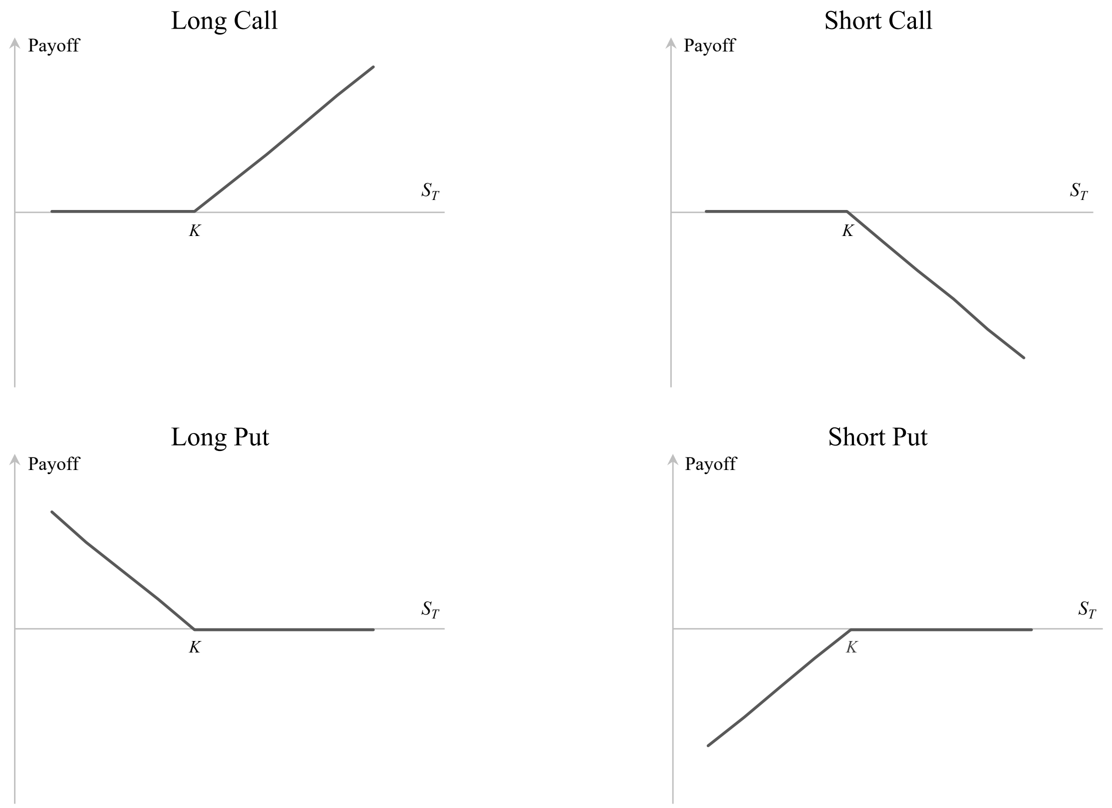
$$\max(K - S_T, 0) \qquad \textit{Equation 3}$$

and the payoff from a short position in a European put option is

$$-\max(K - S_T, 0) = \min(S_T - K, 0) \qquad \textit{Equation 4}$$

To better understand the payoffs, *figure 6.1* illustrates the various examples.

Figure 6.1: Options payoff



Source: Authors' own creation

The formulas for payoffs are presented in their generic form with the underlying asset being a stock, however, the payoffs are identical when the underlying is a futures contract. The practical interpretation of this is substituting S_T with F_0 (Hull, 2018, p. 414). A common misconception regarding options on futures is that the underlying asset is the spot price relevant to the future, however this is incorrect. The notation F_0 is the *futures* price at the time of the exercise.

Options are usually valued by utilizing the *Black-Scholes-Merton model*, however, options on futures are most commonly valued by using the *Black-model*. The reason for this is that the *Black-model* does not require the estimation of the income (or convenience yield) of the underlying asset. By using the futures or forward price, it incorporates the market estimates of said income (Hull, 2018, p. 416).

Fisher Black was the first to accurately value European futures options in his article *The Pricing of Commodity Contracts* first published in 1976 (Hull, 2018, p. 414). Assuming that the futures price follows a lognormal process, the European call price *c* and the European put price *p* for futures options are

$$c = e^{-rT}[F_0N(d_1) - KN(d_2)] \qquad \textit{Equation 5}$$

$$p = e^{-rT}[KN(-d_2) - F_0N(-d_1)] \qquad \textit{Equation 6}$$

Where,

$$d_1 = \frac{\ln{(F_0/K)} + \sigma^2T/2}{\sigma\sqrt{T}} \qquad \textit{Equation 7}$$

$$d_2 = \frac{\ln{(F_0/K)} - \sigma^2T/2}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \qquad \textit{Equation 8}$$

$$N(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx \qquad \textit{Equation 9}$$

$$= cumultative\ distribution\ function\ of\ standard\ normal\ distribution$$

and σ is the volatility of the futures price, F_0 is the futures price, K is the strike price, *r* is the risk-free rate and T the time to maturity (Hull, 2018, p. 414).

When determining an option premium, there are mainly two aspects worth considering; intrinsic value and time value. The intrinsic value of an option is an option's inherent value, illustrated by the spread between the option's strike price and the current spot price. Should a call option have a strike of €40 and the underlying asset currently is trading at €45, the intrinsic value is €5. However, the option in this example might trade at €7, where the additional €2 is, 'unaccounted for', and is what makes for the time value. The price of time value is the additional price premium that represents the time to maturity. This is influenced by a range of factors from interest rates, stock- and strike price, and implied volatility. Of these factors, implied volatility is the most significant factor (Kohler, 2019).

Having identified the various parameters needed to price an option, one can consider reverse engineering implied volatility from the option's quoted price. The exercise price is known, and the price of an option, the price of the underlying asset, risk-free rate, and time to maturity are all observable in the financial markets, which together can yield the implied volatility. This implied volatility indicates whether an option is ‘cheap’ or ‘expensive’ relative to its previous price trajectory. If the implied volatility of an option rises, as will the price of said option; with the opposite also being true for declining implied volatility and declining prices. How an option might respond to changes in implied volatility will depend on a range of factors, such as time to maturity, and their degree of in-the-moneyness (out-of-moneyness / at-the-moneyness). Studying the development of the implied volatility over time will indicate how market participants are anticipating the underlying asset will develop over time (Kohler, 2019).

Ex-post comparison of an option’s implied volatility with realized volatility indicate whether the option *was* cheap or expensive. Options with higher implied volatility than realized volatility have been expensive, indicating that a volatility risk premium have been present in the market. The mechanism for market participants buying options at a premium are often associated with either inefficient markets or that the option purchaser is willing to pay more to achieve volatility risk mitigation from the underlying asset.

6.2 Futures explained

Futures contracts are a subset of financial derivatives that constitutes a legal agreement to buy or sell a certain commodity asset or security at a predetermined price at a specified time in the future (Hull, 2018, p. 30). Dependent upon the market view of the market participant, a long or short position in the underlying asset can be achieved by either purchasing or selling a futures contract. In the following paragraphs, futures and futures pricing theory will be explained in relation to the theory of storage.

When buying a futures contract, the buyer is usually obligated to buy and receive the underlying asset when the futures contract expires (Hull, 2018, p. 30). Similarly, the seller of a futures contract is obligated to provide and deliver the underlying asset at the expiration date. However, when it comes to the delivery and reception of the underlying asset, the settlement procedures vary dependent upon the counterparties in the transactions. Speculators are seldom interested in the physical reception or delivery of the underlying asset and will “close out” their position by entering an opposing trade to cancel out their original position or selling the contract at the market. Additionally, there exists contracts that never entail physical delivery, but rather constitute a cash settlement calculated as the spread between the spot price in the delivery period and the agreed upon futures price. Such a contract is considered to be *financially settled*, and due to the nature of the underlying product, all power futures traded on the Nordic power market are financially settled.

As can be deduced from the titles in the literary review, both futures- and forwards contracts have traded with Nordic power as the underlying asset. To understand the current offering of financial products, it is useful to consider the historical derivatives traded with Nordic power as the underlying asset. A *futures* contract is a standardized, legally binding contract between two parties outlining the details of the transaction. A *forward* contract is similar to a futures contract in the aspect that they both trade on the same underlying asset, but a forward contract trades over-the-counter (OTC) and have customizable terms (Hull, 2018, p. 28).

To potentially increase the confusion, a derivative called *DS Futures* has historically been traded, and was a hybrid between a futures contract and a forward. A DS Futures was a so-called *deferred settlement* futures contract, where mark-to-market value were accumulated in the trading period and realized in the delivery period (Nasdaq, 2020a). Due to their settlement structure, DS Futures were essentially traded as forward contracts (Reuters, 2015), where contract holders needed to provide only 20 per cent of equity thus levering their positions (Appendix 2). However, as the European Union in the years after the financial crisis of 2008 identified significant risks in OTC derivatives markets, the EU adopted the European market infrastructure regulation (EMIR) in 2012. EMIR aimed to increase transparency in the OTC derivatives market, mitigate credit risk and reduce operational risk (European Commission, 2020a). As a result of this, Nasdaq moved their market making from *DS Futures* to futures on the 21st of November 2016. As some DS Futures had a long time to maturity, some remaining contracts are still being traded, but Nasdaq continuously remove contracts where the open interest is zero. Additionally, Nasdaq offers their customers to convert DS Futures to regular futures, to increase the trading volume in these (Appendix 5). This has led to ordinary futures contracts being the most traded financial derivative with Nordic power as the underlying asset.

The futures contracts being traded have a delivery period of either days, weeks, months, quarters, or years. In some of the contracts, the futures contract will *cascade* into other futures contracts. An example of cascading is quarterly contracts, which on expiry will cascade into three monthly contracts spanning the same delivery period as the quarter (Nasdaq, 2020a).

6.2.1 Valuing futures

The price of a futures contract is determined by a set of assumptions that in a liquid market holds true. Courtesy of arbitrageurs, the price of a futures contract without income or yield is determined by:

$$F_0 = S_0 e^{rT} \qquad \textit{Equation 10}$$

Where, F_0 is the price of the futures contract at time t, S_0 is the spot price of the underlying at time t, r is the interest rate and T is the time to maturity (Hull, 2018, p. 149). As the futures on the Nordic power market are financially settled, there is no physical storage of the commodity, in this case, power. Thus, there is zero known income generated by the underlying asset in the holding period.

Having assessed the standard method for futures pricing, it is useful to consider the two most popular schools for explaining the pricing of the underlying contracts. It is important to note that the two schools offer alternative, but not competing views on how futures pricing can be explained.

6.2.2 The theory of storage

The theory of storage by Kaldor (1939), Working (1948) and Brennan (1958) explains the spread between the current spot price and the current futures price, with factors such as interest forgone by storing the underlying commodity, warehouse costs and a convenience yield on the inventory. One recalls that power futures differ from traditional futures due to their financial settlements. Additionally, the storage of power is only done as a price-arbitrage play; and is not economically viable in a large scale in most states of the market. This implies that the explanation of difference between the current spot price and the current futures price, probably lies elsewhere.

6.2.3 Forward premium

The article *Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage* by Eugene F. Fama and Kenneth R. French (1987) finds that the spread between the current futures price and the current spot price can be expressed as the sum of an expected premium and an expected change in the spot price. The generic formula is expressed as:

$$F_{t,t+T} - S_t = E_t[S_{t+T} - S_t] + FP_{t+T}^{ea} \qquad \textit{Equation 11}$$

Where $F_{t,t+T}$ is the futures price at time t with a holding period of T and delivery in $t + T$, and S_t is the spot price at time t. From Fama and French's (1987) definition, the forward premium FP_{t+T}^{ea} is the expected, ex-ante, forward premium expressed as:

$$FP_{t+T}^{ea} = F_{t,t+T} - E_t[S_{t+T}] \qquad \textit{Equation 12}$$

The issue of determining the ex-ante forward premium lies in the last term of the equation, the expected spot price, $E_t[S_{t+T}]$. As the expected spot price is subject to the model applied to induce an expected spot price from market data, the common practice by researchers is to investigate the ex-post forward premium, defined as:

$$FP_{t+T}^{ep} = F_{t,t+T} - S_{t+T} \qquad \textit{Equation 13}$$

Where S_{t+T} is the realized spot price in delivery period $t + T$. The relationship between the ex-post and the ex-ante forward premium can be expressed as follows:

$$FP_{t+T}^{ep} = FP_{t+T}^{ea} + E_t[S_{t+T}] - S_{t+T} \qquad \textit{Equation 14}$$

This means that the ex-post forward premium is the sum of the ex-ante forward premium and the spread between the realized spot price and the expected spot price.

Having assessed how futures contracts work and how they are priced, a practical assessment on the markets they trade will be performed in *Chapter 7. Definitions*.

6.3 Ordinary Least Squares (OLS) regression

Ordinary Least Squares (OLS) regression is a method used to analyze the relationship between variables. This thesis utilizes OLS regression to test whether potential systematic forward premiums are statistically significant. The regression can be both univariate, with one explanatory variable, or multivariate with multiple variables. An ordinary least squares regression is based upon minimizing the squared distance between data points and estimated parameters. This subsection explains the fundamental principles of OLS regression models and how to test its assumptions. Furthermore, theories outlining significance tests are explained and illustrated. Finally, the thesis' application of the unbiased forward rate hypothesis (UFH) is explained by the use of standard OLS regression theory.

6.3.1 Univariate linear regression

The univariate linear regression model consists of one explanatory variable and one response variable. The model is regressed using the following formula (Weisberg, 2005, p. 19):

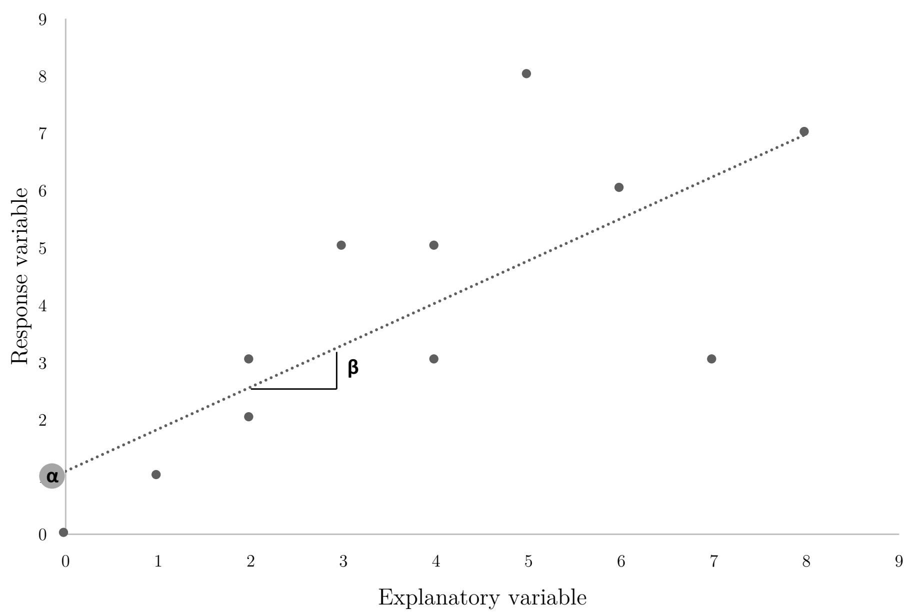
$$y = \alpha + \beta x_i + \epsilon_i \qquad \textit{Equation 15}$$

In a linear regression model, two parameters are estimated. The first parameter, alpha (α), is equal to the regressed intercept, whereas the second parameter, beta, is interpreted as the rate of change in response variable (y-axis) if explanatory variable (x-axis) changes by one unit. The standard formula for α and β is shown below together with a graphical illustration of the two parameters and response- and explanatory variables (Weisberg, 2005, p. 21).

$$\alpha = \overline{y} - \beta\overline{x}, \qquad \overline{x} = \frac{\sum x_i}{n}, \qquad \overline{y} = \frac{\sum y_i}{n} \qquad \textit{Equation 16}$$

$$\beta = \frac{\sum(\mathrm{x_i} - \overline{\mathrm{x}})(\mathrm{y_i} - \overline{\mathrm{y}})}{\sum(x_i - \overline{x})^2} \qquad \textit{Equation 17}$$

Figure 6.2: Ordinary Least Squares Regression illustrated



Source: Authors' own creation

Both α and β is estimated to minimize the sum of squared errors of each data point, where error of each observed data point is calculated as:

$$\epsilon_i = y_i - \alpha - \beta x_i \qquad \textit{Equation 18}$$

When using OLS regression the following assumptions are made (Frost, 2018):

1. Data generating process is linear: $y_i = \alpha + \beta x_i + \epsilon_i$.
2. n observations of x_i are fixed numbers.
3. n error terms ϵ_i are random, with $E(\epsilon_i) = 0$.
4. Variance of n errors is fixed: $E(\epsilon_i^2) = \sigma^2$.
5. Errors are uncorrelated: $E(\epsilon_i, \epsilon_j) = 0 \; \forall \; i \neq j$.
6. α and β are unknown but fixed for all observations.
7. $\epsilon_1, \dots, \epsilon_n$ are jointly normally distributed.

6.3.2 OLS regression with seasonal dummy variables

An OLS regression with dummy variables is defined as a model which includes binary coded variables. An OLS regression with *j* categories has a total of $j - 1$ dummy variables, and the category not given a dummy is defined as the reference group (Hardy, 1993, p. 8). An OLS regression with four seasonal categories and winter as the reference group has the following formula:

$$Y_i = \alpha + \beta * x_i + D_{spring} * x_{spring} + D_{summer} * x_{summer} + D_{fall} * x_{fall} + \epsilon_i \qquad \textit{Equation 19}$$

The seasonal x's from the model are binary dummy variables and have a value of one if the observations are recorded within its associated category and a value of zero otherwise. The D-values are regression coefficients associated with the dummy variables affecting the value of Y positively or negatively. A positive regression coefficient indicates increasing values of Y_i for the associated category in relation to the reference group (Hardy, 1993, p. 20).

6.3.3 Testing OLS regression assumptions

There are several statistical tests that can be conducted to test whether the aforementioned regression assumptions hold. Below is a table with the tests this thesis performs, as well as graphical visualizations that are used for assumption testing. In addition, the table provides an overview of highlighted consequences of failing to fulfill assumptions, as well as possible actions to limit or remove these consequences.

Figure 6.3: Testing OLS regression assumptions

Statistical test or graphing	Related to	Consequence of failure	Possible Actions
• **Scatterplot with x and Y**	• Assumption 1 • Assumption 6	• OLS estimates not optimal	• Change regression • Log transformation
• **Residual plot with x** • **Standardized residual plot**	• Assumption 3 • Assumption 4 • Assumption 5	• Confidence intervals may be either too narrow or wide • Type I and/or II errors	• Weighted least squares regression • Log transformation • Newey-West robust standard error correction
• **Breusch-Pagan / Cook-Weisberg test**	• Assumption 4	• Error variances not fixed • Confidence intervals may be either too narrow or wide • Type I and/or II errors	• Newey-West robust standard error correction
• **Durbin-Watson test**	• Assumption 5	• Confidence intervals may be either too narrow or wide • Type I and/or II errors	• Newey-West robust standard error correction
• **Shapiro-Wilk test**	• Assumption 7	• Lack of normality within residuals • Confidence intervals may be either too narrow or wide • Type I and/or II errors	• Newey-West robust standard error correction

Source: Authors' own creation

The common consequences of inaccurate confidence intervals are type I and II errors. A type I error occurs if a null hypothesis is falsely rejected, whereas a type II error is defined as a failure to reject the null hypothesis when the alternative hypothesis are true (Campbell, Lo, & Mackinlay, 1997, p. 204). In other words, a significance test experiencing a type I or II error may return incorrect test statistics, resulting in wrong interpretations about regression estimates' model importance.

Breusch-Pagan / Cook-Weisberg test

Breusch-Pagan / Cook-Weisberg test is a test used for testing heteroscedasticity. The test's null hypothesis states that the residuals has a constant variance, and the test can be conducted in Stata using the "*estat hettest*" code (Coca Perraillon, M., 2017) (Appendix 9) (File 6, 7 & 8).

Durbin-Watson test

Durbin-Watson is a test statistic testing whether it exist autocorrelation in the regression residuals. The null hypothesis states that there is no first order autocorrelation, whereas the alternative hypothesis states that first order autocorrelation exist (Beran, Yuanhua, & Hebbel, 2015, p. 423). The following formula in Stata is used for calculating Durbin-Watson test statistics:

$$DW = \frac{\sum_{t=2}^{T}(\hat{\epsilon}_t - \hat{\epsilon}_{t-1})^2}{\sum_{t=1}^{T}\hat{\epsilon}_t^2} \qquad \textit{Equation 20}$$

Figure 6.4: Durbin-Watson test statistic interpretation

DW Test Statistics	Interpretation
DW = 2	No autocorrelation
0 < DW < 2	Positive autocorrelation
2 < DW ≤ 4	Negative autocorrelation

Source: - Authors' own creation

Shapiro-Wilk test

The Shapiro-Wilk test calculates W statistics that tests if a variable is normally distributed. Small statistical values may be evidence of non-normality. W statistics are calculated utilizing following formula (Shapiro & Wilk, 1965):

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \overline{x})^2}, \qquad \textit{Equation 21}$$

$$x_{(i)} = ordered\ sample\ values, \qquad a_i = constants\ from\ mean, var\ and\ covar\ table$$

6.3.4 Actions when OLS assumptions do not uphold

Figure 6.4 highlights the Newey-West robust standard error correction as an action to employ when assumptions are violated related to regression residuals. This can be explained by the structure of the errors are found to be heteroscedastic with possible autocorrelation in lags, indicating that some regression assumptions do not hold. Regressions with Newey-West corrections are conducted using *"newey"* in Stata in combination a maximum lag order of autocorrelation found by looking at the partial autocorrelation plot for the explanatory variable. To correct regression coefficient variances using Newey-West theory, Stata utilize the following formula (Stata, 2020):

$$\boldsymbol{X}'\widehat{\boldsymbol{\Omega}}\boldsymbol{X} = \boldsymbol{X}'\widehat{\boldsymbol{\Omega}}_{\boldsymbol{0}}\boldsymbol{X} + \frac{n}{n-k}\sum_{l=1}^{m}\left(1-\frac{l}{m+1}\right)\sum_{t=l+1}^{n}\hat{e}_t\hat{e}_{t-l}(\boldsymbol{x}_t'\boldsymbol{x}_{t-l} + \boldsymbol{x}_{t-l}'\boldsymbol{x}_t) \qquad \textit{Equation 22}$$

$$where;\ \boldsymbol{x}_t = row\ in\ the\ \boldsymbol{X}\ matrix\ at\ time\ t$$

Logarithmic transformation can also be used when regression assumptions do not hold. A transformation using the natural logarithm is common when solving issues related to non-linear relationships and highly skewed variables (Benoit, 2011). The following formula is regressed when conducting logarithmic transformation:

$$\log Y_i = \alpha + \beta \log x_i + \epsilon_i \qquad \textit{Equation 23}$$

6.3.5 Significance test – Univariate linear regression

A significance test can be conducted to test whether parameters estimated in the OLS regression are significantly different from a specified value. A significance test can be completed utilizing the student t-test as OLS regression assumptions are considered valid. This can be done as the data is assumed to have independent and normally distributed error terms (Reliawiki, 2019). The t-test is testing the null hypothesis of whether the true regression coefficient is equal to a constant value. In other words, to test whether an alpha coefficient is significantly different from zero the following hypothesis test is conducted:

$$H_0: \alpha = 0, \qquad H_1: \alpha \neq 0$$

The significance test is done by first calculating t-values and thereafter compare it to critical values and p-values:

$$t - value = \frac{\left(\hat{\alpha}_{OLS,i} - \alpha_i\right)}{\sqrt{\widehat{Var}\left(\hat{\alpha}_{OLS}\middle|\underline{x}\right)}} \sim t(n-k) \qquad \textit{Equation 24}$$

The null hypothesis is rejected if the calculated t-value is more extreme than the critical value determined by the student t-distribution, degrees of freedom, and significance level. A rejection of the null hypothesis indicates that the alpha parameter is different from zero. Thus, it can statistically be concluded that the alpha parameter is significant.

6.3.6 Significance tests – Multivariate linear regression

When introducing dummy variables to a regression, an F-test can be conducted to test whether the regression coefficients simultaneously equals zero. The formula for F-test and its distribution are presented below (Hardy, 1993).

$$F - test = \frac{\frac{RSS_R - RSS_{UR}}{q}}{\frac{RSS_{UR}}{n-k-1}} \sim F_{q,n-k-1} \qquad \textit{Equation 25}$$

where,

$$q = number\ of\ restrictions, \qquad RSS_R = Restricted\ residual\ sum\ of\ squares$$

$$RSS_{UR} = Unrestricted\ residual\ sum\ of\ squares, \qquad n = number\ of\ observations$$

$$k = parameters\ in\ unrestricted\ model$$

Furthermore, t-values can be calculated to test the significance of the effect allocated to observations located in different categories than the reference group.

6.3.7 Unbiased forward rate hypothesis

The unbiased forward rate hypothesis (UFH) applies OLS regression theory to test the null hypothesis stating that futures prices are unbiased predictors of future spot prices (Hatemi-J & Roca, 2012). The regression formula considered in the hypothesis is

$$S_{i,t+1} = \alpha + \beta F_{i,t,t+1} + \epsilon_{i,t+1} \qquad \textit{Equation 26}$$

Where $S_{i,t+1}$ in the thesis equals the system price in a period and $F_{i,t,t+1}$ equals the futures price at time t with delivery in the same period (Haugom & Ullrich, 2012, p. 1935). For the null hypothesis to hold, the regression coefficient α should be equal to zero and β be equal to one. An α significantly different from zero may be evidence of a present systematic forward premium, which indicates that an overall forward premium is present on the market and that premiums not solely rely on individual observations. To test whether α is significantly different from zero the significance test defined in *Section 6.3.5 Significance test - Univariate linear regression* is performed.

6.4 Hedging and portfolio theory

Derivatives are often included in hedging strategies with the hedgers aiming to reduce a particular risk (Hull, 2018, p. 71). There exist different risk measurements, with volatility being one of the most usual. As a result of this, many hedgers use strategies aiming to minimize their total variance. For this strategy to hold it is assumed that investors have behaviours explained by a quadratic utility function, and that asset returns have a multivariate elliptical distribution. In other words, it assumes that the mean-variance framework is the most optimal. However, researchers such as Scott and Horvath (1980) found that hedgers have preferences related to higher moments of return as well, making *Value at Risk (VaR)* a good risk measure as it considers standard deviation, skewness and kurtosis when returns are non-normally distributed (Harris & Shen, 2006, s. 3). Furthermore, both the mean-variance framework and VaR may be used by speculators aiming to optimize portfolio returns with a given risk profile. The most commonly used model for portfolio optimization is Markowitz's *mean-variance* analysis (Munk, 2018, p. 195). The following section evaluates minimum-variance- and value at risk hedges, in addition to Markowitz portfolio optimization.

6.4.1 Minimum-variance hedge

A minimum-variance hedge is constructed for hedgers aiming to enter market positions which return the lowest variance on a portfolio combining short and long positions in both the underlying asset and futures. The minimum-variance hedge ratio (h^*) formula is presented below, with h^* being equal to the slope of the most befitting line when regressing changes in underlying asset against changes in futures (Hull, 2018, p. 81).

$$h^* = \rho \frac{\sigma_S}{\sigma_F}$$ *Equation 27*

$$where;\ \sigma_S = std.dev\ of\ \Delta Stock, \qquad \sigma_F = std.dev\ of\ \Delta Futures$$

6.4.2 Value at Risk hedge

Optimal hedge portfolios measured on value at risk (VaR) aim to minimize the maximum expected loss in a defined time period, within a pre-defined confidence level. In other words, *VaR* is easy to understand as it answers the question *"how bad can it get?"*. One way to calculate value at risk is by historical simulations, using historical data to find the worst daily expected loss given a confidence level (Hull, 2018, p. 523).

6.4.3 Markowitz's mean-variance portfolio optimization

In 1952, Harry Markowitz published a paper about portfolio selection discussing the modern portfolio theory that later would revamp portfolio theory. The theory, which earned Markowitz the Nobel Memorial Prize in Economic Sciences, assumes that all investors aim to maximize profits at given levels of risk and that portfolio risk could be reduced through diversification (Guided Choice, 2020). In other words, investors are assumed to be *mean-variance optimizers.*

Markowitz assumed that a portfolio consisting of N risky assets have a total weight of 1, and that the expected return of such a portfolio is given by

$$\mu(\boldsymbol{\pi}) = \boldsymbol{\pi} * \boldsymbol{\mu} = \sum_{i=1}^{N} \pi_i \mu_i, \qquad \textit{Equation 28}$$

$$where; \boldsymbol{\mu} = expected\ return\ vector, \qquad \boldsymbol{\pi} = portfolio\ weight\ vector.$$

The variance of the same portfolio is calculated utilizing the formula below.

$$\sigma^2(\boldsymbol{\pi}) = \boldsymbol{\pi} * \underline{\underline{\boldsymbol{\Sigma}}}\boldsymbol{\pi} = \sum_{i=1}^{N} \sum_{j=1}^{N} \pi_i \pi_j \Sigma_{ij} \qquad \textit{Equation 29}$$

$$where; \underline{\underline{\Sigma}} = non - singular\ variance - covariance\ matrix.$$

Furthermore, a mean-variance efficient portfolio is a portfolio consisting of asset combinations returning the lowest portfolio variance at a defined average return. The following quadratic minimization problem is solved to find mean-variance efficient portfolios at different levels of returns (Munk, 2018, p. 196).

$$\min_{\boldsymbol{\pi}} \boldsymbol{\pi} * \underline{\underline{\Sigma}}\boldsymbol{\pi}, \qquad s.t. \ \ \boldsymbol{\pi} * \boldsymbol{\mu} = \overline{\mu}, \qquad \boldsymbol{\pi} * \mathbf{1} = 1$$

All the mean-variance efficient portfolios are parts of the efficient frontier, indicating that these portfolios are the ones with lowest variance at given levels of returns (Munk, 2018, p. 196).

6.5 Summary of the theoretical frameworks applied

This chapter has aimed to answer the sub-question "*Which theories are used to research derivative pricing premiums and hedging strategies?"*. This thesis presents the works of Fisher Black to price options where the underlying asset is a futures contract as the best way to assess the price of options. Furthermore, futures contract pricing was discussed at length where both the theory of storage and the notion of a forward premium were introduced. Additionally, to test whether a systematic forward premium is present throughout the data set, OLS regressions will be performed. Therefore, to ensure a high reliability, the theories of which OLS regressions are based upon, were presented alongside the hypothesis of an unbiased forward rate. Finally, key hedging concepts related to risk, as well as Markowitz's mean-variance analysis were reviewed. The theories, concepts, and hypothesis presented in this chapter provides the theoretical framework within which this thesis aims to investigate a pricing premium in the Nordic market for power.

7. Definitions

The complexity of the Nordic power market, including physical aspects, locational pricing, different derivatives and physical products, increases the importance of understanding market dynamics and concepts before conducting market premium analyses. This section aims to answer the sub-question "*How is the market for Nordic power derivatives structured, and which market concepts and mechanisms are important?"*, with the objective of improving readers' market comprehensiveness.

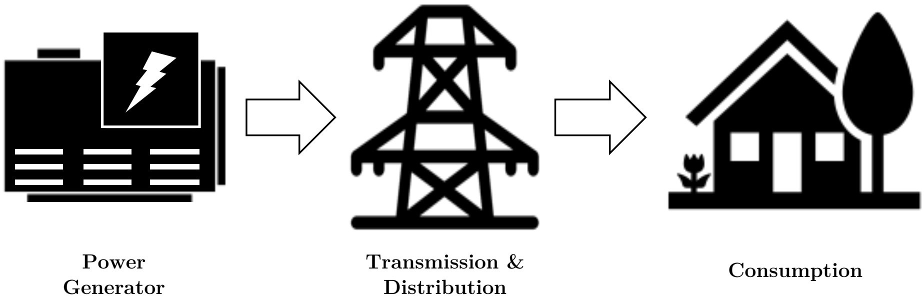
7.1 Electricity, power, power market, and power trading

Electricity is defined as a *"form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current"* (Oxford, 2020). Electricity is the underlying asset in the Nordic electricity market which is referred to as 'the Nordic power market'. The Nordic power market has become increasingly important throughout the 20th century, as electricity is needed to support many of our daily activities. Thus, ability to delivery electricity economically efficient is paramount, and to increase market efficiency, regulators are welcoming traders who want to participate in the market. Despite this, there is restricted access to the market due to high economic barriers, and the technical knowledge required to profitably trade electricity and power derivatives (Taillon, 2019).

To better understand the underlying product of the commodity trading, the physical aspects of electricity are worth noting, as some readers of this thesis may be unfamiliar with electrical quantities. *Voltage* is the electrical force that makes electricity move throughout the power grids, lines and wires, and is measured in volts. The electrons flowing through the power grid are named *electrical current* and measured in amperes. Combining voltage with current will yield *power*, measured in watts. The bigger the voltage and current, the more electrical power is delivered. However, these measurements are static, and does not consider the time spent using electricity. To assess how much *energy* is consumed, one multiplies the units of power consumed by the time; most commonly measured for end users in kilowatt per hours, kWh (Woodford, 2019). Due to the large quantum of power traded, the contracts are quoted in megawatts, MW, which can be converted to megawatt hours (The Ice, 2020). As a reference point to the relative size of a megawatt, the reader can note that the average Norwegian household consumed approximately 16 megawatts in 2016 (Statistisk Sentralbyrå, 2018).

Worldwide, all power markets have system operators as market operators. A system operator is defined as *"a neutral, independent (…) organization with no financial interest in generating facilities that administers the operation and use of the transmission system"* (Agera Energy, 2020). System operators are in charge of managing intraday and real-time markets on different physical grid arrangements known as *network topologies* (Taillon, 2019). A physical electricity grid, illustrated below, is defined as the electrical system that conducts the electricity from the generating plant to the consumer (Kehinde, 2020).

Figure 7.1: Electricity grid illustrated



Source: Authors' own creation

As the system operators are in charge of operating the electricity grids, they are required to continuously adjust power plant output to ensure fulfilment of its areas demands. System operators can adjust the power plant supply at two stages. The *unit commitment* is the first stage and occurs the day ahead of delivery. In this stage, by considering area demand expectations, it is decided which power plants will run the following day. The second stage the system operators must consider is the *dispatch stage*, where run time and utilization rates of the committed power plants are established (Dutton, 2020a). Run time and utilization rates decisions are taken each hour throughout the day and are affected by hourly electricity demands. In other words, system operators have an important impact on electricity supply in different areas.

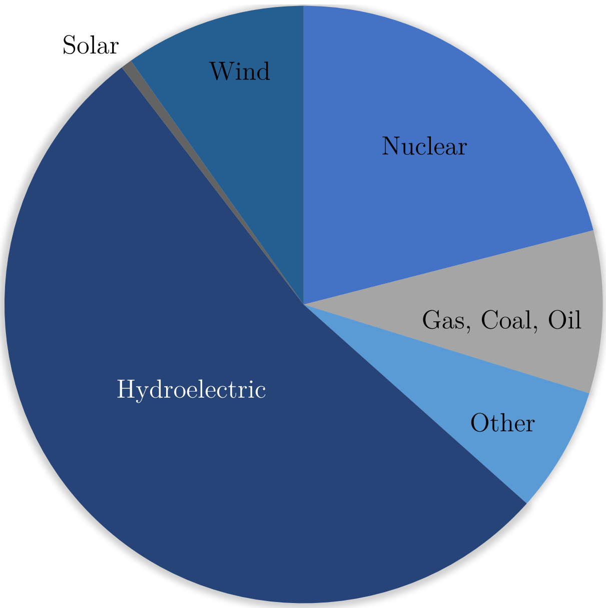
Electricity spot prices are known as being highly volatile, and generators and load-serving entities are often interested in fixing the electricity price for a later delivery. The Day-Ahead market serves to increase market consistency and makes it easier for the electricity markets to operate efficiently. The increased consistency occurs as intraday system capacities are decided based on results from the day-ahead auction (Nord Pool, 2020b). The Day-Ahead market in combination with the Real-Time (Intraday) market are together known as a dual settlement market design ensuring end-users' electricity demands are met throughout the day (Taillon, 2019).

There are many factors that affect the supply-demand equilibrium for electricity prices in the Nordic power market. The most commonly known affecting factors are fuel prices, CO_2 permits, weather, availability, construction costs and fixed costs (Taillon, 2019). Fuel prices in the Nordic markets are of less importance due to most of the demand for electricity is met by renewable energy production.

Despite this, Nordic companies must comply with European CO_2 emission allowances, resulting in electricity prices being impacted by prices on CO_2 permits (Appendix 4) (European Commission, 2020b).

In 2017 and 2018, around two thirds of Nordic electricity production originated from renewables (Nordic Energy Research, 2020). The current energy-mix is therefore increasingly dependent upon the weather conditions, as electricity production now relies on sources such as hydropower and wind (Aleasoft Energy Forecasting, 2019).

Figure 7.2: Nordic energy mix illustrated



Source: Authors' own creation based on statistics from Nordic Energy Research

Construction- and fixed costs on power plants are also affecting power supply. Construction costs are defined as the total cost of bringing power plant facilities online and vary depending on type of power plant (ProEst, 2018). Fixed costs are defined as land- and capital costs (Dutton, 2020b). Higher costs on power plant construction increases energy prices as suppliers strive for profitability. Additionally, higher costs may also limit new power plant projects, thus affecting the electricity available in the market. With two thirds of Nordic electricity production being renewables, the potential introduction of 'zero-bids' in auctioning schemes discussed in *Chapter 1. Introduction & Motivation* might limit producers' incentives to build new wind farms.

Researchers agree that factors such as economic activity, weather and efficiency of consumption affect the demand for electricity. Volatile temperatures increase electricity demand as people require heating when temperatures are low and air-condition when temperatures are high (Raval & Hook, 2019). Lastly, energy efficiency is an important factor as increased efficiency will, ceteris paribus, decrease the demand for electricity, as less electricity is needed to perform various tasks (Environmental And Energy Study Institute, 2020).

The clearing price is one of the reasons why factors affecting supply and demand are so important. The clearing price is defined as the price where demand and supply are at an equilibrium (Kenton, 2018). In other words, the factors outlined below are affecting intraday- and day-ahead clearing prices in different ways.

Figure 7.3: Factors affecting supply and demand

Supply	**Demand**
Fuel prices	Economic activity
CO2 permit prices	Weather
Weather	Energy efficiency
Availability	
Construction costs	
Fixed costs	

Source: Authors' own creation

However, when pricing electricity, system operators use the concept of *Locational Marginal Pricing*. The *marginal* rate within electricity supply is the cost of delivering one additional megawatt to the market. That the margin price is *locational* means that the rate always depends on delivery location, as the cost of delivering one additional megawatt to a specified location varies (Taillon, 2019).

The participants in the market for Nordic power are producers, suppliers, consumers and speculators. The power suppliers' objective is to provide electricity to consumers at a competitive market rate. This rate may either be based upon the locational marginal rate, an agreed upon fixed rate, or a standard variable power rate (Smarte Penger, 2020). The standard variable power rate is influenced by the locational marginal rate at the present time, and the rate cannot be changed without the supplier giving consumers at least a two-week notice (strømtest.no, 2020). In other words, the standard variable power rate may be considered as a two-week, smoothed delayed locational marginal rate, and it increases power rate predictability for both the consumers and the suppliers.

7.2 Nord Pool

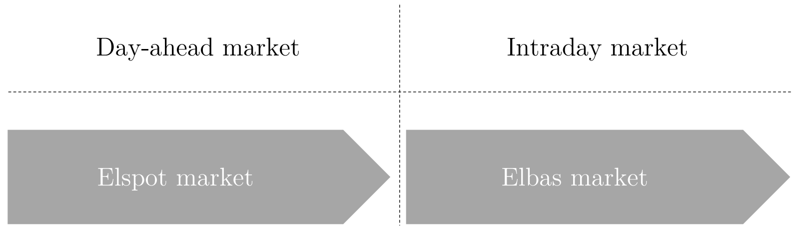
The Nordic power exchange, currently known as Nord Pool, was established in 1996 and is the leading physical power market for trading, clearing, settlement and associated services in Europe. Nord Pool offers both day-ahead- and intraday spot-contracts trading of power, which in 2019 were used by 360 companies from 20 countries to both speculate and hedge power positions (Nord Pool, 2020c).

A total of 494 TWh of power were traded through Nord Pool in 2019. The spot price is determined by geographical supply and demand. In other words, different geographic areas have different spot prices (Nord Pool, 2020d). This can further be explained by the fact that electricity cannot be stored in large quanta and needs to be converted to other forms of energy before storage (Association, 2020). As a result, storage limitations, logistics such as geographical interconnectors, and time of delivery have all become important factors when quoting electricity prices.

The Nord Pool day-ahead market is the most common way of trading electricity, with approximately 2,000 trades daily. The day-ahead market is as the *Elspot* market, where customers can buy and sell energy for the forthcoming 24 hours, through a closed auction. Capacities on interconnectors are published every day at 10:00 CET. Thereafter, auction participants may submit auction bids from 10:00 to 12:00 CET. Bids are made for each delivery hour the upcoming day. By using an algorithm called Euphemia, orders are matched in such fashion that bid/ask prices in each bidding zone ends up in equilibrium after taking network constraints into account. Finally, hourly clearing prices are announced, and physical deliveries are performed (Nord Pool, 2020e).

The Nord Pool intraday market, known as *Elbas*, supplements the day-ahead market to ensure that equilibrium occurs between supply and demand. The market participants are offered 15-minute, 30-minute, hourly, and block products to ensure that electricity demand in different bidding zones are fulfilled. The Nord Pool intraday market is a continuous market where trades are executed day and night, usually up to one hour before delivery (Nord Pool, 2020f).

Figure 7.4: The two financial Nordic power markets



Source: Authors' own creation

Both *Elspot*- and *Elbas* prices are affected by congestion- and capacity restrictions, and sudden changes in either factor may have tremendous impact on power prices. To address these biases, Nord Pool also quotes a Nordic system price, which is an unconstrained market clearing price for electricity in the Nordic region. The *Elspot System Price*, or Nordic System Price, does not consider congestion- and capacity restrictions and is used as the universal reference price for all Nordic Power derivatives (Nord Pool, 2020g).

As with many technical markets, the Nordic power market has its own market-specific notations. In traditional financial theory, one often relates futures contracts to have an underlying spot price as a reference. The same holds true for Nordic power, however, this is most commonly referred to as the *Nordic System Price*, and to mitigate any confusion in nomenclature; this paper refers to the Nordic system price as the spot price, and vice-versa.

7.3 Nasdaq OMX Commodities Europe

Spot prices on electricity have historically been highly volatile, and different types of derivatives on Nord Pool *Elspot System Price* are traded for hedging and speculative purposes (Taillon, 2019). These derivatives were traded through Nord Pool before 2010. However, after NASDAQ's acquisition of Nord Pool's clearing- and consulting divisions in November 2010, all derivatives with the Nordic system price as the underlying asset have been traded through NASDAQ OMX Commodities Europe (Nasdaq, 2010). NASDAQ OMX Commodities Europe (hereafter 'Nasdaq') offers financially settled Nordic power futures and options on power futures with different maturities and loads (Nasdaq, 2020a).

Power futures can either be a base load- or a peak load futures contract. A base load is defined as "*The permanent minimum load that a power supply system is required to deliver*" (Lexico, 2020), and covers all hours of all days in the delivery period. On the other hand, peak load is *"a period of time when electrical power is needed a sustained period based on demand"* (Energywatch, 2017). To illustrate the difference between base- and peak load, one can consider the energy consumption of a house. The base load electricity for a house is the accumulated electricity needed for products that are always connected, such as heaters and fridges. Peak load electricity is the electricity used on top of the base load, for example electricity usage when watching TV, cooking, or charging an electric vehicle.

Nasdaq offers base load contracts on Nordic electricity futures. The different base loads available for trading are days, weeks, months, quarters, and years (Nasdaq, 2020b). A futures contract with a daily base load last for the entire day specified, whereas a contract with a monthly base load is active throughout every hour of the specified month. The settlement price for contracts with weekly and monthly base loads are equal to the difference between the futures price and the arithmetic mean of the hourly Nordic system price quoted by Nord Pool (The Ice, 2020). Futures contracts with daily, quarterly and yearly base loads have a settlement price found by calculating the hourly difference in system price and futures price (Nasdaq, 2020b). All futures are settled financially daily at a mark-to-market basis (Nasdaq, 2018, p. 131).

The contracts traded on Nasdaq are mostly futures, which the reader recalls indicate that the contracts are standardized. The standard contract base size is 1 MWh throughout the futures' delivery period. Thus, the payoff of a Nordic power futures contract is a function of the number of delivery hours in the base load and the spread of 1 MW for every hour in the base load. To illustrate, one may consider a month with 31 days, which is equal to $31 * 24 = 744$ hours. If an average monthly system price is 14 €/MWh, and the futures price is 15.2 €/MWh, the total monthly premium is calculated as follows: $744 * (15{,}2\ €/\mathrm{MWh} - 14\ €/\mathrm{MWh}) = 892.8$ EUR.

Tradeable options on Nasdaq have futures with monthly-, quarterly- or yearly base load as underlying (Nasdaq, 2020a).

7.4 Summary of important definitions used in the thesis

Chapter 7 – Definitions has described the structure of the market for Nordic power derivatives as well as the auction market for physical Nordic electricity. This has been done to answer the sub-question "*How is the market for Nordic power derivatives structured, and which market concepts and mechanisms are important?"*, considering both market attributes and supply-demand relationships. How prices on physical electricity quoted on Nord Pool and Nordic power futures and options listed on Nasdaq are being set, have been outlined in detail. *Figure 7.5* contains an overview of these central concepts and derivatives to better understand further research in the thesis.

Figure 7.5: Central concepts from Chapter 7 summarized

Nord Pool - Prices

Underlying	Product name	Description
Nordic power	*Elbas*	Intraday market price
	Elspot	Day-ahead market price
	Nordic system price	Day-ahead market price without congestion and capacity restrictions
	Nordic system price, continued	Reference price for nordic power derivatives

Nasdaq Commodities - Products

Derivative	Derivative name	Description
Options	*ENOFUTBL[C/P]Q[QY][MMMY]-[XX]*	Option on futures with quarterly baseload
	ENOFUTBL[C/P]YR[Y][MMMY]-[XX]	Option on futures with yearly baseload
Futures	*ENOAFUTBLW[WW]-[YY]*	Average rate futures with weekly baseload
	ENOFUTBLW[WW]-[YY]	Futures with weekly baseload. Identical to ENO[WW]-[YY]
	ENO[WW]-[YY]	Futures with weekly baseload. Identical to ENOFUTBLW[WW]-[YY]
	ENOAFUTBLM[MMM]-[YY]	Average rate futures with monthly baseload
	ENOFUTBLQ[Q]-[YY]	Futures with quarterly baseload
	ENOFUTBLYR-[YY]	Futures with yearly baseload

Source: Authors' own creation

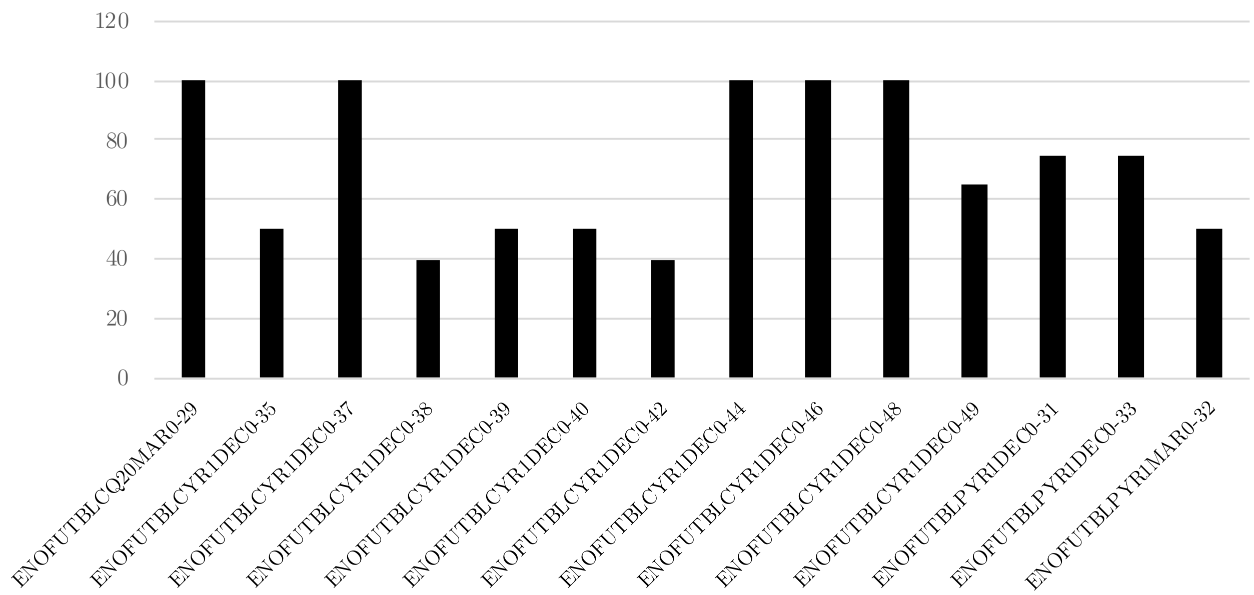
8. Liquidity analysis

Futures, forwards and options on futures have historically traded on the Nordic power market with varying liquidity. However, since the regulatory changes of 2016, Nasdaq has only operated as market maker for futures and options on futures on its exchange. Thus, the liquidity analysis mainly focuses on futures and options on futures, as it can be assumed that hedging strategies with DS Futures cannot be conducted in the future. Furthermore, *Open Interest (OI)* on the last trading day prior to the delivery period is used as a measure for a derivative's liquidity. Open interest is defined as the total number of outstanding contracts and is not to be confused with daily trading volume as the latter only accounts for intraday trades. Increased open interest indicates an increase of active contracts in the market for the given financial instrument, in other words increased liquidity on the derivative (Ganti A., 2019a). As all power derivatives are assumed to have some attributes suitable for hedging, the following sub-question is answered by focusing on open interest analyses; *"Which Nordic power derivatives are suitable to be included in hedging strategies today and in the future?"*. By answering the sub-question, the liquidity analysis provide insight into which derivatives further market premium analyses should be based on, as well as which derivatives may be included in various hedging strategies.

8.1 Options on futures

Options on futures have experienced decreasing liquidity during the last couple of years. According to Mr. Torbjørn Haugen, this could be caused by *"futures on power being so cheap that market participants today are buying the underlying instead of options on futures."* (Appendix 2). Even though this statement contradicts fundamental theory regarding option- and futures pricing, where options are a cheaper way of gaining exposure to the underlying asset, the mechanism specifically holds true for options on power futures. This is further elaborated upon in *Chapter 11. Where are the options?*. Combined with a lack of knowledge on power options trading by the market participants, options are less applicable in hedging strategies, as one should expect fewer counterparties participating in the market. On the next page is a table showing open interest on the options on the Nordic Power Market as of 28th of February 2020.

Figure 8.1: Open interest on options



Source: Authors' own creation based on figures from Nasdaq on the 28th of February 2020

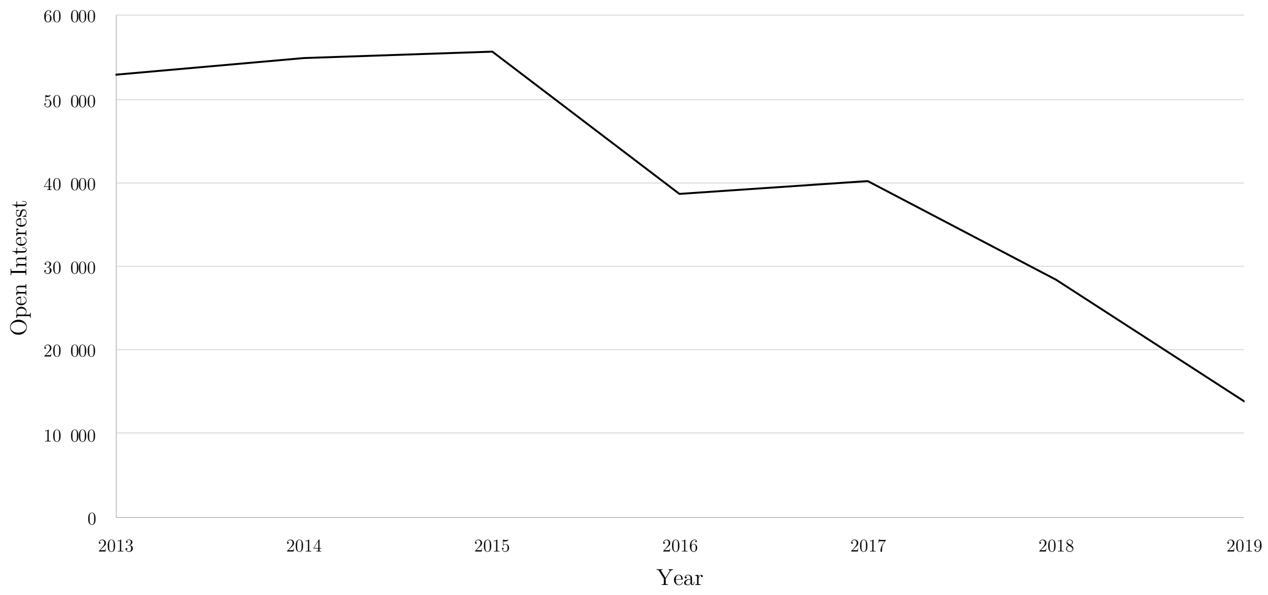
A total of 210 options were listed on the market 28th of February 2020. However, only 14 had registered open interest on Nasdaq (Nasdaq, 2020c). This supports Mr. Haugen's statement and provides evidence against using options when analyzing market premiums and optimal hedging strategies, due to their low liquidity.

8.2 Weekly baseload futures

The liquidity analysis of weekly power futures is conducted by studying the weekly futures[4] on Nasdaq. Further contract characteristics are found in *Section 7.3 Nasdaq OMX Commodities Europe*. By analyzing power futures with weekly baseload, it can be concluded that the open interest has ranged from 13,762 to 55,709 (File 1). Furthermore, the open interest has been reduced by an annual average of 10,486 yearly since 2015. This decline may be explained by decreasing market interest from financial institutions due to the 2016 regulatory changes. The historical development in open interest on weekly futures is graphed below.

[4] *Generic contract name: ENOFUTBLW*

Figure 8.2: Yearly open interest weekly futures



Source: Authors' own creation with values from Montel

The graph above illustrates that open interest on weekly futures have been decreasing the last years, and that the open interest is considered to be sufficiently liquid. However, it is important to investigate whether this development can be explained by trading seasonality. Such findings are important for hedgers to gain knowledge on whether the futures are liquid and possible to utilize in a hedging strategy.

Figure 8.3: Seasonal open interest on weekly futures

	All	**Winter**	**Spring**	**Summer**	**Fall**
Open Interest	283 821	86 359	80 954	54 493	62 015

Winter is defined as week 47 through week 7, and the other seasons are defined as the subsequent 13 week periods.

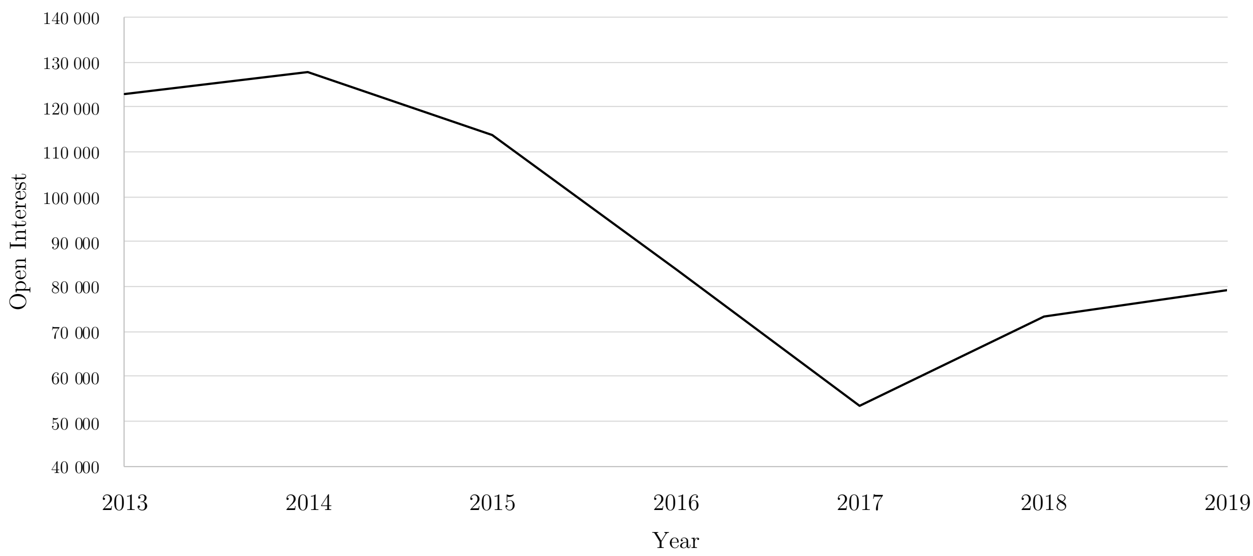
Source: Authors' own creation

The seasonal pattern for open interest on weekly futures shows that contracts with delivery in winter and spring are more liquid and that futures with delivery in the summer are less liquid. The table also indicates that, despite a lower open interest during the summer, the liquidity is still considered to be sufficient. Thus, various hedging strategies can be executed throughout the four seasons with weekly futures contracts.

8.3 Monthly baseload futures

When analyzing the liquidity of Nordic power futures contracts with monthly delivery[5], it can be seen that open interest increased from 2013 to 2014. In the following three years, OI decreased on average 24,772 from 2014 to 2017, but the radical decrease reverted in 2017 and OI subsequently grew during the last two years. A graphical illustration of the development is illustrated below.

Figure 8.4: Yearly open interest on monthly futures



Source: Authors' own creation with values from Montel

Furthermore, a seasonality analysis is conducted to see if there is any seasonality in the liquidity.

Figure 8.5: Seasonal open interest on monthly futures

	All	**Winter**	**Spring**	**Summer**	**Fall**
Open Interest	654 004	178 395	180 335	150 575	144 699

Winter is defined as December to February , and the other seasons are defined as the subsequent 3 month periods.

Source: Authors' own creation

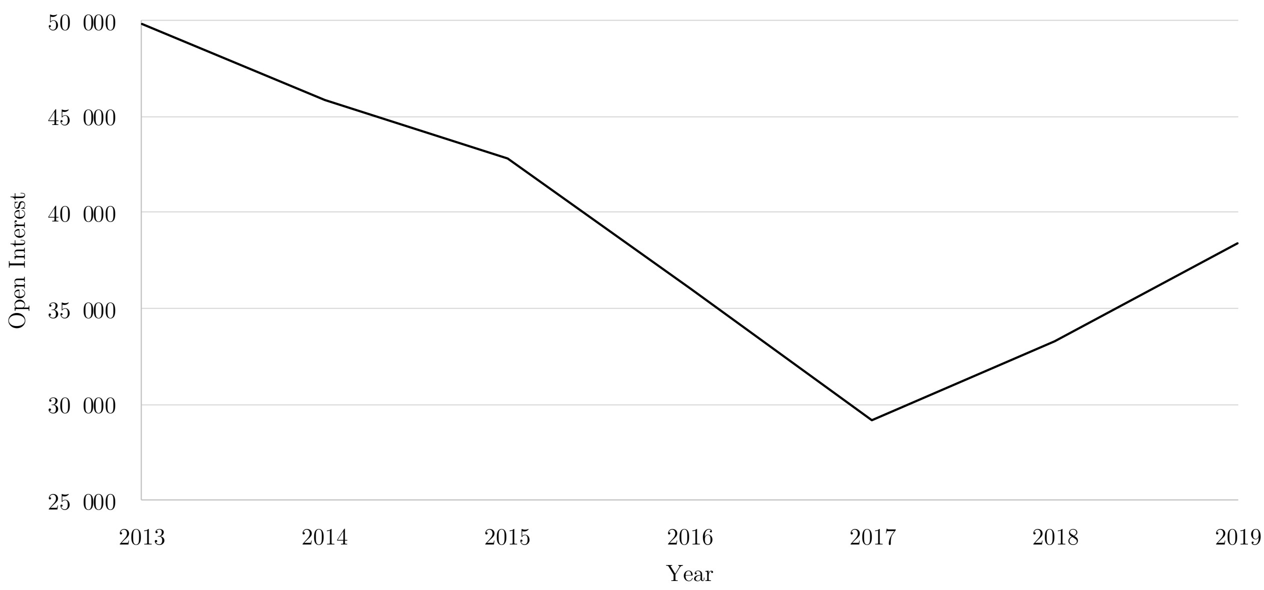
[5] *Generic contract name: ENOAFUTBLM*

Monthly futures depict the same pattern of seasonality as weekly futures with the highest open interest during winter and spring. Fall is the season with lowest OI on monthly futures with 19.7% lower open interest than in the summer.

8.4 Quarterly baseload futures

The liquidity analysis of Nordic Power Futures with quarterly baseload is performed by analyzing open interest on contracts[6] from 2013 throughout 2019. The thesis assumes that the cascading described in *Section 6.2 Futures explained* will not affect the open interest on quarterly futures contracts, and thus is the potential effect of cascading not considered in the liquidity analysis.

Figure 8.6: Yearly open interest on quarterly futures



Source: Authors' own creation with values from Montel

As seen above, open interest for quarterly baseload futures have varied from 29,190 contracts in 2017 to 49,800 contracts in 2013. OI has decreased from 2013 to 2019, but a similar correction as with monthly futures has resulted in increasing liquidity the last three years.

[6] *Generic contract name: ENOFUTBLQ*

Further, the total open interest for Quarterly futures from 2013 to 2019 is 275,365. As illustrated in the table below, Q1 contracts has been the most liquid with an open interest of 81,820. Q2 and Q3 have been the least liquid with OI approximately 26% lower than Q1.

Figure 8.7: Quarterly open interest on quarterly futures contracts

	All	**Q1**	**Q2**	**Q3**	**Q4**
Open Interest	275 365	81 820	59 800	60 275	73 470

Source: Authors' own creation

8.5 Yearly baseload futures

Yearly futures contracts[7] are less liquid than other power futures listed on the Nordic power market. Two potential reasons for this pattern is the large contract size, or that investors might be less interested in the cascading mechanism of this contracts, and rather buy quarterly or monthly contracts directly. A yearly futures contract is financially settled by the hourly difference between the Nordic system price and the fixed futures price throughout the whole year. Similar to quarterly contracts, the potential effects of cascading are not taken into consideration when analyzing historical open interest.

Figure 8.8: Yearly open interest on yearly futures contracts

Yearly	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Open Interest	10 900	9 050	8 950	9 410	885	5 580	8 050

Source: Authors' own creation

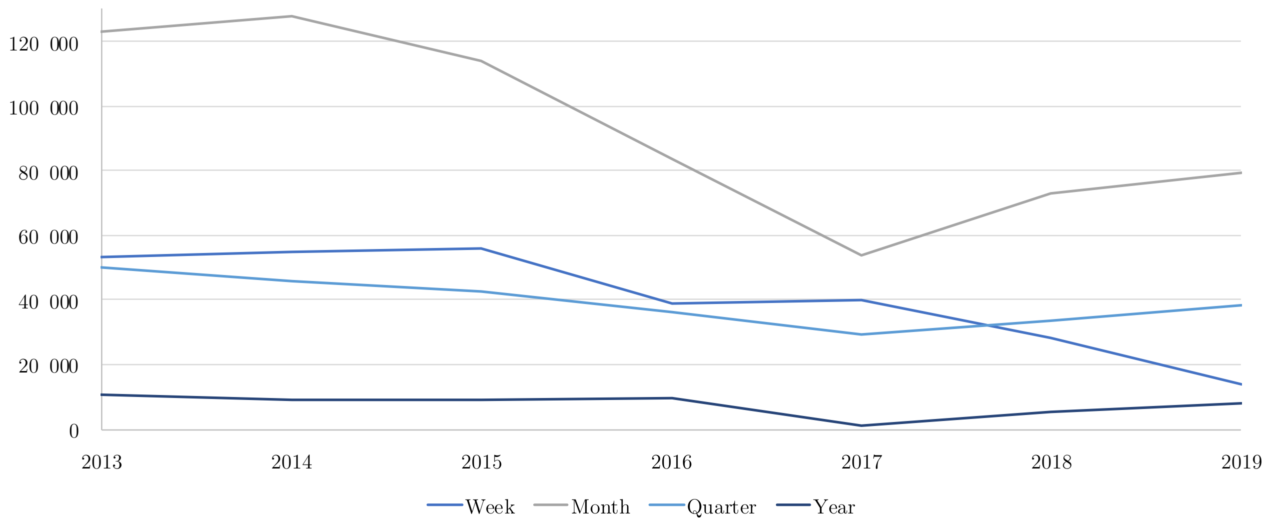
There naturally exist no seasonality in yearly contracts' open interest as they are quoted annually. The yearly open interest has varied from 885 to 10,900 in the data period, where the low liquidity in 2017 may be explained by the new market regulations introduced during 2016.

[7] *Generic contract name: ENOFUTBLYR*

8.6 Summary of liquidity analysis

This chapter has aimed to answer the sub-question *"Which Nordic power derivatives are suitable to be included in hedging strategies today and in the future?"*. This has been achieved by analyzing the open interest of options and futures on the Nordic power market. The findings identify which derivatives have sufficient liquidity to be included in market premium analyses and subsequent hedging strategies. Derivatives on the Nordic power market are susceptible to significant changes in open interest within the various seasons and contract types. First, findings from this section excludes the use of options on futures. High option prices and lack of knowledge make power options less attractive and overall decreases the open interest. Furthermore, futures with high liquidity are more applicable for further analyses than futures with low liquidity. An open interest comparison is conducted to answer the sub-question of which derivatives that are liquid enough to be part of hedging strategies.

Figure 8.9: Summary of open interest



Source: Authors' own creation

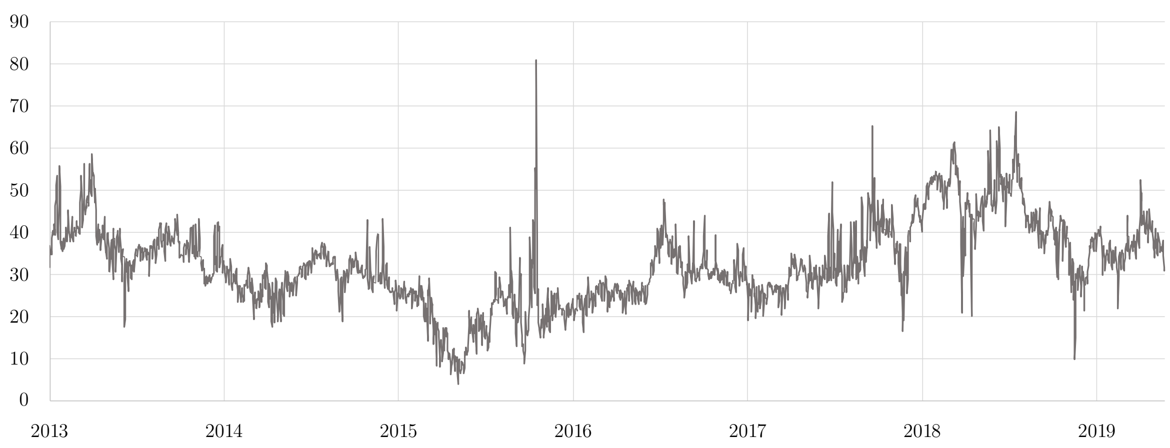
Monthly power futures had a higher average open interest throughout the data period compared to other power futures. Based on this, monthly power futures are considered to be best suited for further analyses. Furthermore, weekly power futures are considered to be more applicable than quarterly contracts, despite higher open interest on quarterly contracts in 2018 and 2019, as the average open interest is higher on weekly futures compared to quarterly futures. In addition, weekly futures have more data points, thus providing increased validity over quarterly futures. In other words, monthly and weekly baseload power futures are sufficiently liquid, thus considered best suited to use when conducting market premiums analyses and investigating optimal hedging strategies.

9. Descriptive statistics

In this section, an assessment of price variables impacting historical forward premiums on the Nordic power market is presented. Variables related to options' volatility risk premiums are excluded from the descriptive statistics due to low liquidity on power options in the market. The following sub-question is answered by investigating historical development in system- and futures prices; *"How has the Nordic system price and futures prices developed historically and is seasonality present in prices?"*. The sub-question is answered with the purpose of establishing a foundation for interpreting the market premium findings which will be identified in *Chapter 10. Forward premium analysis.*

9.1 Nordic system price

Figure 9.1: Nordic system price, €/MWh



Source: Authors' own creation with data from Nord Pool

The data on the Nordic system prices is provided by Nord Pool. The time series starts on the 1st of January 2013 at 00:00 AM and ends on the 31st of December 2019 at 11:00 PM. The time series is presented in thirty-minute intervals, and subsequently adjusted annually for daylight saving time. In total, there are 61,344 observations with an average system price of 32.56 €/MWh. One can observe the highest average seasonal price during winter (34.87 €/MWh), and the lowest during the summer (29.49 €/MWh). In the Nordic market, this is as expected as substantial power volumes are consumed by residential heating. The Nordic countries naturally consume more power during the wintertime to offset the colder climate, thus increasing demand and therefore the prices. Furthermore, the seasonal findings are consistent with previous studies on Nordic power.

Figure 9.2: Summary statistics of Nordic system price

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	61 344	15 480	15 281	15 288	15 295
Mean	32.56	34.87	32.42	29.49	33.43
Standard deviation	10.68	11.42	9.67	11.11	9.65
Minimum	1.14	1.14	2.79	1.15	2.00
Median	31.46	32.57	30.18	28.43	33.39
Max	199.97	199.97	198.29	57.56	84.95
Skewness	0.77	1.62	1.09	0.13	0.18
Kurtosis	5.73	11.78	7.47	-0.02	0.71

Winter is defined as week 47 through week 7, and the other seasons are defined as the subsequent 13 week periods. All prices are quoted in €/MWh.

Source: Authors' own creation

The highest observed system price occurred on the 21st of January 2016 at 08:00 AM with a recorded price of 199.97 €/MWh. The lowest observed price occurred on the 25th of December 2015 at 02:00 AM with a recorded price of 1.14 €/MWh. Of the ten highest recorded system prices, eight are observed in January and the remaining two in November and March, respectively[8]. Of the ten lowest prices, five were observed in July, two in June and three in December. Observing record-low prices in December might seem counterintuitive with the general price pattern for the system price, but the three observations all concerns hourly prices on the 26th of December 2015. The date in question was a

[8] For detailed list of highest and lowest observed values, see appendix 6.

Saturday, and furthermore a holiday, which entailed a minimal energy demand from production facilities. In addition to the limited demand, heavy winds on the shores of Denmark caused the system price to fall significantly for a three-hour period (Danmarks Meteorologiske Institut, 2015).

As can be seen in the data, the system price is highly volatile, with a standard deviation of 10.68 €/MWh for the complete time series. Summer and winter have the highest volatility levels of 11.43 €/MWh and 11.11 €/MWh, respectively. In itself, this observation is somewhat counterintuitive as one would expect low volatility in the summer, consistent with previous studies (see e.g. Haugom et al. 2018). However, over the past years, the Nordic summers have experienced both higher temperatures and more precipitation (Meterologisk Institutt, 2019). This leads to volatile reservoir levels as well as an increase in demand for energy, as more households require cooling during the summer months. The lowest volatility is observed during the fall with a volatility of 9.65 €/MWh.

Excess kurtosis and a right skewed distribution, both presented in *figure 9.2*, suggest frequent spikes in the spot price, underlining the extreme volatility.

Figure 9.3: Yearly volatility in the Nordic system price

Year	**All**	**Winter**	**Spring**	**Summer**	**Fall**
2013	6.9	7.42	7.39	5.4	3.7
2014	5.4	4.93	3.77	5.01	5.13
2015	7.9	8.46	3.23	6.16	5.40
2016	9.0	14.03	3.55	3.08	7.29
2017	5.2	6.93	3.69	3.14	3.63
2018	9.9	11.40	10.02	5.78	9.23
2019	8.1	8.93	4.75	6.89	5.55

Source: Authors' own creation

An important observation in *figure 9.3* is the trend of increasing volatility. This might be explained by the overall temperature increase, as well as more 'extreme' weather. As the Nordic countries are supplied with energy from wind- and hydropower, hydrologic and anemologic conditions greatly influence system prices. As the energy produced from wind is instantly provided to the power grid, periods of extreme winds will, all else equal, significantly reduce the system price for the duration of the heavy winds and revert when the wind diminishes.

9.2 Futures contracts

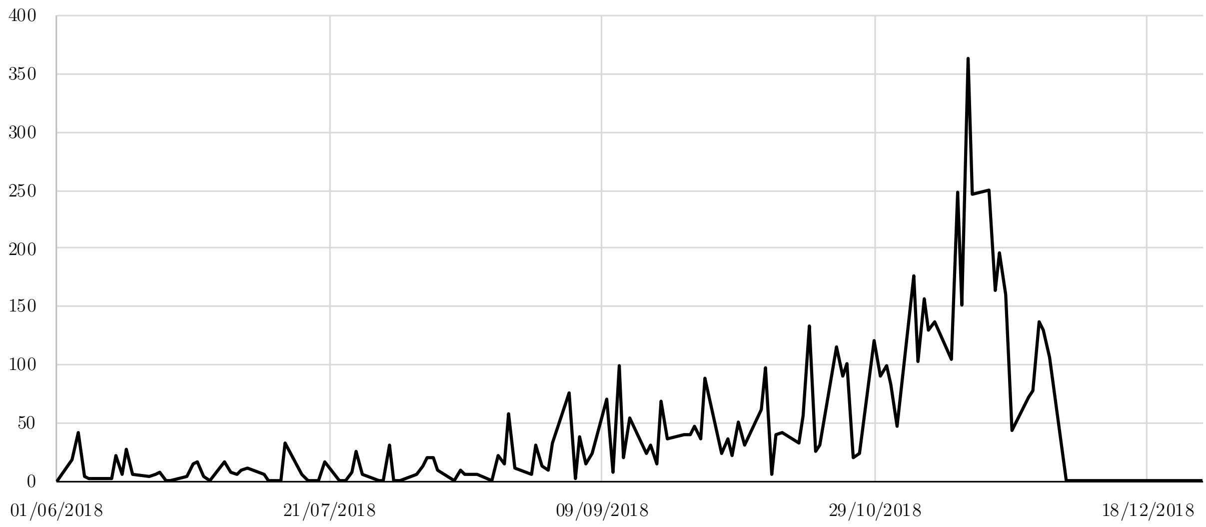
The data for futures contracts is provided by the online research portal, Montel, with underlying trading data originating from Nasdaq. The contracts extracted are weekly, monthly, quarterly and yearly contracts with delivery (maturity) in the period from January 2013 to December 2019. The following paragraphs outline the construction of indices and presents the descriptive statistics from weekly and monthly futures; quarterly contracts are found in Appendix 8, excluded from the thesis due to too few observations.

9.2.1 Theoretical construction of indices

As the data provided by Montel concerns futures contracts with a defined delivery period, this thesis finds it advantageous to create an index to measure futures prices development over time. The motivation for constructing indices lays in the fact that each futures contract only exists for a finite time period as the contract expires. To account for this characteristic, indexation facilitates the simultaneous comparison between futures prices and the underlying system price. Details regarding index construction is found in *Section 9.2.2 Practical construction of indices.*

If one considers the monthly contract with maturity in December 2018, 'ENOAFUTBL Dec-2018', one can observe that the trading in this contract commences on the 1st of June 2018 and trades continuously throughout its delivery period, 28th of December 2018. In the period June to October, the total volume of contracts traded amounts to 2,836. In the month prior to delivery, November, the total volume of traded contracts amounts to 3,285. This pattern is graphically illustrated below and is furthermore a common trajectory for all futures contracts traded with the Nordic system price as the underlying asset. To accommodate this characteristic, this thesis created a trailing index based upon contracts with time to maturity being $T + 1$ and settlement price $F_{t,T+1}$ on the last trading day prior to delivery.

Figure 9.4: Volume of December 2018 futures contract



Source: Authors' own creation with data from Montel

However, as interview with industry experts revealed, several market participants use weighted indices consisting of several futures contracts to construct a future price index (Appendix 2). Therefore, this thesis creates three indices per contract type consisting of equally weighted contracts with time to maturity being one, two and three periods, respectively. The generic names, attributes, strengths and weaknesses of the various indices are shown in the table below.

Figure 9.5: Indexation considerations

Index	Description	Calculations	Strengths	Weaknesses
Index1	• Time to delivery: 1 period • Price weight: 1/1		• Close to delivery • High volumes	• Irregular trading bias
Index2	• Time to delivery: 1 and 2 periods • Price weight: 1/2	$Index_2 = \frac{1}{2} * (P_{period1} + P_{period2})$	• Decreased risk of irregular trading biases	• Distance to delivery • Risk of low volume biases
Index3	• Time to delivery: 1, 2 and 3 periods • Price weight: 1/3	$Index_3 = \frac{1}{3} * (P_{period1} + P_{period2} + P_{period3})$	• Decreased risk of irregular trading biases	• High risk of low volume biases • Distance to delivery

Source: Authors' own creation

Index2 and *3* are less affected by irregular trading biases as individual contracts are weighted less. This make the indices, especially *Index3*, more applicable when considering general trading patterns. However, the two indices have disadvantages related to time to delivery which *Index1* not possess.

An illustration of how these indices are created is the value of the three-month index, *Index3 – Months,* at the 29th of November 2013 being 38.98 €/MWh. This value is computed as an arithmetic average of the Dec-13, Jan-14 and Feb-14 contracts on the 29th of November 2019, illustrated in *figure 9.6*.

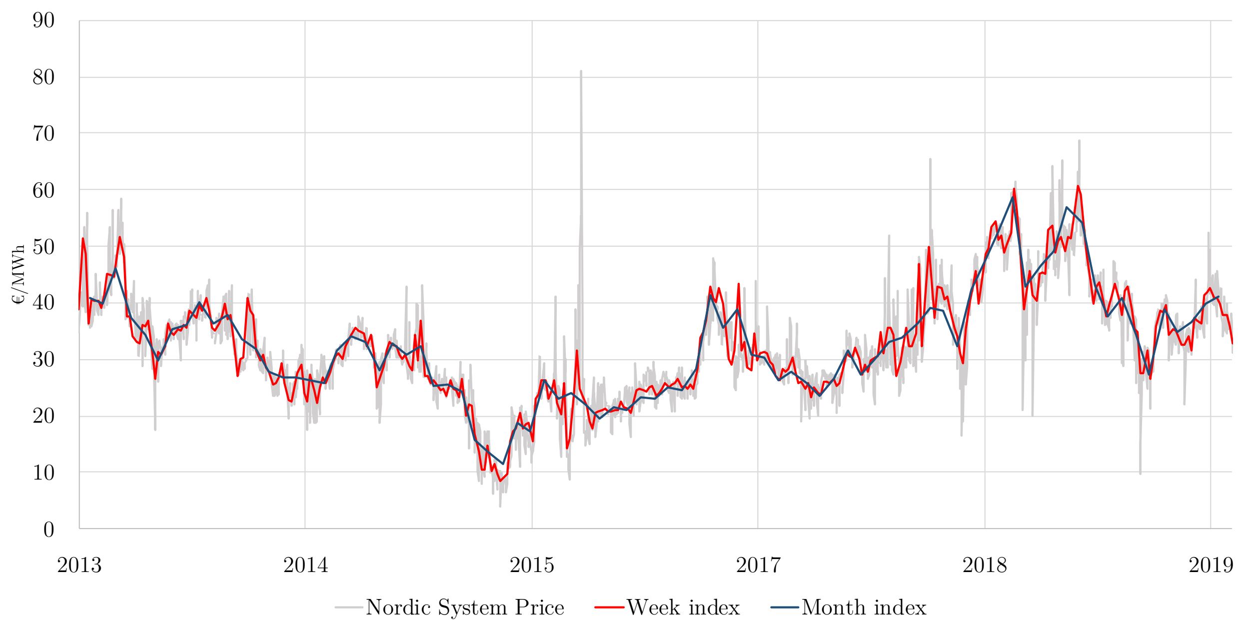
Figure 9.6: Illustration of three-month index on the 29th of November 2013

Date	Dec-13	Jan-14	Feb-14	3 Month index
29/11/2013	37.95	39.00	40.00	38.98

Source: Authors' own creation

In the graph below, one-month and one-week indices have been charted against the system price in the period of 2013-2019 to illustrate how they follow each other closely.

Figure 9.7: Indices plotted against Nordic system price



Source: Authors' own creation with Nordic system price from Nord Pool

9.2.2 Practical construction of indices

To increase reliability of the thesis, further details regarding the practical construction of the indices are presented. All calculations are conducted in file 4 and 5, and a detailed description of the construction of indices follows.

The last trading day prior to the last day of each week/month is identified by utilizing the *WORKDAY* formula in Excel in combination with a list of public holidays in the data period. This enables the identification of the settlement prices in the last trading day for futures with delivery on the consecutive week/month. This settlement prices equals *Index1*. *Index2* is constructed with similar approach, where the settlement prices for futures with two weeks/months to delivery are identified, and subsequently equally weighted against futures with one week/month to delivery, i.e. the *Index1* settlement price. *Index3* is constructed by finding the price of the futures with three weeks/months to delivery, thereafter, calculating *Index3* by weighting the three futures against each other. Finally, seasonal dummies are constructed to calculate summary statistics for each season. These return the settlement price if settlement price is recorded within the applicable season and return a FALSE otherwise. The FALSE function is important for Microsoft Excel to not record the observation, thus affecting summary statistics formulas such as AVERAGE, but rather ignoring all cells that returns a FALSE.

9.2.3 Monthly futures

Monthly futures have the distinct advantage of being the most traded maturity with Nordic power as the underlying asset. However, it is important to note that with the creation of an index that is based upon the last trading day closing price, will yield only 83 observation over the whole data set when creating a trailing *Index1 - Months*.

Figure 9.8: Monthly future indices

	Index1 - Months	**Index2 - Months**	**Index3 - Months**
Observations	83	83	83
Mean	32.54	32.54	32.50
Standard deviation	9.48	9.42	9.28
Skewness	0.43	0.53	0.58
Kurtosis	0.32	0.30	0.19

All prices are quoted in €/MWh

Source: Authors' own creation

The monthly futures prices exhibit many of the same characteristics as the system price. Considering the kurtosis in the closing prices, one can observe 0.32 in *Index1 - Months* and 0.19 in *Index3 - Months*. The negative relationship between holding period and kurtosis is as can be expected, as the contracts with longer time to maturity tend to not reach the same extreme values frequently as the system price and the futures with shorter time to maturity. This mechanism also explains the lower volatility observed in *Index3 - Months*, as the contract(s) with longer maturity will, all else equal, contribute to lower volatility, compared to *Index1 - Months*.

9.2.4 Weekly futures

Weekly future prices have the advantage of yielding a sufficient large sample size to perform a meaningful and significant analysis, due to the fact that there are 364 observation in the data set. However, it is important to note that the trading of weekly contracts follows the pattern of monthly contracts, as depicted in *figure 9.4*. This implies that contracts with longer time to maturity has a low liquidity.

Figure 9.9: Weekly futures prices

	Index1 - Weeks	**Index2 - Weeks**	**Index3 - Weeks**
Observations	364	364	364
Mean	32.49	32.56	32.60
Standard deviation	9.63	9.66	9.65
Skewness	0.31	0.35	0.38
Kurtosis	0.13	0.21	0.24

Mean Prices

	Index1 - Weeks	**Index2 - Weeks**	**Index3 - Weeks**
Winter	35.32	35.63	35.84
Spring	31.63	31.34	31.09
Summer	29.28	29.23	29.19
Fall	33.74	34.04	34.27

All prices are quoted in €/MWh

Source: Authors' own creation

The weekly futures prices exhibit many of the same characteristics of the system price with the lowest average prices during the summer and highest average prices during the winter. However, the development in standard deviation between the three indices needs further explanation. Intuitively, the standard deviation should be reduced with longer time to maturity, as the futures contracts with longer time to maturity seldom will reach the extreme values observable in the system price market. However, as the time to maturity decreases, it is expected that the futures contract volatility will converge with the system price volatility, thus increasing the volatility of futures contracts with shorter time to maturity. As can be observed from the summary statistics from the various weekly futures indices; no such pattern is present in the time series.

A possible explanation of this phenomenon lies within the construction of the indices related to which data sets are available. In the period 2013 to 2018, the futures contract 'ENOFUTBL' is traded, whereas in the subsequent year, the contract 'ENOAFUTBL' is traded. The main difference between the contracts is explained in *figure 7.5*, but the change to the average-settled contract entailed a change in trading pattern. Whereas the previous trading pattern included trading in the week up to three weeks prior to maturity, the trading in the average-settled future contract three weeks prior to maturity is minimal. This can potentially lead to statistically insignificant prices due to poor liquidity, and further induce results in the standard deviation that also can be considered to be statistically insignificant. To account for the low liquidity, this thesis has also constructed a summary statistic of the time period 2013 throughout 2018 to better depict the weekly indices.

Figure 9.10: Weekly futures prices from January 2013 to December 2018

	Index1 - Weeks	**Index2 - Weeks**	**Index3 - Weeks**
All			
Observations	311	311	311
Mean	31.34	31.35	31.36
Standard deviation	9.55	9.47	9.43
Skewness	0.40	0.41	0.43
Kurtosis	0.14	0.13	0.13

All prices are quoted in €/MWh

Source: Authors' own creations

In the time period 2013 to 2018, one can observe the expected pattern of declining standard deviation as the time to maturity increases.

9.3 Summary of descriptive statistics

This chapter has aimed to answer the sub-question "*How has the Nordic system price and futures prices developed historically and is seasonality present in prices?*". First, descriptive statistics for the Nordic system price were presented as unprocessed data. From this, trends in volatility, seasonality and extreme values were identified and presented to illustrate how the Nordic system prices develop with a seasonal pattern with high prices during the winter and summer and lower during fall and spring. Additionally, various indices of futures contract with different times to maturity and delivery periods were created and presented to illustrate how they covary with the system price. Furthermore, the futures indices presented similar mathematical characteristics of high standard deviation, excess kurtosis, and positive skewness.

10. Forward premium analysis

This section aims to answer the following sub-question: "*Are historical premiums present in liquid Nordic power derivatives?*". Based upon conclusions from the previous sections, calculations of market premiums are historical ex-post forward premiums on monthly and weekly futures contracts. This is motivated by the findings from *Chapter 8. Liquidity analysis* which concludes that options, unlike monthly and weekly futures contracts, do not possess sufficient liquidity to be included in future hedging strategies. Furthermore, *Section 6.2 Futures explained* discussed the practical complications regarding the calculations of *ex-ante* forward premiums. Thus, ex-post forward premiums calculations are conducted by utilizing the formula in equation 13:

$$FP_{t+T}^{ep} = F_{t,t+T} - S_{t+T} \qquad \textit{Equation 13}$$

10.1 Data processing

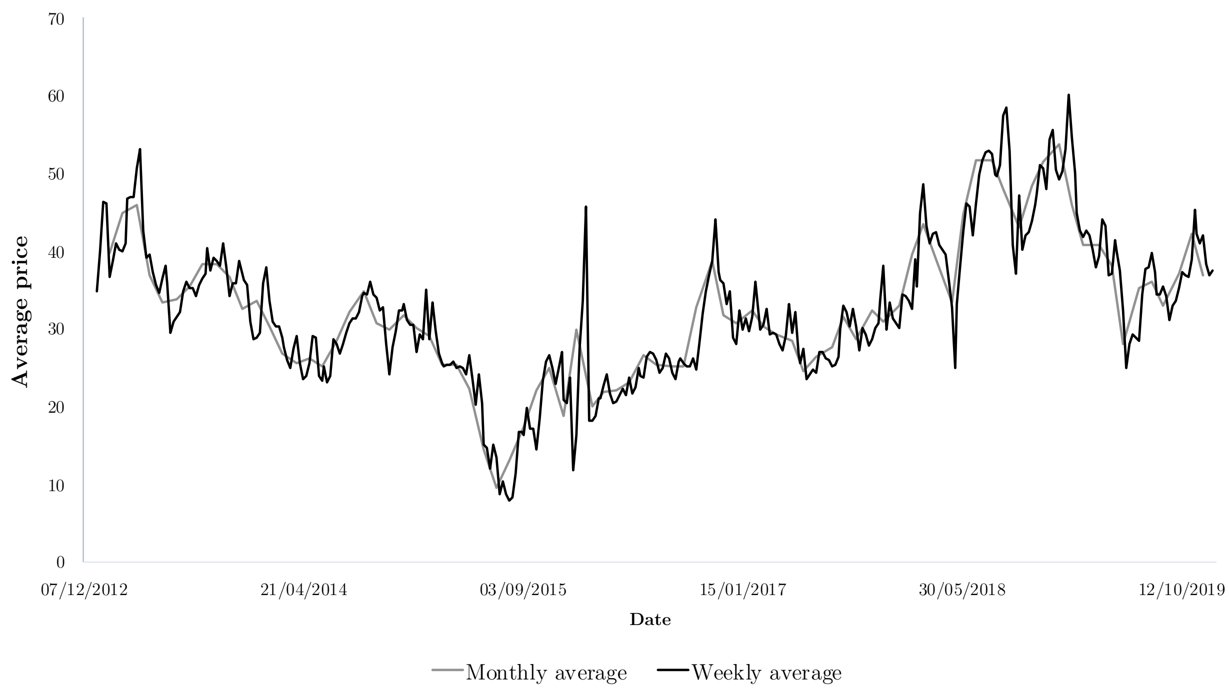
When calculating the ex-post forward premium, historical data on both realized system price in delivery period (S_{t+T}) and the futures price ($F_{t,t+T}$) at time t with a holding period of T and delivery in $t+T$ are considered. Quantitative data on the Nordic system price and futures prices are collected from Nord Pool and Montel respectively, and the data is presented in *Chapter 9. Descriptive statistics*.

10.1.1 Nordic system price

When processing the collected data on the Nordic system price, it is important to ensure the realized system price is matched to the futures price in the corresponding delivery period. Knowing that the delivery period of weekly and monthly futures is throughout the whole week or month, the realized system price is calculated as the weekly or monthly average system price. To illustrate, the realized system price used when calculating the premium for a *Week 1 2013* futures contract is the average Nordic system price from Monday 31st of December 2012 to Sunday 6th of January 2013.

Calculating weekly average system prices in the data period returns 264 observations, whereas the monthly average system price has 83 observations. The developments of both weekly and monthly average system prices are presented below.

Figure 10.1: Nordic system price plotted as weekly and monthly averages



Source: Authors' own creation

From *Figure 10.1* it can be seen that monthly average system prices are slightly less volatile than weekly average prices. This is expected as an average based on more observations will experience increased smoothing as each observation are weighted less.

10.1.2 Considerations relating to futures indices

There are many factors to consider when processing futures prices for premium calculations. First, prices collected from Montel are quoted in *Open, High, Low, Close* and *Settlement* prices, and the quotes have different attributes. Second, time to delivery needs to be considered as futures prices depend on market information that vary with time. Futures with shorter time to delivery are based on more information, compared to futures with longer time to delivery. In other words, before processing futures prices, it is important to entertain a discussion on which prices to consider and when to consider them.

The *Close* price is the most common price to use when conducting market analyses. This is in part explained by the *Open* prices being less recent and that *High* and *Low* prices may reflect unusual trading. The *Close* price is therefore the most recent contract price and should be equal to the *Settlement* price (Appendix 5). In Montel's data base, settlement prices are quoted daily throughout the data period, whereas close prices are less consistent with dates omitted. This makes the settlement price beneficial as premium calculations can be completed without manual adjustments to the data set. In addition, the latest information and news regarding the underlying asset are included in quoted settlement prices and is furthermore the price on which derivatives are settled.

Quoted market prices may be impacted by biases from abnormal trading and algorithms. Two common biases relevant to last settlement prices are irregular trading- and low volume biases. Irregular trading biases are trading that differ from expected market developments explained by non-efficient markets or potential insider trading. Low volume biases are defined as unreasonable settlement prices occurring from unusual low volume trades. There are many ways to consider and limit biases reflected in the settlement prices. As an example, an average of the settlement prices in the last trading week prior to delivery could be calculated to limit potential irregular trading biases and might depict the data correctly. Additionally, settlement prices from the day of the highest trading volume will also indicate at which levels most participants chose to buy or sell their contracts and could also be used to avoid low volume biases. Each method has its strengths and weaknesses which are outlined below.

Figure 10.2: Considerations towards quotation systems

	Strengths	Weaknesses
Settlement price	• Contains newest information	• Irregular trading • Unusual volumes
Last Trading week average	• Less risk of irregular trading bias • Less volatile price development	• Price may not reflect newest information
Max volume trading week	• Many participants may evaluate price as reasonable	• May not reflect newest information • One large trade might decide

Source: Authors' own creation

Further analysis in this section are based on the settlement price on the last day prior to delivery. This is motivated in the consideration that the quoted settlement prices both exist throughout the data period and that they are based on the newest information on the market at the time. However, premium calculations with last trading week average and highest trading volume in the last trading week are conducted and compared in *Section 10.5 Sensitivity analysis.*

10.2 Premium calculations

Forward premium calculations are done by utilizing *Equation 13* for ex-post forward premium. To illustrate, the forward premium calculation for *Index1 – Weeks* in Week 2-2013 are provided below. Both monthly and weekly premium calculations for every index can be found in File 4 and 5.

$$FP_{t+T}^{ep} = F_{t,t+T} - S_{t+T} \qquad \textit{Equation 13}$$

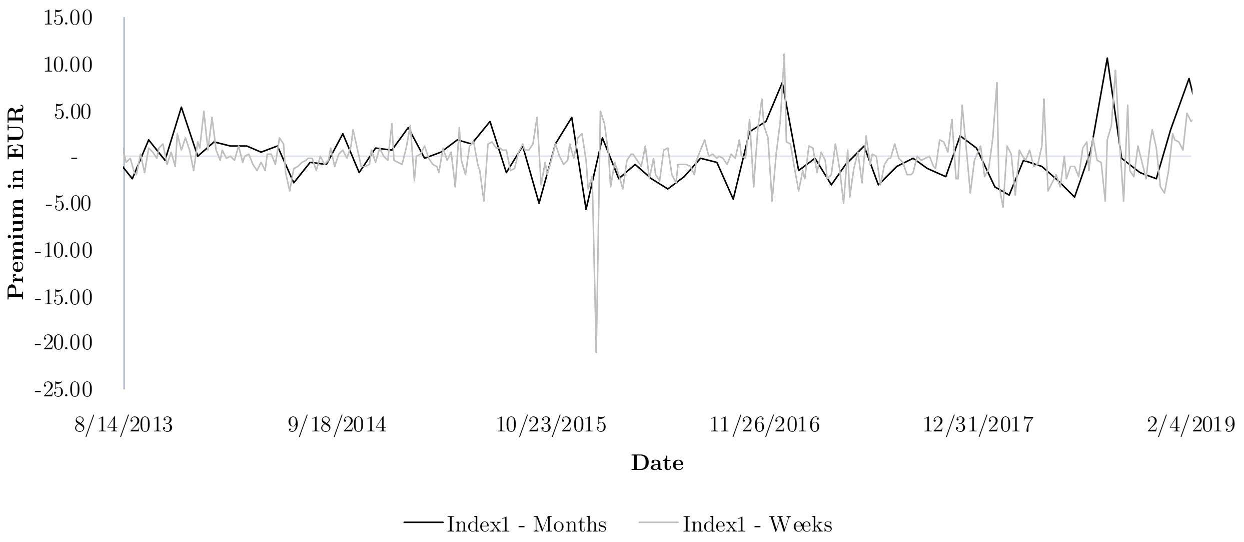
$$FP_{week\ 2,2013}^{ep} = F_{01/06/13\ ,week\ 2} - S_{week\ 2_{avg}}$$

$$FP_{week\ 2,2013}^{ep} = 38.38 - 40.06 = -1.68$$

As can be seen above, the *Index1 – Weeks* forward premium for a futures contract with delivery in Week 2-2013 equals negative €1.68. This indicates that average system price in the delivery period was higher than the price of buying a futures contract on the last trading day prior to delivery. The negative forward premium contradicts findings from *Chapter 7. Definitions* and conducted interviews as a positive forward premium were expected. This is due to power producers in the Nordic market mainly focus on long term contracts, leaving power suppliers, aiming to hedge its two-week fixed standard variable power rate, as the main buyers of short-term futures contracts (Appendix 4). As there are more buyers than sellers, the counterparties to the power suppliers are able to skew the market in their favour to ensure compensation for their risk-taking. Thus, a positive forward premium is expected as demand on short term futures contracts are higher than supply (Appendix 4). However, negative, and often large, forward premiums are occasionally observed, as short-term futures are priced by considering weather expectations, which historically only forecast correctly 80% of the time (NASA, 2020).

Graphical illustrations of the overall historical premium for *Index1 – Weeks* and *Index1 – Months* are presented below.

Figure 10.3: Forward premium for Index1



Source: Authors' own creation

Historically, premiums on *Index1 – Months* and *Index1 – Weeks* have experienced similar trends, with seasonality equalities. However, as with all commodities, some dates have unusual high or low system- and/or futures prices, which will impact the forward premium. To illustrate, Week 4-2016 had a negative forward premium of €-21.05 explained by the record high system price on the 21st of January 2016 at 08:00 AM (Appendix 6).

10.3 Summary statistics and interpretations

In the next sections, summary statistics for forward premiums on the indices from *Section 9.2 Futures contracts*, are presented and interpreted. Additionally, seasonality patterns are investigated, and apparent outliers are explained.

10.3.1 Monthly futures contracts

Forward premium statistics from monthly indices are presented in the table below.

Index1 – Months

Figure 10.4: Last closing prices for Index1 monthly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	83	20	21	21	21
Sum	7.38	9.99	0.65	-10.61	7.34
Mean	0.09	0.50	0.03	-0.51	0.35
Standard deviation	3.14	3.68	2.28	3.65	2.89
Kurtosis	0.32	0.48	1.78	3.88	-0.84
Skewness	0.43	0.41	0.74	1.14	-0.05

All prices are quoted in €/MWh.

Source: Authors' own creation

The total average historical forward premium generated from *Index1 – Months* in the data period is €0.09, indicating that the overall futures price from 2013 throughout 2019 were above the average system price in the delivery periods. Furthermore, a standard deviation of 3.14 indicates that historical forward premiums have been relatively stable with few extreme absolute values.

Figure 10.5: Extreme observations in Index1 monthly futures contracts

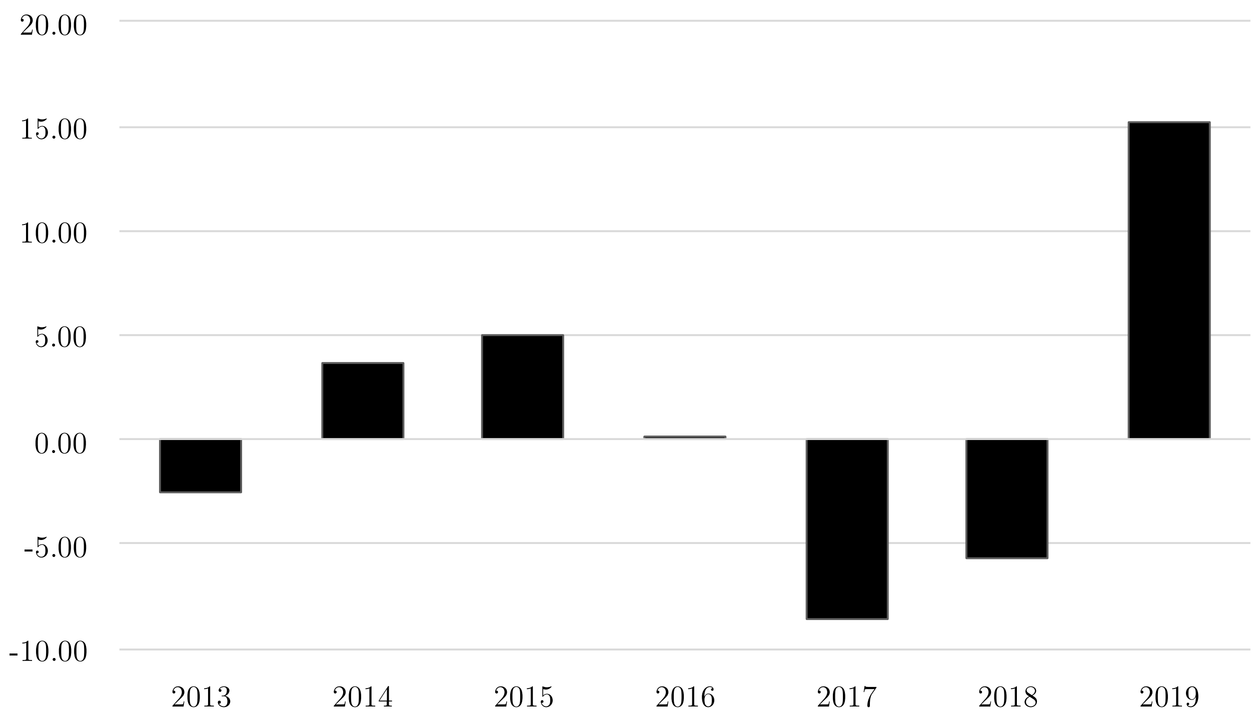
Rank	**Max**	**Date**	**Rank**	**Min**	**Date**
1	10.67	September 2018	**1**	-7.80	July 2019
2	8.34	February 2019	**2**	-5.70	January 2015
3	7.99	January 2016	**3**	-5.04	March 2013
4	6.39	June 2019	**4**	-4.93	October 2015
5	5.29	December 2013	**5**	-4.48	October 2016

All prices are quoted in €/MWh.

Source: Authors' own creation

The four highest premiums are found within the last four years, and four out of the five most negative premiums are in 2016 or earlier. In addition, extreme absolute premiums are not present, supporting the standard deviation found in figure 10.4.

Figure 10.6: Index1 monthly futures contracts premium



Source: Authors' own creation

Figure 10.6 illustrates the accumulated yearly premiums generated from *Index1 – Months*. Premiums have varied from year to year, and only four out of seven years show a positive premium. However, premiums have slowly increased since 2017, a trend which generated positive premiums in 2019.

As can be seen in *figure 10.6*, and will be observable in all subsequent indices, 2019 were extreme in regard to forward premiums. The reasons for such results are explained by Mr. Torbjørn Haugen as "*weak hydrology and strong CO_2 prices"* (Appendix 4). The practical interpretation of this is less precipitation than expected combined with above normal prices for CO_2 in Europe, which again led to increased volatility. This resulted in market participants being willing to pay above normal premiums to hedge their positions.

Index2 – Months

Figure 10.7: Last closing prices for Index2 monthly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	82	20	21	21	20
Sum	2.45	7.15	-10.07	-8.43	13.81
Mean	0.03	0.36	-0.48	-0.40	0.69
Standard deviation	3.96	4.46	3.68	4.29	3.51
Kurtosis	0.66	-0.07	0.32	3.78	-0.47
Skewness	0.58	0.26	0.38	1.54	-0.07

All prices are quoted in €/MWh.

Source: Authors' own creation

Index2 – Months returned a positive average premium of €0.03 throughout the data period, but lower compared to the average premium generated from *Index1 – Months*. However, standard deviation has increased relative to *Index1 – Months* despite decrease in premium. This is explained by an increase in extreme absolute premium values which also results in the doubling of kurtosis, compared to *Index1 – Months*.

Figure 10.8: Extreme values for Index2 monthly futures contracts

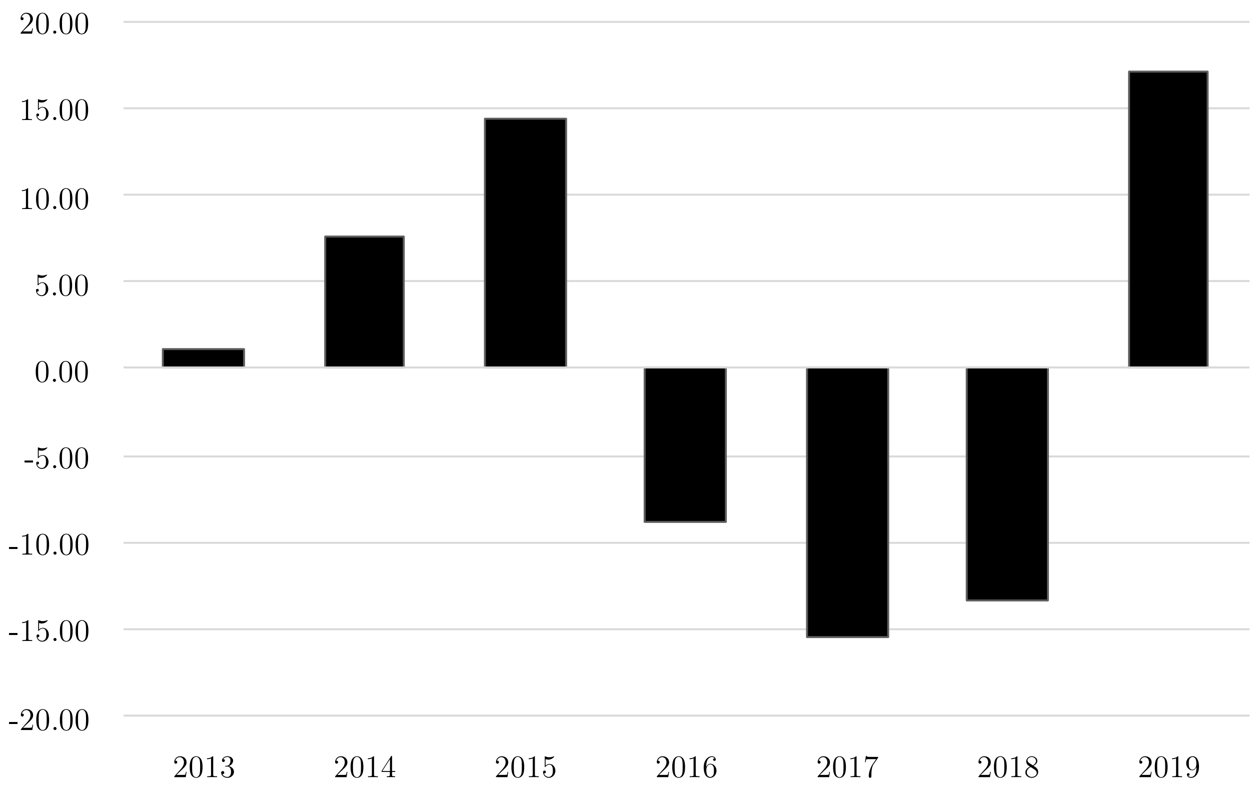
Rank	**Max**	**Date**	**Rank**	**Min**	**Date**
1	12.98	September 2018	**1**	-7.90	February 2018
2	9.57	February 2019	**2**	-7.08	July 2019
3	8.25	May 2019	**3**	-6.68	October 2016
4	7.80	January 2018	**4**	-6.66	May 2018
5	7.11	November 2016	**5**	-6.56	June 2018

All prices are quoted in €/MWh.

Source: Authors' own creation

The five highest premiums from *Index2 – Months* are 18% higher than the five highest premiums generated from *Index1 – Months*. The same pattern can be seen in low values, with the five lowest values in absolute terms being 25% higher in *Index2 – Months*.

Figure 10.9: Index2 monthly futures contracts premium



Source: Authors' own creation

Accumulated yearly premiums generated from *Index2 – Months* have increased from 2017, which is supported by *figure 10.8* as many extreme premiums are observed within the last two years. Four out of the five highest premiums are found in 2018 and 2019, and negative premiums in the same period are less extreme.

Index3 – Months

Figure 10.10: Last closing prices for Index3 monthly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	81	20	21	21	19
Sum	-0.97	-0.02	-19.50	-9.02	27.57
Mean	-0.01	0.00	-0.93	-0.43	1.45
Standard deviation	4.46	5.02	4.82	4.23	3.57
Kurtosis	0.25	-0.37	-0.02	2.88	-0.05
Skewness	0.25	0.29	-0.19	1.37	0.37

All prices are quoted in €/MWh.

Source: Authors' own creation

Index3 – Months has, unlike the other monthly indices, a slight negative premium in the data period. Furthermore, standard deviation has increased, and kurtosis and skewness are at their lowest levels.

A negative forward premium may be explained by considering market participants and their objectives related to buying and selling futures contracts. In the Nordic countries, many of the power producers are state-owned companies relying on predictability in results (Appendix 4). With the Nordic power market being highly volatile, power producers sell long-term Nordic power futures contracts, increasing the supply of such contracts. *Index3 – Months* contain contracts with longer time to delivery than the other monthly indices. However, these contracts have a higher volatility, which entails that the counterparty of the transaction might charge a premium for their risk-taking. Thus, it is possible that power producers accept lower futures prices as there might be an over-supply of contracts, resulting in a negative forward premium. However, since the average negative forward premium is - €0.01, it could be argued that this observation might be an outlier and furthermore a function of the specific data period used in this thesis.

Figure 10.11: Extreme values for Index3 monthly futures contracts

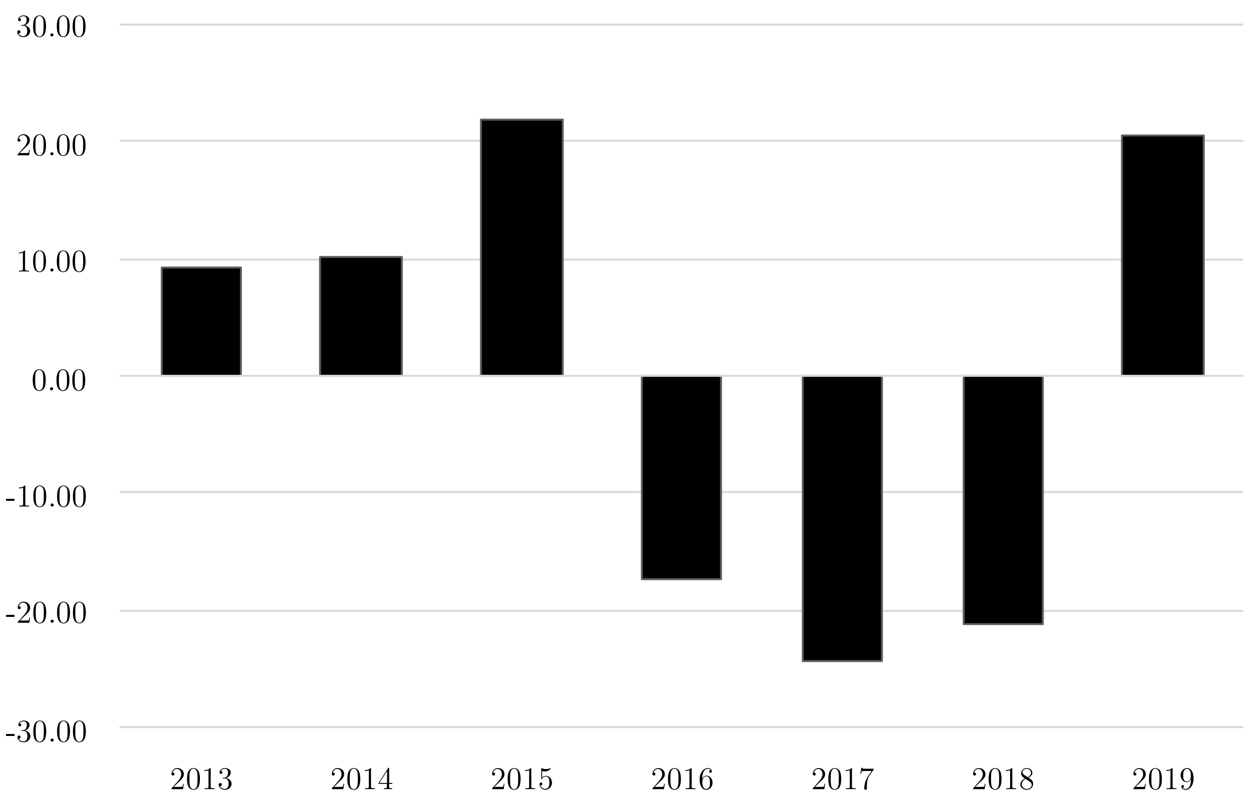
Rank	Max	Date	Rank	Min	Date
1	12.23	September 2018	**1**	-11.65	May 2018
2	9.82	January 2018	**2**	-8.66	February 2018
3	9.38	February 2019	**3**	-7.71	June 2018
4	9.25	November 2016	**4**	-7.15	September 2016
5	7.51	May 2019	**5**	-6.66	April 2018

All prices are quoted in €/MWh.

Source: Authors' own creation

The absolute value of the five most extreme negative and positive premiums are 5% and 20% higher than the same values of *Index2 – Months*. All these values are observed within the last four years.

Figure 10.12: Index3 monthly futures contracts premium



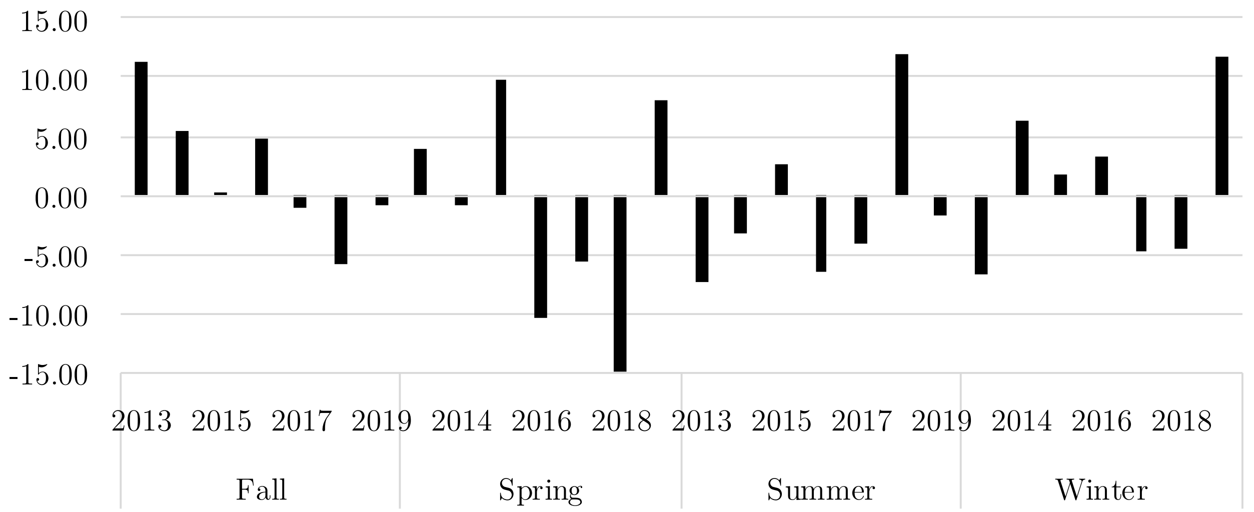
Source: Authors' own creation

Accumulated yearly premium for *Index3 – Months* has varied from year to year, consistent with the other indices. Compared to the other indices the yearly premiums are more extreme, whilst the trend of increasing premiums the last three years is still present.

Monthly forward premium seasonality

Section 9.2.1 Theoretical construction of indices found *Index3* to be the most optimal when analysing seasonality pattern within forward premiums. Despite this, seasonality is analysed through *Index2 – Months* due to contracts in *Index3 – Months* having lower liquidity than contracts in *Index2 - Months*.

Figure 10.13: Seasonality in monthly forward premium



Source: Authors' own creation

Figure 10.7: Last closing prices for Index2 Monthly futures contracts shows that the overall premium generated from winter and fall months are positive, whereas spring and summer historically have generated negative premiums. Furthermore, *figure 10.13* shows that four out of the seven falls and winters have generated positive forward premiums, and that four out of the seven last springs, and five out of the seven last summers have generated negative forward premiums. These findings are as expected considering the seasonal patterns found in the Nordic system price. Findings from *Section 9.1 Nordic system price* indicated that the price is at its highest during winters and falls, and that the system price in these seasons are the most volatile. In addition, higher volatility results in increased trading incentives for speculators and traders, as possible gains increase with volatility risk.

10.3.2 Weekly futures contracts

Futures with weekly baseload were found the second most optimal futures measured on historical liquidity. Below are summary statistics from forward premium calculations for indices with weekly baseload.

Index1 – Weeks

Figure 10.14: Last closing price for Index1 weekly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	362	90	91	91	91
Sum	-24.77	42.06	-45.13	-31.19	9.72
Mean	-0.0684	0.47	-0.50	-0.34	0.11
Standard deviation	2.49	3.60	1.87	1.94	2.05
Kurtosis	15.33	13.92	2.13	7.14	4.32
Skewness	-0.91	-2.05	0.62	1.28	0.98

All prices are quoted in €/MWh.

Source: Authors' own creation

Index1 – Weeks had an average historical forward premium present in the data period of negative €0.07. A negative forward premium contradicts findings from past literature on the field. When analyzing the results, it can be seen that forward premiums from *Index1 – Weeks* are affected by a negative forward premium of €21.05 in Week 4 – 2016, and that the five highest forward premiums are less extreme compared to the five lowest premiums in the data period. These findings are supported by the overall negative skewness, which is an indication of increased probability of observations returning extreme negative values. However, it must be noted that even when adjusting the data to omit the extreme value of €-21.05, the overall forward premium is still slightly negative.

Figure 10.15: Extreme values for Index1 weekly futures contracts

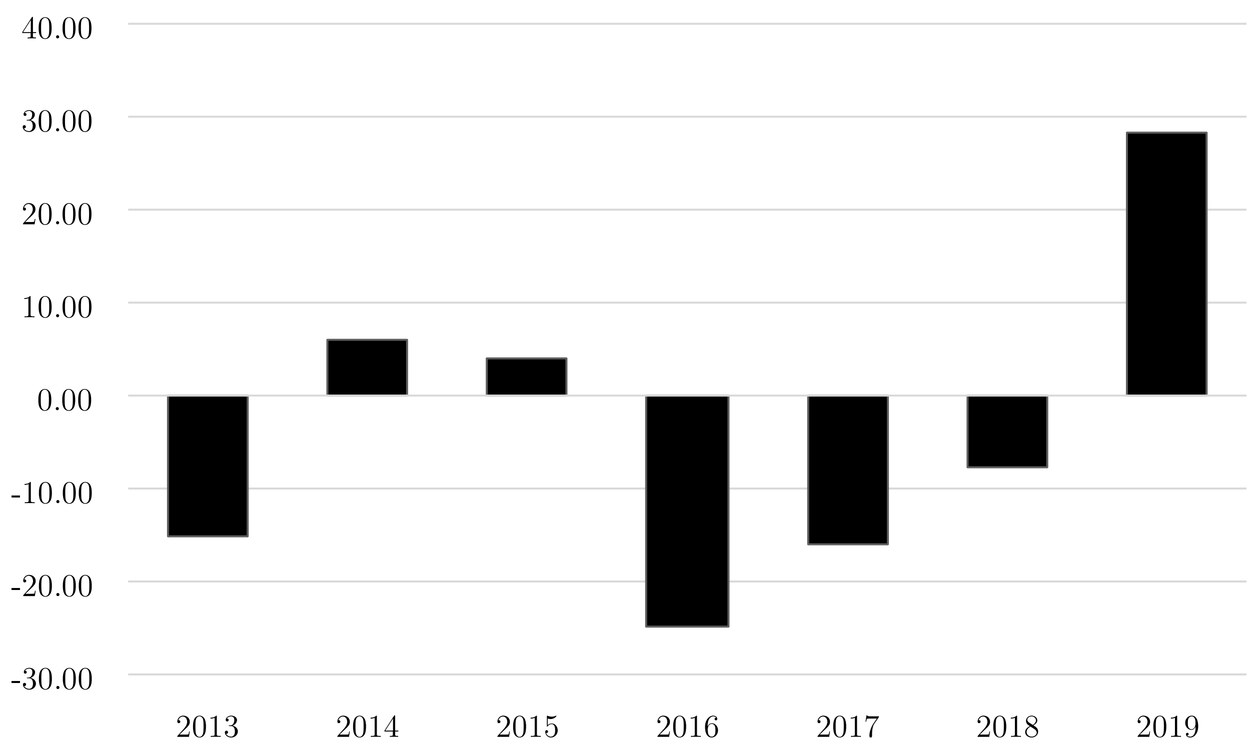
Rank	Max	Date	Rank	Min	Date
1	11.00	2017 - Week 1	**1**	-21.05	2016 - Week 3
2	9.72	2019 - Week 22	**2**	-5.42	2018 - Week 7
3	9.31	2018 - Week 37	**3**	-5.03	2017 - Week 17
4	7.93	2018 - Week 5	**4**	-4.87	2018 - Week 34
5	6.21	2016 - Week 47	**5**	-4.82	2018 - Week 39

All prices are quoted in €/MWh.

Source: Authors' own creation

Considering *figure 10.15*, four out of the five highest forward premiums are observed the past three years, and these premiums are in absolute terms greater than the absolute values of the lowest premiums observed in the corresponding years. This is an indication of increasing forward premiums, a pattern that can be seen in the chart below.

Figure 10.16: Index1 weekly futures contracts premium



Source: Authors' own creation

Index2 – Weeks

Figure 10.17: Last closing price for Index2 weekly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	361	89	91	91	91
Sum	0.17	80.79	-55.27	-51.40	26.30
Mean	0.0005	0.91	-0.61	-0.56	0.29
Standard deviation	2.72	3.45	2.16	2.37	2.47
Kurtosis	2.23	1.46	0.65	2.46	5.67
Skewness	0.47	-0.53	0.52	0.78	1.62

All prices are quoted in €/MWh.

Source: Authors' own creation

Index2 – Weeks has, unlike *Index1 – Weeks*, a slight positive forward premium of €0.17, returning a daily average of €0.0005 in the data period. Additionally, the standard deviation has increased compared to *Index1 - Weeks*, and kurtosis has decreased. An increased and positive kurtosis can be seen in relation to the increased standard deviation as it is an indication of the data observations having a distribution with longer tails than a normal distribution. This is caused by a greater number of outliers present in the data period.

Figure 10.18: Extreme values for Index2 weekly futures contracts

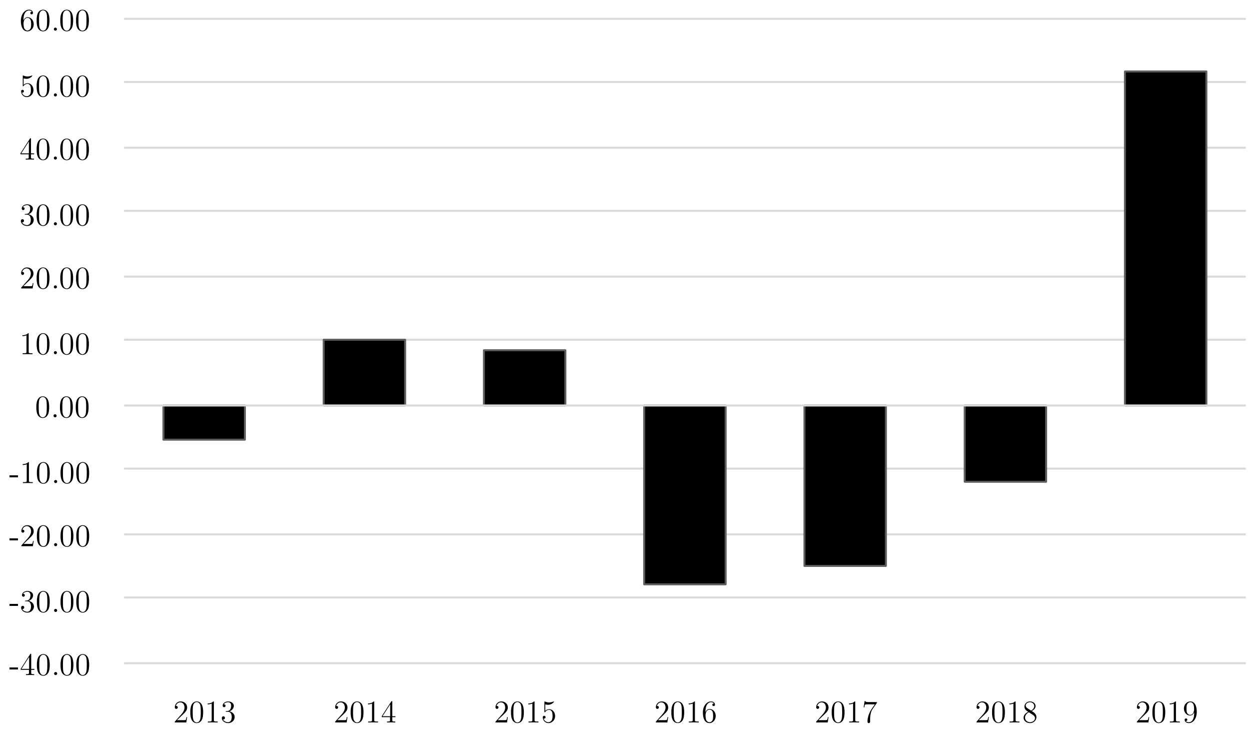
Rank	**Max**	**Date**	**Rank**	**Min**	**Date**
1	11.63	2018 - Week 37	**1**	-10.73	2016 - Week 2
2	10.48	2017 - Week 1	**2**	-7.24	2016 - Week 3
3	9.00	2018 - Week 36	**3**	-6.96	2018 - Week 7
4	8.10	2019 - Week 22	**4**	-6.84	2016 - Week 1
5	7.83	2019 - Week 21	**5**	-6.41	2019 - Week 27

All prices are quoted in €/MWh.

Source: Authors' own creation

As with *Index1 – Weeks*, most of the highest forward premiums are found within the last three years. Naturally, high premiums from *Index2* correlates with the time of high premiums in *Index1* as *Index2 – Weeks* includes weighted premiums from *Index1 – Weeks*. The same pattern can be seen in the dates with the lowest forward premiums. However, an elevated frequency of the low premiums is observed in 2016, with three of the five lowest premiums observed in the winter of 2016.

Figure 10.19: Index2 weekly futures contracts premium



Source: Authors' own creation

The trend of increasing forward premiums observed in *Index2 – Weeks* are similar to the trend observable in *Index1 – Weeks*. However, *Index2 – Weeks* has higher premiums in 2019 and lower premiums in 2017 and 2018 compared to *Index1 – Weeks*, indicating increased volatility in contracts with longer time to delivery.

Index3 – Weeks

Figure 10.20: Last closing price for Index3 weekly futures contracts

	All	**Winter**	**Spring**	**Summer**	**Fall**
Observations	360	87	91	91	91
Sum	12.36	109.11	-62.78	-73.59	39.62
Mean	0.0343	1.25	-0.69	-0.81	0.44
Standard deviation	3.03	3.69	2.49	2.60	2.79
Kurtosis	1.67	1.62	0.79	0.99	3.66
Skewness	0.41	-0.51	0.35	0.30	1.48

All prices are quoted in €/MWh.

Source: Authors' own creation

Index3 – Weeks had a positive average forward premium of €0.03 in the data period, and an increased standard deviation compared to the other weekly indices. Despite the trend of increased standard deviation, it must be noted that futures contracts with three weeks to delivery have a lower standard deviation compared to contracts with two weeks to delivery. Additionally, the kurtosis is 1.67, which is less than with the other indices, and as would be expected due to the index infrequently reaching as extreme values as the other two indices.

Figure 10.21: Extreme values for Index3 weekly futures contracts

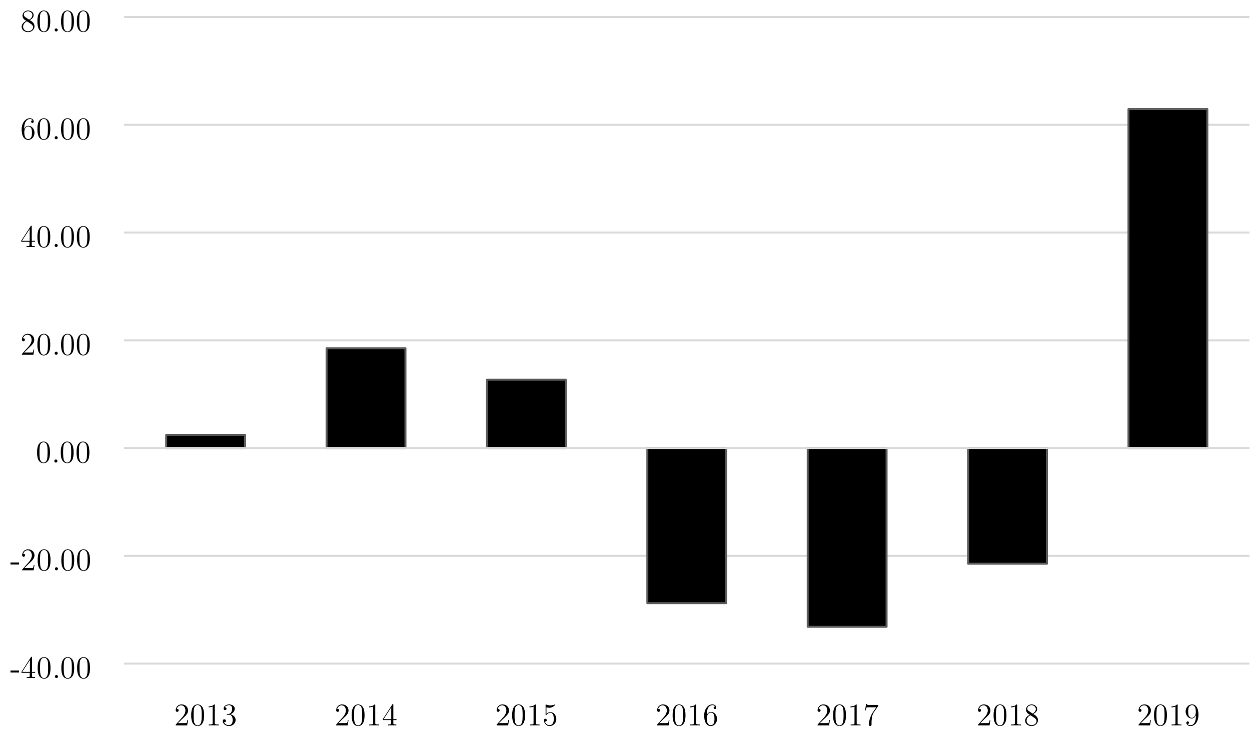
Rank	**Max**	**Date**	**Rank**	**Min**	**Date**
1	11.95	2018 - Week 36	**1**	-11.99	2016 - Week 1
2	9.45	2019 - Week 4	**2**	-7.66	2018 - Week 6
3	9.28	2017 - Week 1	**3**	-7.57	2019 - Week 27
4	8.91	2018 - Week 35	**4**	-7.22	2015 - Week 52
5	8.86	2018 - Week 37	**5**	-6.52	2018 - Week 19

All prices are quoted in €/MWh.

Source: Authors' own creation

All five highest forward premiums from *Index3 – Weeks*, and three out of five of the lowest premiums, are found within the previous three years, which is supporting the trend in premium development observed in the two other weekly indices.

Figure 10.21: Index3 weekly futures contracts premium



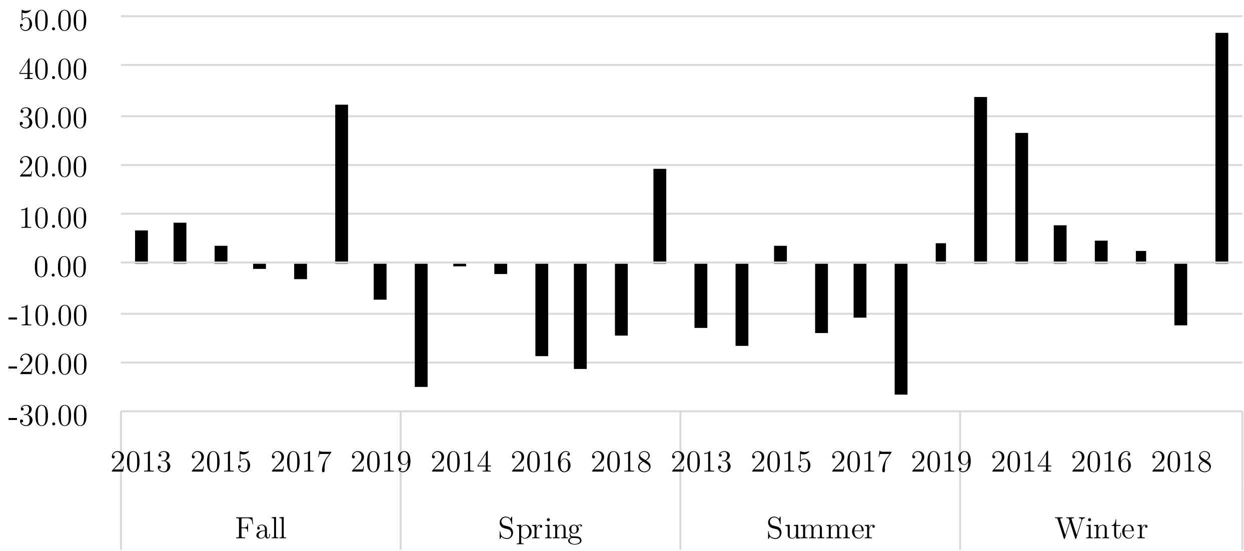
Source: Authors' own creation

Index3 – Weeks' accumulated yearly premiums are in absolute terms more extreme than the accumulated yearly premiums in the other indices. One explanation is that contracts with one and two weeks to delivery are priced based on long-term weather forecasting, which increase the predictability in the system price (Appendix 4). The system prices three weeks into the future are naturally harder to predict, thus, increasing contract volatility and the absolute forward premiums.

Weekly forward premium seasonality

Weekly premium seasonality analysis is based on *Index3 – Weeks* as the index provide a more representative picture of the premiums as it is less affected by the time to delivery. *Index3 – Weeks* premiums are divided into seasons and years below.

Figure 10.22: Seasonality in weekly forward premium



Source: Authors' own creation

Figure 10.22 present the seasonality effect on premiums. Falls and winters affect premiums positively in contrast to springs and summers with mostly negative impact on premiums. This is supported by summary statistics on the weekly indices.

10.4 Unbiased forward rate hypothesis

Section 10.3 Summary statistics and interpretations proved that historical premiums have been present within the data period for all indices except *Index3 – Months* and *Index1 – Weeks*. Despite this, it is still uncertain whether historical premiums are proof of systematic forward premiums on the market (Haugom, et al., 2018, p. 1801). To address this uncertainty, OLS regression theory, presented in *Section 6.3 Ordinary Least Squares (OLS) regression*, is applied to test the unbiased forward rate hypothesis (UFH) indicating whether regressed systematic forward premiums are significantly different from zero.

10.4.1 Regression

First, system prices for different delivery periods are regressed with the corresponding futures price as explanatory variable. From *Section 6.3.7 Unbiased forward rate hypothesis*, the following model is regressed for each index

$$S_{i,t+1} = \alpha + \beta F_{i,t,t+1} + \epsilon_{i,t+1} \qquad \textit{Equation 26}$$

Secondly, graphical visualizations and statistical tests from *figure 6.3*, *Section 6.3.3 Testing OLS regression assumptions* are conducted to test whether OLS-regression assumptions are fulfilled. The process of testing OLS assumptions is conducted with the use of the statistical software package *Stata*, and process interpretations for *Index1 – Weeks, last settlement* are seen below. All Stata codes used for the regressions are found in do-files located in file 6, 7 and 8, with its associated browse-files.

Figure 10.23: Regression output for Index1 - Weeks

Response variable	System price
Explanatory variable	Index1 - Weeks

	Sum of squares	**Degree of freedom**	**Mean Square**
Model	30 272.83	1	30 272.83
Residual	2 148.39	361	5.95
Total	32 421.22	362	89.56

Number of obs	363
F(1,361)	5 086.82
Prob>F	0E+00
R-squared	0.9337
Adj R-squared	0.9336
Root MSE	2.4395

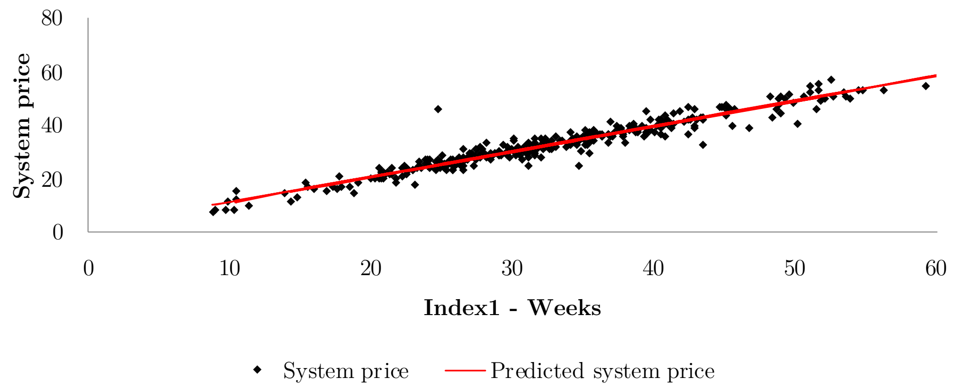
Regression model	**Coefficient**	**Standard Error**	**t**	**P>|t|**	**[95% confidence**	**interval]**
Index1 - Weeks (β)	0.9478	0.0133	71.3200	0.0E+00	0.9217	0.9740
Constant (α)	1.7622	0.4504	3.9100	0.0E+00	0.8765	2.6478

Source: Authors' own creation

Regressing system prices with associated *Index1* prices returns a beta of 0.9478 and a constant of 1.7622. Alpha is significant at a 1%-level, which is evidence against the null hypothesis stating that alpha is equal to zero. This is an indication of a systematic premium being present in the market. Furthermore, a beta significantly different from one is an indication of futures prices being *biased* predictors of system prices. In addition, an R^2 equal to 0.9337 indicates that the regressed model explains 93.37% of the observed system prices. However, *Section 6.3.3 Testing OLS regression assumptions* showed that an OLS-model failing to comply with all assumptions may either return biased estimates or have an increased probability of type I and/or II errors.

Figure 10.24 present a scatterplot between *Index1 – Weeks* prices and the System Prices in the same periods.

Figure 10.24: Scatterplot of Index1 – Weeks and Nordic system price

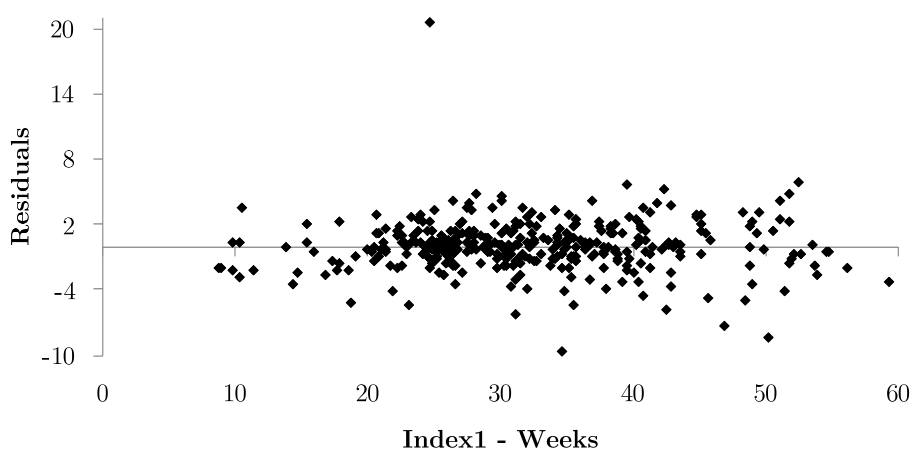


Source: Authors' own creation

The figure indicates that the data generating process may be linear. However, some outliers are observed, with at least one outlier being extreme in relation to the others. This outlier may have a negative impact on regression estimates.

This thesis chooses to graph the regression residuals against the explanatory *Index1* values to verify whether assumption three, four and five holds stating that error terms are random and uncorrelated with a fixed variance.

Figure 10.25: Scatterplot of residuals from Index1 – Weeks

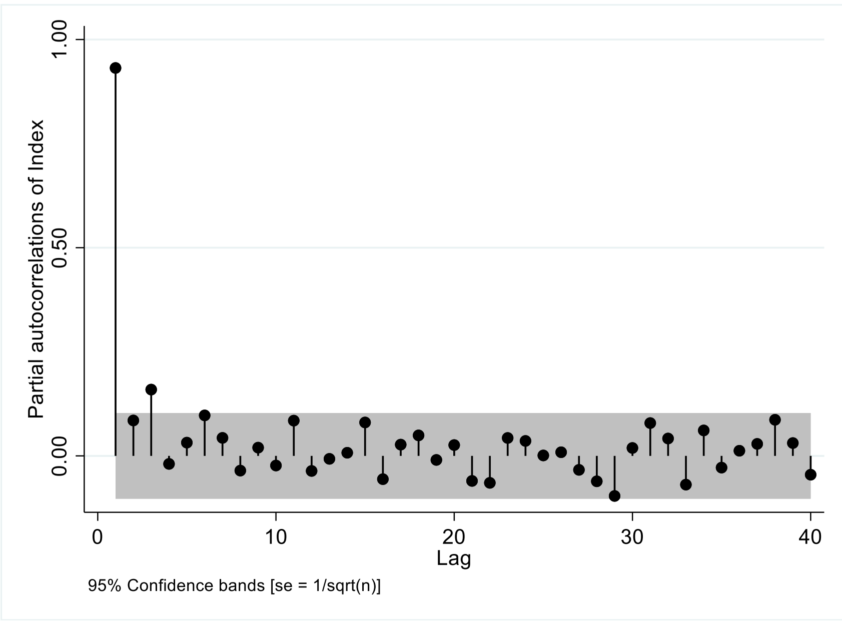


Source: Authors' own creation

From the scatterplot seen in *figure 10.25* it appears that the regression errors are converging towards being randomly distributed. However, there exists some outliers and a minor trend of heteroskedasticity may be observed throughout the data set. These findings, combined with actions discussed in *Section 6.3.3 Testing OLS regression assumptions*, may indicate that a log-transformation or a Newey-West robust standard error correction would optimize regression statistics. Utilizing Breusch-Pagan / Cook-Weisberg test for heteroskedasticity returns a chi-square value of 4.16 and a p-value of 0.0415 (Appendix 9). The low p-value is evidence against the null hypothesis on a 5% significance level, indicating that there exists heteroskedasticity in the error terms. Furthermore, a Durbin-Watson test statistic of 1.7936 indicates that there may exist positive autocorrelation between the error terms. Finally, assumption seven stating that error terms are jointly normally distributed is violated as the Shapiro-Wilk *W test* for normal data, returns a test statistic of 0.8799. This value is low enough to be evidence against the null hypothesis of normally distributed error terms (Appendix 10).

In conclusion, regression of the system price and *Index1 – Weeks* violates assumptions related to error terms. Based on this, in combination with possible actions from *Section 6.3.3 Testing OLS regression assumptions*, logarithmic transformation and Newey-West robust standard error corrections are applied. The logarithmic transformation is performed with utilizing equation 23 in *Section 6.3.4 Actions when OLS assumptions do not uphold*. The Newey-West regression is conducted with a maximum lag of 3, as the partial autocorrelation after lag three are found insignificant through analyzing *figure 10.26.*

Figure 10.26: Partial autocorrelation function of Index 1 – Weeks



Source: Authors' own creation

The regression output from the Newey-West corrected regression is shown below. The Newey-West corrected regression has coefficients identical with coefficients from the standard regression, but t-statistics are adjusted as Newey-West corrected variances for regression estimates are used in the calculations of t-statistics.

Figure 10.27: Newey-West adjusted regression output of Index1 - Weeks

Response variable	System price	**Number of obs**	363
Explanatory variable	Index1 - Weeks	**F(1,361)**	3 659.65
		Prob>F	0E+00

Regression model	**Coefficient**	**Standard Error**	**t**	**P>|t|**	**[95% confidence**	**interval]**
Index1 - Weeks (β)	0.9478	0.0157	60.50	0E+00	0.9170	0.9787
Constant (α)	1.7622	0.4968	3.55	0E+00	0.7852	2.7391

Source: Authors' own creation

Regression outputs for all indices are presented in *table 10.31: Overview of all regression outputs*, and the process of testing OLS assumptions for all conducted regressions are found in files 6,7 and 8.

10.4.2 Seasonality in regression

Section 10.3 Summary statistics and interpretations concluded that historical premiums have varied through seasons, with the most extreme forward premiums found in winters and springs. These findings give reason to believe that the systematic forward premium within the different indices are affected by seasonality as well. The regression model in equation 19 from *Section 6.3.2 OLS regression with seasonal dummy variables* is conducted with winter as reference group to investigate whether the inclusion of seasonality improves the *Unbiased forward rate hypothesis*. The regression with *Index1 – Weeks* as explanatory variable returned the following output:

Figure 10.28: Seasonal regression output for Index1 – Weeks

Response variable	System price
Explanatory variable	Index1 - Weeks
Dummy variables	Spring
	Summer
	Fall
Reference group	Winter

Number of obs	363
F(1,361)	1 280.18
Prob>F	0E+00
R-squared	0.9347
Adj R-squared	0.9339
Root MSE	2.4326

	Sum of squares	**Degree of freedom**	**Mean Square**
Model	30 302.70	4	7 575.67
Residual	2 118.53	358	5.92
Total	32 421.22	362	89.56

Regression model	**Coefficient**	**Standard Error**	**t**	**P>|t|**	**[95% confidence**	**interval]**
Index1 - Weeks (β)	0.9533	0.0136	69.89	0.0E+00	0.9265	0.9801
Dummy: Spring	0.7896	0.3652	2.16	3.1E-02	0.0714	1.5077
Dummy: Summer	0.5262	0.3710	1.42	1.6E-01	-0.2034	1.2558
Dummy: Fall	0.2848	0.3623	0.79	4.3E-01	-0.4277	0.9974
Constant (α)	1.1839	0.5461	2.17	3.1E-02	0.1099	2.2579

Source: Authors' own creation

By comparing this regression output with the output in *figure 10.23* generated from the standard regression, it can be concluded that the inclusion of seasonality improves the *UFH regression*. First, the F-test returned a p-value of 0, which is evidence against the null hypothesis stating that the regression coefficients' means simultaneously equals zero. Furthermore, R^2_{Adj} has increased compared to the standard regression model. *Figure 10.29* present Newey-West corrected F-tests, R^2 and R^2_{Adj} for all indices. The complete regression output is presented in file 6, 7 and 8.

Figure 10.29: Newey-West corrected regression output with seasonal dummy variables

Formula $S_{T+1} = \alpha + \beta * F_{T+1} + D_{spring} * x_{spring} + D_{summer} * x_{summer} + D_{fall} * x_{fall} + \epsilon_i$

	Weeks			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
F-test	981.72***	496.02***	266.62***	401.96***	188.92***	125.29***
R^2	0.9347	0.9238	0.907	0.8911	0.8238	0.7732
R^2_{Adj}	0.9339	0.9229	0.9059	0.8707	0.8147	0.7613

***,** and * indicate significance on a 1%-, 5%-, and 10% level

Source: Authors' own creation

From *figure 10.29* it can be concluded that regression models including seasonal dummy variables, return significant F-tests. *Figure 10.30* below compares R^2 from the standard model with R^2_{adj} generated from the regression model including seasonal dummy variables to compare whether the inclusion of seasonality improves the models' ability to explain system prices.

Figure 10.30: Comparison of regression models

	Weeks			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
$R^2_{standard\ reg.}$	0.9336	0.9212	0.9024	0.8903	0.8233	0.7699
$R^2_{Adj.\ seasonal\ reg.}$	0.9339	0.9229	0.9059	0.8707	0.8147	0.7613

Source: Authors' own creation

For weekly regressions, R^2_{adj} increase compared to R^2 in the standard weekly regression model. However, looking at the monthly regression models, it can be seen that R^2_{adj} decreases. Thus, inclusion of seasonal dummy variables does not necessarily improve the monthly regression models.

Both the historic forward premium analysis and the weekly regression with seasonal dummy variables underlined that seasonality is of importance. Thus, system prices within each season are regressed against futures prices in associated season to quantify how seasonality affects the systematic forward premiums. In other words, system prices located in winter seasons are regressed against observed futures prices in winter seasons. The regression model and output for each season are, together with output from the standard regression, presented in the following section. An important consideration when looking at the regression output is whether seasonal regressions on indices are based on enough observations to make conclusions regarding the presence of seasonal systematic forward premiums.

10.4.3 Regression outputs

Figure 10.31 present outputs generated from the most important conducted regressions in *Chapter 10 Forward premium analysis*. The p-values are calculated based on test statistics corrected with the use of Newey-West robust standard errors correction considered in C*hapter 6. Theories*.

Figure 10.31: Overview of all regression outputs

Formula:	$S_{T+1} = \alpha + \beta * F_{T+1} + \epsilon_{t+1}$						$\log S_{T+1} = \alpha + \beta * \log F_{T+1} + \epsilon_{t+1}$					
	Standard regression						**Log regression**					
	Weeks			**Months**			**Weeks**			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
α	1.7622***	2.5249***	3.1841***	3.223**	4.9344**	6.1156**	0.1206*	0.1922**	0.2388*	0.2006	0.3147	0.4337*
p-value	*0.000*	*0.003*	*0.005*	*0.016*	*0.023*	*0.016*	*0.081*	*0.041*	*0.064*	*0.149*	*0.148*	*0.084*
β	0.9478	0.9224	0.9011	0.8983	0.8468	0.8109	0.9658	0.9447	0.9311	0.9414	0.9089	0.8746
R^2	0.9336	0.9212	0.9024	0.8903	0.8233	0.7699	0.9396	0.9244	0.9086	0.8923	0.8384	0.7793

	Formula:	$S_{T+1_{\{Season\}}} = \alpha + \beta * F_{T+1_{\{Season\}}} + \epsilon_{t+1}$						$\log S_{T+1_{\{Season\}}} = \alpha + \beta * \log F_{T+1_{\{Season\}}} + \epsilon_{t+1}$					
		Standard regression on each season						**Log regression on each season**					
		Weeks			**Months**			**Weeks**			**Months**		
		Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
Winter	α	3.5236**	4.0163***	4.6967***	5.6727*	7.1457**	9.2548**	0.2555*	0.3322**	0.4434***	0.5214	0.5858*	0.8181**
	β	0.8871	0.8618	0.8339	0.8188	0.7783	0.7174	0.92415	0.8996	0.866	0.848	0.8307	0.7656
	R^2	0.863	0.8765	0.8635	0.8434	0.7861	0.7222	0.8609	0.8604	0.8401	0.8446	0.8264	0.7645
Spring	α	1.7556**	2.0945**	2.2946**	0.5655	1.8192	2.1437	0.2126***	0.2581***	0.2809***	0.0825	-0.0163	-0.0271
	β	0.9602	0.9526	0.9484	0.9853	0.9541	0.958	0.943	0.9307	0.9246	0.9762	1.0079	1.014
	R^2	0.9522	0.9334	0.9088	0.8961	0.8074	0.7045	0.9489	0.9389	0.9227	0.902	0.8171	0.7055
Summer	α	0.5786	0.7076	0.7025	3.2491	6.1241**	7.5616***	0.0336	0.0592	0.0287	0.0087	0.2579	0.4469
	β	0.9919	0.9951	1.0036	0.9134	0.8186	0.7786	0.9931	0.9874	0.9986	1.0023	0.9293	0.8759
	R^2	0.9672	0.9516	0.9427	0.9061	0.8572	0.8541	0.962	0.9402	0.9294	0.8985	0.869	0.8523
Fall	α	0.8676	2.6101**	4.0003***	0.9924	2.2456	1.1341	0.006	0.1366	0.2434**	0.3715	0.4782	0.2626
	β	0.9711	0.9149	0.8706	0.9611	0.9166	0.9273	0.9971	0.9588	0.9276	0.8912	0.8593	0.9139
	R^2	0.9443	0.9203	0.899	0.8345	0.8169	0.8139	0.9501	0.9303	0.9138	0.8985	0.7926	0.8264

***,** and * indicate if alpha is significant on a 1%-, 5%-, and 10% significance level

Source: Authors' own creation

From the table it can be concluded that alphas estimated from standard regressions on *Weekly* and *Monthly* indices are positive and significant on a 1%- and 5% significance level, respectively. This indicates that systematic forward premiums are present for all indices. This conclusion is supported by the estimated alphas in the log regressions, as four out of six estimates are found to be significant. Furthermore, when applying *UFH regressions*, it is assumed that β=1, thus, a beta different from 1 is an indication of futures being *biased* predictors of future system prices. Given that most beta coefficients have a value less than one, futures prices can be interpreted as being downward-biased predictors of future system prices. Additionally, betas and R^2's decrease with time to delivery, indicating that the probability of forecasting errors are increasing with time.

The main objective when conducting seasonal regressions is to conclude whether seasonal- and significant systematic forward premiums are present within the different seasons and indices. Outputs from the seasonal regressions show that most alpha estimates from the winter regression are found significant, indicating that systematic forward premiums are present in winter months. The same may be concluded looking at alphas generated from spring regressions on weekly indices. Despite this, significant alphas are not found when performing the same regression on monthly indices, however, these findings may be biased as a result of few observations. Furthermore, standard regressions on fall and summer returns fewer significant alphas, which may be an indication of less significant systematic forward premiums within these seasons. In conclusion, significant systematic forward premiums are present for all indices during winter, and for weekly indices during spring. Alpha values from most fall and summer regressions do not provide enough evidence to reject the hypotheses stating that the systematic forward premium is significantly different from zero.

10.5 Sensitivity analysis

Section 10.1.2 Considerations relating to futures indices explained how different futures price quotes may impact futures price calculations. Thus, historical forward premiums and regression outputs are put into perspective by comparing findings from the use of *Last settlement* futures prices with findings from the use of *Last trading week average*- and *Max volume trading week* futures prices, as first introduced in *figure 10.2*.

Figure 10.32: Sensitivity analysis based on various price quoting mechanisms

$$y = \alpha + \beta x_i + \epsilon_i$$

Last settlement prices	**Weeks**			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
Average historical FP	-0.0684	0.0005	0.0343	0.0889	0.0299	-0.0120
Average regressed FP	-0.0662	0.0006	0.0359	0.0870	0.0345	-0.014
Estimated alpha	1.7622***	2.5249***	3.1841***	3.223**	4.9344**	6.1156**

Last trading week average prices	**Weeks**			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
Average historical FP	-0.0188	0.0216	0.0290	0.0574	-0.0115	-0.0585
Average regressed FP	-0.0185	0.0255	0.0280	0.0594	-0.0114	-0.0599
Estimated alpha	1.7887***	2.5720***	3.2206***	3.0174**	4.8334**	6.0658**

Max volume trading week prices	**Weeks**			**Months**		
	Index1	*Index2*	*Index3*	*Index1*	*Index2*	*Index3*
Average historical FP	-0.0235	0.0069	0.0313	0.058	-0.1169	-0.1703
Average regressed FP	-0.0229	0.0063	0.0311	0.0886	-0.1163	-0.1692
Estimated alpha	2.1182***	2.6011**	3.2177**	3.2223**	4.7486**	5.8461**

***,** and * indicate significance on a 1%-, 5%-, and 10% level, respectively

Source: Authors' own creation

Figure 10.32 illustrate that a change from *Last settlement-* to *Last trading week average* futures prices have some impacts on average historical and regressed forward premiums, but that estimated alphas remain significant on 1%- and 5% levels. Average historical forward premiums increase for *Index1 – Weeks* and *Index2 – Weeks*, and decrease for *Index3 – Weeks* and the monthly indices. Average forward premiums in *Index2 - Months* change from being positive to negative when applying the alternative price recognition mechanisms. In addition, average premiums on four of the indices have more extreme absolute values when using *Last settlement* prices. This is expected as futures prices from the use of *Last trading week average* prices, in general, are smoothed and less volatile compared to prices from the use of *Last settlement* prices.

Nearly the same tendency is observed when changing from *Last settlement-* to *Max volume trading week* prices. *Index1 – Weeks* and *Index2 – Weeks* experience increasing forward premiums and forward premiums from the other indices decrease. All alphas remain significant on a 1%- or 5% level, indicating that significant forward premiums are present on the market regardless of selected futures price calculation criteria.

Chapter 10 – Forward premium analysis has calculated historical forward premiums on all futures indices, tested the unbiases forward rate hypothesis, and tested futures prices' impact on findings with the objective of answering the following sub-question; "*Are historical premiums present in liquid Nordic power derivatives?"*. The chapter found historical forward premiums present in all indices expect for *Index3 – Months* and *Index1 – Weeks.* Despite this, all indices have positive premiums on some seasons, with the average forward premiums being the highest during winter. On the other hand, spring has been the season with the lowest forward premiums. Furthermore, most of the different *UFH-regressions* provided evidence against the null hypothesis stating that α's are equal to zero, indicating that significant systematic premiums exist on the market. However, dividing the *UFH-regression* into seasonal regressions concluded that only winter provided unambiguous evidence of significant systematic forward premiums present. The spring observations provided evidence against the null hypothesis in only the weekly indices. Finally, the importance of futures prices' recognition criteria is considered with a sensitivity analysis illustrating that historical forward premiums do change with change in price criteria. However, a change in futures prices' recognition criteria do not alter the conclusion of a significant systematic forward premium being present on the market.

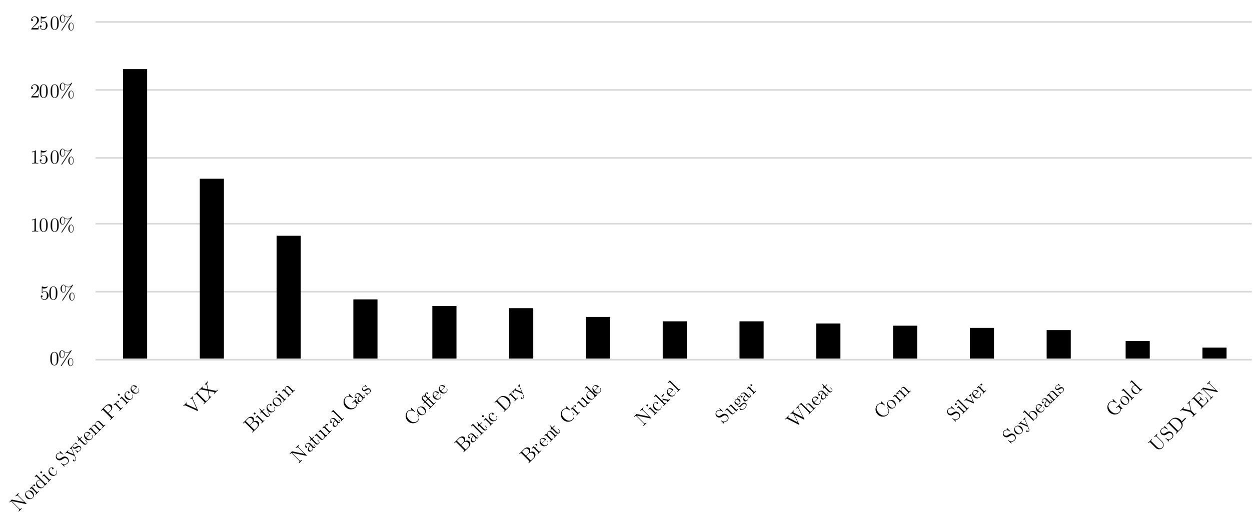
11. Discussion: Where are the options?

The following paragraphs aim to illustrate why options on power futures have become a less favorable derivative to use to gain exposure towards Nordic power.

Section 6.1 Options explained highlighted that participants in the market are quoting options based on future volatility on the underlying asset, known as the implied volatility. *Section 9.2 Futures contracts* found Nordic power futures to be highly volatile, which, all else equal, results in expensive options. High volatility increases the possibility for an expected option payoff for buyers whilst the downside is still limited. The increased expected payoff for buyers results in higher expected loss for sellers, which increases option prices to account for this potential loss.

Throughout this thesis, it is stated that the volatility on the Nordic power market is high, but a comparison against other commodities or indices has yet to be made.

Figure 11.1: Annualized volatility for commodities and indices

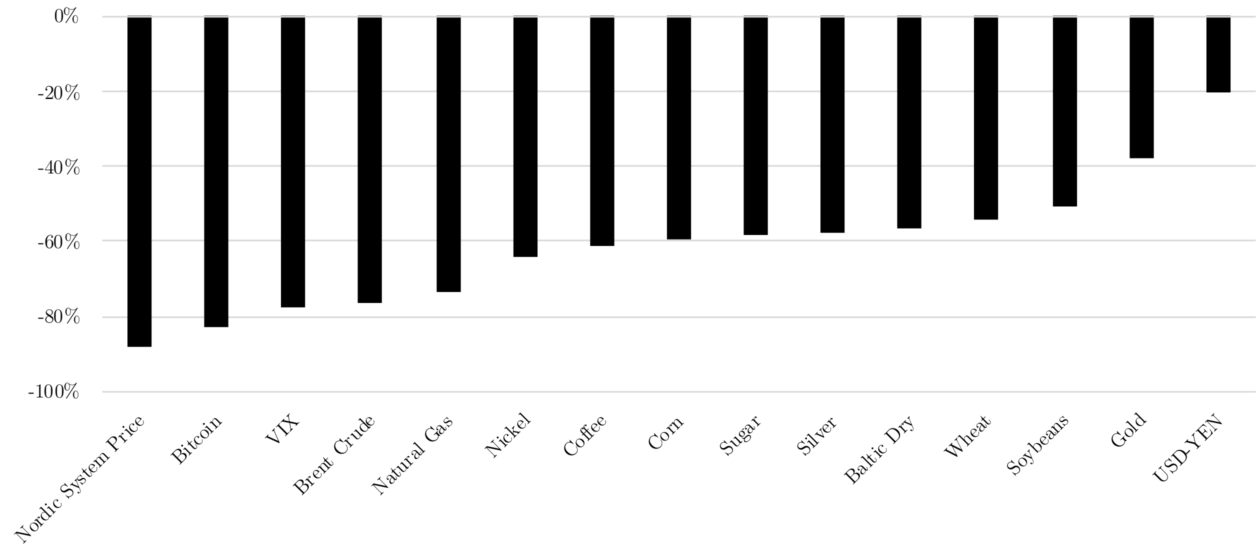


Source: Authors' own creation with data extracted from Bloomberg Terminals

As can be seen from *figure 11.1*, Nordic power is by far the most volatile commodity or index traded amongst assets with known elevated volatility or a well-functioning futures market. It is interesting to note that Nordic power is even more volatile than the VIX-index and Bitcoin, assets associated with excessive volatility.

Another possible measure, and practical interpretation, of volatility is the largest loss incurred in each of the asset-classes throughout the seven-year period. This value is found by identifying the largest quoted closing price for each asset, and the subsequent lowest recorded date, where one can imagine buying at the highest value selling at the lowest value.

Figure 11.2: Largest loss incurred in various commodities and indices



Source: Authors' own creation with data extracted from Bloomberg Terminals

It is observable that the highest incurred loss would result from investing in the Nordic system price, where from its peak value at 80.99, recorded at the 21st of January 2016, fell 88 per cent to 9.79, recorded on the 8th of June 2019. Yet again, one finds Bitcoin and VIX amongst the highest losses incurred, but both being better off than the Nordic system price, underlining a central theme of the thesis that electricity is a highly volatile commodity.

The excessive volatility of Nordic power implies that options with Nordic power as the underlying asset, will under normal pricing theories, become expensive. Interviews with industry experts suggest that the elevated implied volatility used to price options makes the financial instrument prohibitive in use due to extremely high price (Appendix 4). Finally, it must be noted that Mr. Rabbe of Nasdaq highlighted the possibility that many larger market participants might still be utilizing options, but that the trades are executed bilaterally and not through an exchange (Appendix 5).

12. Hedging

The following paragraphs will answer the sub-question "*How can a hedging strategy be structured using the findings about derivative pricing premiums in the market?*". This will be accomplished by first introducing the reader to the fundamentals of hedging, both how and why a market participant might choose to hedge their positions. The findings from Chapters 8, 9, and 10 will provide the basis for which hedging strategies should be tested in a historic context to assess which strategy will perform the best under 'normal' market conditions. Finally, a conclusion regarding the various hedging strategies and when to implement them will be presented.

12.1 Introduction to hedging

In its simplest terms, hedging can be described as the activity of reducing the risk of radical price movements in an asset (Reiff, 2020). To understand a hedge, one might illustrate the hedging activity as analogous to taking out an insurance policy. Consider a home insurance covering the policy holder from house fires. In this case, the policy holder is seeking to mitigate the risks of fires, and by doing so, the policy holder pays a monthly fee to maintain their insurance. The monthly fee illustrates the risk-reward trade-off inherent to hedging, where it is clear that mitigating risks has a price. It is possible to imagine that most property owners who have house insurance for longer periods of time will pay for an insurance that they 'never need', and thus incurring a 'loss'. However, most people will prefer the accumulated loss represented by the sum of all monthly premiums paid to the insurance company, over suddenly losing their home to a fire.

In the financial world of risk mitigation, or hedging, the mechanisms are the same. Investors and producers all use hedging to reduce and control their exposure to risk. One may consider the example of a company that knows it must purchase 10,000 bushels of corn in six months. Assuming that the spot price for corn currently trades at 354.75 USD[9], and the six-month future price is 360'2 USD[10], the company needs to buy two contracts, each ensuring delivery of 5,000 bushels, to cover their entire demand for corn in the future. By buying two contracts, the company knows what they are going to pay for their 10,000 bushels of corn in six months, and this entails they have successfully eliminated their risk for price fluctuations in the future. Should the price in six months be higher than the 360'2 USDs paid per contract, the company will have earned a 'profit' as they are able to buy their 10,000 bushels of corn at a discount to the future spot price. Similarly, should the future spot price be lower

[9] Closing spot price as of 16th of March 2020.

[10] September 2020 futures price as of 17th of March 2020 04:16:29 CT

than the 360’2 USDs paid per contract, the company would incur a ‘loss’, as it could have bought the corn cheaper at the future spot price.

Futures contracts have the distinct advantage of limiting the risk exposure to the uncertainty of price fluctuations. By locking in a price of an asset or commodity, a production company is able to eliminate any ambiguity of expected profits and expenses. Although the futures market is known for its many products, there is a finite variety of futures contracts available, so investors might choose to purchase futures contracts that have close positive or negative correlation with the asset they are wanting to hedge. An example of positive correlation is buying a wheat contract when the hedger seeks to mitigate the price risk of barley (Beers, 2020).

In the futures market, both producers and investors are present to either hedge or speculate on price movements in assets and commodities. In general, the main participants in the Nordic power markets are power producers, power suppliers, traders, and large power consumers. The power producers are usually government owned companies producing either hydro- or wind power. Recent development in the renewable energy market has led commercial players to enter market due to favourable industry prospects. However, as developers are receiving less state subsidies, renewable energy developers turn to the derivatives market to hedge their future power production. This entails that the future revenues are known when initiating a new project, which in turn reduces the overall project risk.

Power suppliers are the companies that provide power to the end users, often supplying the consumer market. Traders are often acting as speculators taking the opposite side of trades vis-à-vis the power producers and -suppliers and provide liquidity to the market. Lastly, the large power consumers often possess significant production facilities; however, interviews with industry experts suggest that these players often engage in bilateral trading with the power produces directly and forego the Nasdaq exchange.

12.1.1 Hedging strategies

In the previous paragraphs hedging has been described in relation to mitigating price fluctuation risk with futures contracts. However, the reader should take note that there are several other risks and financial instruments present in the world of hedging. Financial risks such as credit risk, currency risk, interest rate risk, volatility risk and volume risks are all risks possible to mitigate through futures, options, contracts-for-difference, swaps, swaptions, caplets or a combination of the aforementioned financial products (Hull, 2018, p. 71). However, this thesis focuses on the hedging of price risk, and to such extent considers futures contracts as the best suited financial instrument to achieve such a hedge. Interviews with industry experts suggest that the most common type of hedges in the financial market for Nordic power are futures, mainly aimed at mitigating price risk. Additionally, some markets participants to some extent mitigate geographical price risk through Electricity Price Area Differentials (EPAD) (Appendix 2). Furthermore, they might also hedge their currency risk as the prices are quoted in Euros and since both the Norwegian and Swedish currencies are not pegged at a fixed rate to the Euro, the need for currency hedging arises.

12.1.2 Offset hedging

After having decided to employ a hedging strategy, the hedger must consider how much of total production should be hedged. If the hedger is considered to be risk averse, she may want to hedge her entire position, referred to as offset hedging. This entails entering an opposite position in the underlying asset as previously held, offsetting any price exposure since the future obligation is entirely offset by the hedge (Chen, 2019).

12.1.3 Contango and backwardation in Nordic power markets

In the futures markets, the common pricing patterns seen are contango and backwardation which describe shape of the forward curve. When the market is in contango, the forward price of a futures contract is higher than the spot price. Conversely, when the market is in backwardation, most commonly called normal backwardation as this is the normal shape of the forward curve, the futures prices are lower than current spot prices (CME Group, 2020).

12.2 Introduction to power hedging strategies[11]

Based upon forward premium findings, various hedging strategies will be tested in a historical context and ranked by standard deviation, VaR-criterion, and mean returns. The thesis has identified three

[11] All Excel sheets concerning the various hedging strategies are found in files 10, 11 and 12.

primary participants in the financial market for Nordic electricity derivatives; power producers, -suppliers and speculators. The hedging part of this paper is divided into three parts, where hedging strategies applicable to the specific market participant is presented.

When testing the various hedging strategies, this thesis highlights the importance of being able to implement the hedging strategies going forward. Thus, the strategy cannot be based upon ex-post considerations, such as high/low price considerations. Additionally, it is assumed that the power suppliers and -producers at all times are operating in the spot market, ensuring that their customers are provided with the power they need. Thus, power producers are continuously *long* in the spot price and *short* futures to hedge their positions. Conversely, power suppliers are continuously *short* in the spot price and use *long* positions in futures contracts to offset price risk.

When considering the hedges and corresponding payoffs, the reader recalls that all financial power derivatives in the Nordic market are financially settled. The practical implications of this is that power producers will *always* sell their electricity in the spot market and are entitled to receive the positive delta and similarly obligated to pay the negative delta. This mechanism is illustrated in the following example. A power producer sells a front month[12] futures contract at 40 €/MWh. When the actual month occurs, hydrologic conditions has changed, and the system price is trading at 50 €/MWh. The power producer is now out-of-money by 10 €/MWh for the futures contract but offsets this loss by selling the equivalent at the spot system price. Therefore, the power producer receives 50 €/MWh for the electricity it sells in the given month and pays the difference between futures price and spot price (10 €/MWh) to their counterparty in the futures deal. This leads to the cash flows from the total position, including both the long position in the system price and short position in the futures contract, being:

$$50\ \text{€/MWh} - (50\ \text{€/MWh} - 40\ \text{€/MWh}) = 40\ \text{€/MWh}$$

[12] A front month is defined the nearest expiration date for a futures contract (Ganti A. , 2019b). The same nomenclature is utilized for weeks, where the futures contract with the nearest expiration date is called the front week.

12.3 Hedging for power producers

Hedging strategies for power producers are used to cover power producers' price exposure over longer periods of time. As uncovered through expert interviews, the power producers aim to hedge some of their production for longer periods of time; up to 10 or even 15 years (Appendix 2), and often do this by entering bilateral agreements with large power consumers or power suppliers. However, power producers also operate within shorter hedging periods, and in this capacity use monthly contracts for hedging on a short time period.

As opposed to power suppliers that hedge their costs, power producers hedge their future income by offsetting their long position in the system price by entering a short position in futures contracts. Similar to hedging for power suppliers, the hedging for power producers is based upon findings from *Chapter 9. Descriptive statistics* and *Chapter 10. Forward premium analysis*. This means the strategies will employ a notion of seasonality of if, and when, to enter the various hedging strategies. The outline for the hedging strategies for power producers is presented below.

Figure 12.1: Hedging strategies for power producers

Strategy 1
Continuously long position in system price combined with a monthly futures hedge in one season

Strategy 2
Continuously long position in system price combined with monthly futures hedges in more than one season

Scenario	**When to enter the hedge**
a	Last settlement price before delivery
b	Last settlement price 1 month before delivery
c	Last settlement price 2 months before delivery

Source: Authors' own creation

Strategy 1 has the objective of testing which seasonal hedges are most optimal on a stand-alone basis, considering standard deviation and 5%VaR as risk measures, as well as the average revenue received by holding the position. The output from ex-post testing the strategy from January 2013 to December 2019 is presented below.

Figure 12.2: Long position in Nordic system price and monthly hedging in different seasons

	Strategy 1a: Last close			Strategy 1b: 1 Month to delivery			Strategy 1c: 2 Months to delivery		
	Std Dev	VaR(95%)	Avg. Return	Std Dev	VaR(95%)	Avg. Return	Std Dev	VaR(95%)	Avg. Return
Baseline	**9.87**	**16.77**	**32.45**	**9.87**	**16.77**	**32.45**	**9.87**	**16.77**	**32.45**
Short winter	9.74	18.65	32.89	9.75	18.59	33.05	9.48	18.55	32.89
Short spring	9.65	17.16	32.30	9.76	17.13	32.02	10.03	16.50	32.02
Short summer	9.66	16.11	32.26	9.27	18.35	31.98	9.09	18.60	31.74
Short fall	9.96	17.15	32.43	10.22	16.30	32.41	10.05	17.81	32.09
All year	**9.42**	**18.65**	**32.51**	**9.40**	**19.45**	**32.36**	**9.19**	**19.20**	**32.10**

Source: Authors' own creation

From *figure 12.2*, considering standard deviation as a measure of risk, close to all seasonal hedges in the outlined scenarios perform better than the baseline of not hedging anything. The lowest standard deviation is found in *Strategy 1c – Short summer*, where hedging occurs during summertime by buying monthly futures contracts continuously with two months to delivery. This pattern may be explained by the findings from *Chapter 9. Descriptive statistics* which indicate that system prices during summers are highly volatile. Therefore, hedging months that are volatile will, all else equal, reduce the standard deviation of the portfolio. However, *Strategy 1c – Short summer*, is the hedging strategy that yields the lowest average return, which in turn is consistent with classic economic theory that reduced risk also reduces the potential returns. For power producers who aims to maximize revenue, *Strategy 1b – Short winter* would be suitable as it possesses the highest average return. Furthermore, this hedging strategy yields a lower standard deviation than the baseline of zero hedging, whilst still offering a higher expected return. The second highest average return is achieved by shorting either a front month futures or two months to delivery throughout the winter, with an average return of 32.89 €/MWh. However, *Strategy 1c – Short winter* has the lower standard deviation of the two, which indicated that this might be the strategy to pursue for the best risk/return relationship.

Strategy 2 aims to exploit the findings from *Chapter 10. Forward premium analysis* by testing strategies that entail both long and short positions. The pattern of deciding when to go long or short is determined by whether a positive or negative forward premium is present in the given season. By going long in some of the strategies, the overall returns may be higher, but at an added risk for the power producer, as he now no longer holds offsetting hedging positions.

Figure 12.3: Long position in Nordic system price and various positions in different seasons

	Strategy 2a: Last close			Strategy 2b: 1 Month to delivery			Strategy 2c: 2 Months to delivery		
	Std Dev	**VaR(95%)**	**Avg. Return**	**Std Dev**	**VaR(95%)**	**Avg. Return**	**Std Dev**	**VaR(95%)**	**Avg. Return**
Baseline	**9.87**	**16.77**	**32.45**	**9.87**	**16.77**	**32.45**	**9.87**	**16.77**	**32.45**
Short winter and fall	9.84	18.19	32.87	10.09	18.15	33.09	9.71	19.21	32.76
Short winter, spring and fall	9.63	18.65	32.71	9.99	18.00	32.75	9.92	18.00	32.57
Short winter, spring and fall, long summer	10.32	18.06	32.91	11.63	15.25	33.13	12.34	16.50	33.05
Short winter, long summer	10.42	18.00	33.09	11.41	16.13	33.44	11.98	16.12	33.37
Long summer	10.55	16.46	32.65	11.55	14.89	32.76	12.30	15.00	32.69
Long summer and spring	11.18	15.27	32.80	12.48	13.84	33.11	13.29	13.53	32.88
Long summer and spring, short winter and fall	11.14	17.15	33.22	12.59	15.25	33.83	13.17	14.63	33.43
All year	**9.42**	**18.65**	**32.51**	**9.40**	**19.45**	**32.36**	**9.19**	**19.20**	**32.10**

Source: Authors' own creation

As can be observed from *figure 12.3*; the profit maximization hedging strategy would entail buying (long) futures contracts with one months to delivery during the summer and spring, whilst selling (short) contracts for winter and fall, i.e. *Strategy 2b – Long summer and spring, short winter and fall.* However, consistent with an expected risk/return relationship, one can observe that this strategy also yields the third highest standard deviation that is substantially higher than the baseline. Being a strategy that does not have offsetting properties in all seasons and have a higher standard deviation than the baseline, it could be argued that this strategy is actually speculation rather than hedging.

If one were to apply the criteria that the hedging strategy should entail a standard deviation lower than the baseline of zero hedging, the three strategies that meet this criterion are short-only strategies. Shorting front month contracts throughout either winter and fall or winter, spring and fall, or shorting two months to delivery contracts during the winter and fall, would yield a standard deviation lower than the baseline. Between the three, shorting contracts throughout winter, spring and fall is the risk averse hedging strategy as it yields the lowest standard deviation. However, this also results in a marginally lower average return, which implies that the profit maximizing hedger would prefer shorting solely winter and fall front month contracts.

Figure 12.4: Top five strategies within its parameter for power producers

	Top 5 Strategies			
	Std.dev	VaR (95%)	Avg. Return	Offset
Strategy 1a - Short winter	x	**3**	x	Yes
Strategy 1a - Short spring	**5**	x	x	Yes
Strategy 1a - Short summer	x	x	x	Yes
Strategy 1a - Short fall	x	x	x	Yes
Strategy 1b - Short winter	x	**5**	x	Yes
Strategy 1b - Short spring	x	x	x	Yes
Strategy 1b - Short summer	**2**	x	x	Yes
Strategy 1b - Short fall	x	x	x	Yes
Strategy 1c - Short winter	**3**	x	x	Yes
Strategy 1c - Short spring	x	x	x	Yes
Strategy 1c - Short summer	**1**	**4**	x	Yes
Strategy 1c - Short fall	x	x	x	Yes
Strategy 2a - Short winter and fall	x	x	x	Yes
Strategy 2a - Short winter, spring and fall	**4**	**2**	x	Yes
Strategy 2a - Short winter, spring and fall, long summer	x	x	x	No
Strategy 2a - Short winter, long summer	x	x	x	No
Strategy 2a - Long summer	x	x	x	No
Strategy 2a - Long summer and spring	x	x	x	No
Strategy 2a - Long summer and spring, short winter and fall	x	x	**4**	No
Strategy 2b - Short winter and fall	x	x	x	Yes
Strategy 2b - Short winter, spring and fall	x	x	x	Yes
Strategy 2b - Short winter, spring and fall, long summer	x	x	**5**	No
Strategy 2b - Short winter, long summer	x	x	**2**	No
Strategy 2b - Long summer	x	x	x	No
Strategy 2b - Long summer and spring	x	x	x	No
Strategy 2b - Long summer and spring, short winter and fall	x	x	**1**	No
Strategy 2c - Short winter and fall	x	**1**	x	Yes
Strategy 2c - Short winter, spring and fall	x	x	x	Yes
Strategy 2c - Short winter, spring and fall, long summer	x	x	x	No
Strategy 2c - Short winter, long summer	x	x	**3**	No
Strategy 2c - Long summer	x	x	x	No
Strategy 2c - Long summer and spring	x	x	x	No
Strategy 2c - Long summer and spring, short winter and fall	x	x	x	No

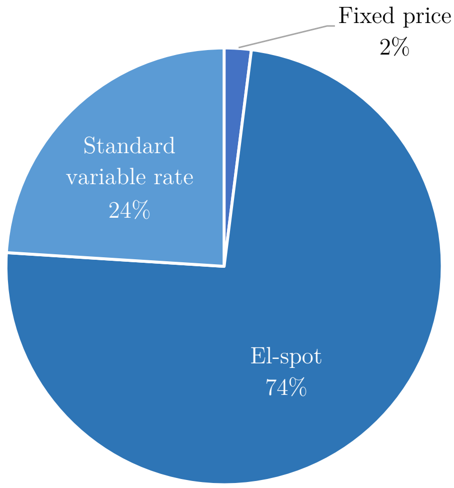
Source: Authors' own creation

As can be observed in *figure 12.4*, the hedging strategies that yield the lowest standard deviation are short-only strategies, implying that they are offsetting hedges. The same holds true for value at risk, where the short-only strategies yield the highest VaR-values. Thus, shorting two-month to delivery futures contracts throughout the winter and fall will ensure the highest VaR. The top five strategies in terms of average returns are all combinations of long-short strategies, that therefore, in some seasons expose, the power producers to spot price fluctuations as well as the inverse forward premium. Such strategies entail a higher degree of risk, which can be observed in the elevated standard deviations. Furthermore, on a stand-alone basis, it is unlikely that long-short strategies will fulfil the requirements for hedge accounting compliant with IFRS 9 (EY, 2014). This entails that the profit or losses associated with the futures contracts will have to be classified as an income, rather than going on the balance sheet. However, as it is assumed that most power producers have several strategies employed to mitigate risk, long-short strategies might in combination with the total positions held by the power producer be considered as hedges. Additionally, it is well worth noting that many large companies employ traders alongside their hedging department to optimize their hedges, contribute to market insight and profit from short term fluctuations in energy prices (Ørsted, 2020, s. 142). Therefore, long-short strategies might be employed by power producers, contingent upon compliance with the specific company's risk parameters.

12.4 Hedging for power suppliers

The optimization of cost hedging for power suppliers is done solely by considering weekly futures contracts. This, as it is assumed that Nordic power suppliers aim to mitigate the risk related to the difference in power procurements and power rates to customers. Most of the hedges performed by power suppliers are short term hedges as the objective is to secure profit, or minimize losses, generated from supplies of power to customers. Knowing that power contracts with customers are based on spot prices, fixed prices or standard variable rates, and that power prices are highly volatile, short time futures are considered most appropriate for power supply hedges. This is supported by looking at the distribution of contract types in Norway presented in *figure 12.5* (file 13).

Figure 12.5: Distribution of power contract types



Source: Authors' own creation based on data from SSB

74% of Norwegian customers have power contracts based on local spot prices, 24% have standard variable contracts, and only 2% have contracts based on prices fixed for at least a year. In other words, by securing procurement prices on a weekly basis, parts of the obligations related to standard variable contracts and spot rates are hedged, and the cost predictability increased. Furthermore, the following hedge optimization solely focus on mitigating risks related to the cost of power, and do not consider risk related to income. This as income for suppliers is hard to predict considering varying power rates offered to customers. In summary, this section evaluates optimal hedging strategies for suppliers looking to offset cost of a short position in the system price using weekly futures. Thus, an optimal hedge is a hedge that mitigate part of the standard variable contract and/or spot rate obligation with the lowest possible risk.

Chapter 9. Descriptive statistics found the system price volatility to be varying throughout seasons, with the highest volatility during winters. A similar seasonal pattern is seen on weekly futures in *Chapter 10. Forward premium analysis*, with winter and fall both having the highest forward premium volatility. These findings make it reasonable to believe that optimal hedges based on different risk measures should consider seasonality. This resulted in the design of two main hedge strategies with three different scenarios of when to enter the hedge.

Figure 12.6: Hedging strategies for power suppliers

Strategy 1
Continuously short position in system price combined with a weekly futures hedge in one season

Strategy 2
Continuously short position in system price combined with weekly futures hedges in more than one season

Scenario	When to enter the hedge
a	Last settlement price before delivery
b	Last settlement price 1 week before delivery
c	Last settlement price 2 weeks before delivery

Source: Authors' own creation

Strategy 1 has the objective of testing which seasonal hedges are most optimal considering standard deviation and 5%-value at risk as risk measurements, as well as the average cost of the position. The output from ex-post testing the strategy from January 2013 to December 2019 is presented below.

Figure 12.7: Continuously short the Nordic system price combined with a weekly futures hedge in one season

	Strategy 1a: Last close			Strategy 1b: 1 Week to delivery			Strategy 1c: 2 Weeks to delivery			Offset
	Std Dev	VaR(95%)	Avg. cost	Std Dev	VaR(95%)	Avg. cost	Std Dev	VaR(95%)	Avg. cost	hedge
Baseline	**9.89**	**-50.82**	**-32.55**	**9.89**	**-50.82**	**-32.55**	**9.89**	**-50.82**	**-32.55**	
Long winter	9.84	-51.50	-32.71	10.00	-51.50	-32.94	10.02	-50.82	-33.06	Yes
Long spring	9.83	-50.47	-32.43	9.78	-50.19	-32.38	9.75	-50.46	-32.29	Yes
Long summer	9.82	-50.40	-32.45	9.79	-50.41	-32.35	9.67	-50.01	-32.24	Yes
Long fall	9.81	-50.60	-32.56	9.89	-51.10	-32.55	9.92	-51.13	-32.52	Yes
All year	**9.62**	**-51.00**	**-32.48**	**9.78**	**-51.10**	**-32.61**	**9.75**	**-50.55**	**-32.62**	**Yes**

Source: Authors' own creation

First, considering standard deviation as a measure of risk, close to all seasonal hedges in the different scenarios are better than the baseline of not hedging anything. However, some of the strategies are inefficient as they have higher average cost and a higher risk than other strategies. The most optimal strategy with lowest standard deviation is *Strategy 1c – Summer*, where hedging occurs during summers by buying futures contracts continuously two weeks before delivery. This may be consistent with findings from *Chapter 9. Descriptive statistics* indicating that system prices during summers are highly volatile, in combination with the negative seasonal forward premium on weekly futures and their relatively high volatility found in *Chapter 10. Forward premium analysis*. Volatile system prices potentially increase suppliers' propensity to hedge given that volatility as the most important risk measurement. Furthermore, a negative forward premium indicates that the cost of taking a long position in the futures are lower than the system price, resulting in a decrease in the total cost of the position.

The same conclusion can be made when measuring risk using the 5% value at risk. *Strategy 1c – Summer* returns a value at risk of negative 50.01 €/MWh which is the lowest absolute value. A VaR(95%) of -50.01 €/MWh indicate that the supplier with a 5% probability will pay 50.01 €/MWh or more for its position. It can be seen that seasonal hedging in winter seasons do not decrease absolute VaR(95%) compared to the baseline, and that most of the seasonal hedges alone decreases supplier's risk compared to continuously hedging throughout the whole year. Comparing these findings with findings from previous chapters, seasons, i.e. winter, with high skewness and/or kurtosis on system prices and forward premiums typically has a more extreme VaR(95%), than seasons with lower skewness and kurtosis. Increasing kurtosis and skewness increase probability of more extreme values occurring.

Finally, even if suppliers focus on volatility risk mitigating or value at risk, still aim to minimize the total cost of having a short position in the system price and a long position in futures. In other words, average cost is an important measure to consider as power suppliers aim to optimize profits or hedge as cheaply as possible. Average cost optimization may be directly linked with findings from *Chapter 10. Forward premium analysis* as it is more expensive to hedge system prices in seasons with high forward premiums, i.e. winter and fall. *Strategy 1c – Summer* is the strategy with the lowest cost for the supplier with an average cost of 32.24 €/MWh.

Strategy 2 aim at exploiting findings from *Chapter 10. Forward premium analysis* by testing strategies shorting weekly futures in seasons with positive forward premiums, and longing futures in seasons with negative forward premiums. Output from the historical implementation of Strategy 2 is presented below.

Figure 12.8: Continuously short the Nordic system price combined with weekly futures hedges in more than one season

	Strategy 2a: Last close			Strategy2b: 1 Week to delivery			Strategy 2c: 2 Weeks to delivery			Offset
	Std Dev	VaR(95%)	Avg. cost	Std Dev	VaR(95%)	Avg. cost	Std Dev	VaR(95%)	Avg. cost	hedge
Baseline	**9.89**	**-50.82**	**-32.55**	**9.89**	**-50.82**	**-32.55**	**9.89**	**-50.82**	**-32.55**	
Short winter and fall	10.95	-51.57	-32.40	11.15	-51.51	-32.11	11.40	-51.38	-31.91	No
Long spring and summer	9.76	-49.95	-32.33	9.67	-49.60	-32.19	9.54	-49.75	-32.03	Yes
Short winter and fall, long spring and summe	10.83	-51.05	-32.17	10.93	-50.73	-31.78	11.08	-49.75	-31.44	No
All year	**9.62**	**-51.00**	**-32.48**	**9.78**	**-51.10**	**-32.61**	**9.75**	**-50.55**	**-32.62**	**Yes**

Source: Authors' own creation

The least expensive hedging strategies are found in Strategy 2 as it exploits the negative forward premiums from *Chapter 10*. However, taking short positions in futures is not considered offset hedges for suppliers, and these should not be compared equally with hedges complying with the offset requirement in this chapter. *Strategy 2 – Long spring and summer* hedge seasons where system price historically had a standard deviation of 9.67 and 11.11, respectively. The standard deviation from holding a long position in weekly futures during springs and summers together with a short position in the system price, returns a standard deviation of 9.76, which is lower than the baseline. The same conclusions can be made with 5% value at risk as *Strategy 2 – Long spring and summer*, regardless of scenarios, is better than the baseline.

To conclude, power suppliers within the Nordic power market have historically had the possibility to mitigate volatility risk, value at risk, and optimize average cost by taking long positions in weekly futures in different seasons. The most optimal strategies and when to enter the hedges rely on which measure of risk the power supplier prefers and what they are willing to pay for the positions. Below is a table presenting the five best strategies measured on standard deviation, 5% Value at Risk, and average cost.

Figure 12.9: Top five strategies within its parameter for power suppliers

	Std Dev	VaR(95%)	Avg. cost	Offset
Strategy 1a - Long winter	x	x	x	Yes
Strategy 1a - Long spring	x	x	x	Yes
Strategy 1a - Long summer	x	x	x	Yes
Strategy 1a - Long fall	x	x	x	Yes
Strategy 1b - Long winter	x	x	x	Yes
Strategy 1b - Long spring	x	x	x	Yes
Strategy 1b - Long summer	x	x	x	Yes
Strategy 1b - Long fall	x	x	x	Yes
Strategy 1c - Long winter	x	x	x	Yes
Strategy 1c - Long spring	4	x	x	Yes
Strategy 1c - Long summer	3	5	x	Yes
Strategy 1c - Long fall	x	x	x	Yes
Strategy 2a - Short winter and fall	x	x	x	No
Strategy 2a - Long spring and summer	5	4	x	Yes
Strategy 2a - Short winter and fall, long spring and summer	x	x	x	No
Strategy 2b - Short winter and fall	x	x	5	No
Strategy 2b - Long spring and summer	2	1	x	Yes
Strategy 2b - Short winter and fall, long spring and summer	x	x	2	No
Strategy 2c - Short winter and fall	x	x	3	No
Strategy 2c - Long spring and summer	1	2	4	Yes
Strategy 2c - Short winter and fall, long spring and summer	x	2	1	No

Source: Authors' own creation

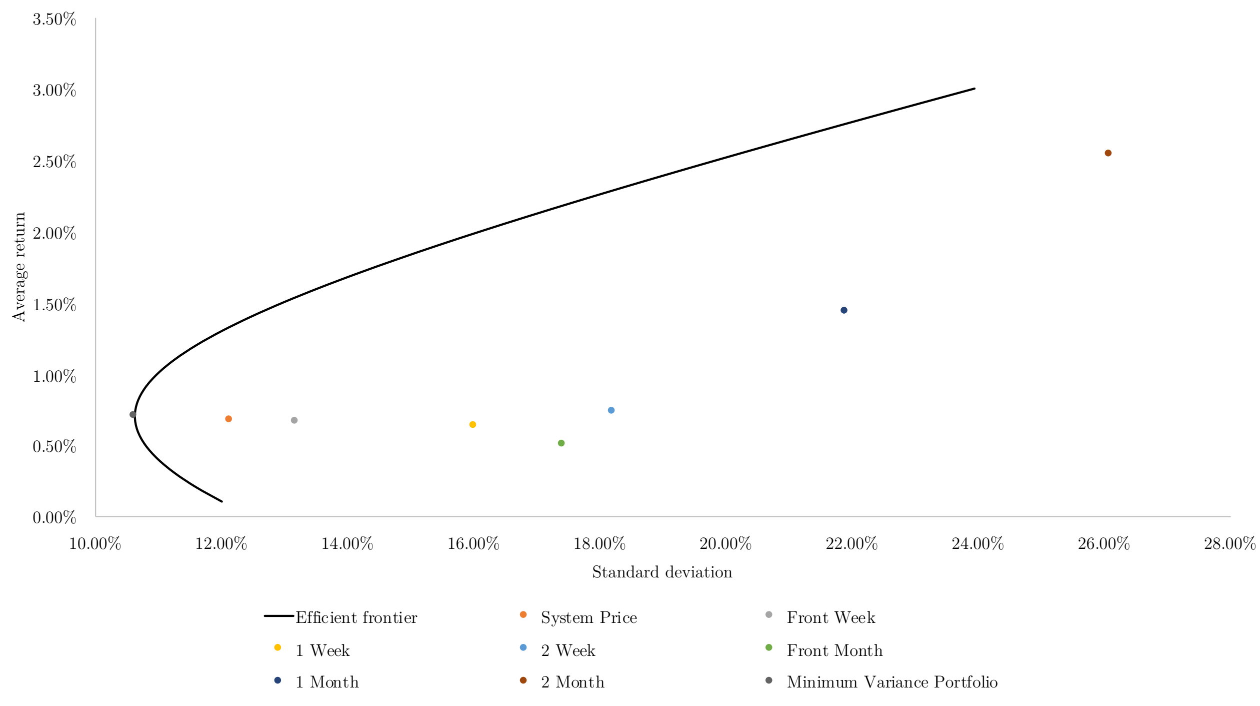
The best seasonal hedge for power suppliers aiming to minimize the standard deviation of costs is *Strategy 2c – Long spring and summer*. A short position in the system price together with long positions in summer and winter weekly futures with two weeks to delivery returns a standard deviation of 9.54 €/MWh. The hedge strategy returning the lowest VaR(95%) is *Strategy 2b – Long spring and summer*. A supplier having a short position in the system price and long positions in weekly futures bought one week to delivery in springs and summers will have a position returning a VaR(95%) of -49.6 €/MWh. Finally, *Strategy 2c – Long spring and summer* is the offset-hedge returning the lowest average cost in the historical data period, indicating that *Strategy 2c – Long spring and summer* is the offset-hedge with the best overall-performance considering standard deviation, value at risk and the average cost.

12.5 'Hedging' for speculators

Interviews with market experts revealed that many power producers and -suppliers have trading activities that supplements their hedging activities, and that there exists collaboration between hedging- and trading divisions (Appendix 4). Given these findings, this section assesses different investment combinations for speculators returning mean-variance efficient portfolios based on ex-post calculations. The main objective is to exploit findings from *Chapter 9. Descriptive statistics* and *Chapter 10. Forward premium analysis* contracts by constructing portfolios consisting of the system price and weekly- and monthly futures with different timing to maturity.

Chapter 6. Theories found Markowitz's mean-variance analysis to be beneficial when constructing optimal portfolios. Furthermore, selling and purchasing futures have similar attributes as selling and buying stocks (You & Daigler, 2012). In other words, Markowitz's mean-variance analysis is considered applicable for portfolios consisting of both futures and the system price. The following ex-post efficient frontier for 2013 to 2020 are generated utilizing Markowitz's mean-variance portfolio analysis on different average daily returns.

Figure 12.10: Efficient frontier



Source: Authors' own creation

The efficient frontier is generated by optimizing portfolio compositions using the system price, and weekly- and monthly futures with different time to delivery. The optimization is done using *Excel Solver* to minimize portfolio variance at different levels of average daily returns. Minimum variance efficient portfolios, as well as other efficient portfolio compositions are presented in *figure 12.11*.

Figure 12.11: Optimal portfolio weights

	Avg. Ret.	Std dev	Sys. Price	Front Week	1 Week	2 Week	Front Month	1 Month	2 Month
All Seasons	0.1%	12.00%	0.55	0.36	0.00	-0.15	0.40	0.18	-0.33
	0.5%	10.78%	0.56	0.39	0.00	-0.11	0.18	0.08	-0.10
	0.70%*	**10.62%**	**0.56**	**0.41**	**0.00**	**-0.09**	**0.07**	**0.03**	**0.02**
	1.0%	10.98%	0.57	0.43	0.00	-0.06	-0.09	-0.04	0.19
	2.0%	16.13%	0.58	0.52	0.00	0.03	-0.62	-0.28	0.77
	3.0%	23.95%	0.60	0.60	0.00	0.14	-1.17	-0.52	1.36
Winter	0.1%	12.20%	0.76	0.22	0.00	-0.01	0.01	-0.13	0.15
	0.23%*	**12.16%**	**0.75**	**0.20**	**0.15**	**-0.15**	**0.02**	**-0.10**	**0.13**
	0.5%	12.18%	0.76	0.22	0.16	-0.22	0.06	-0.08	0.10
	1.0%	12.30%	0.78	0.27	0.16	-0.36	0.14	-0.04	0.04
	2.0%	12.90%	0.83	0.37	0.18	-0.63	0.30	0.05	-0.09
	3.0%	13.90%	0.87	0.46	0.20	-0.90	0.46	0.13	-0.22
Spring	0.1%	8.90%	0.58	0.33	0.00	-0.36	0.54	-0.12	0.04
	0.5%	8.73%	0.54	0.40	-0.06	-0.20	0.38	-0.06	0.00
	0.81%*	**8.69%**	**0.51**	**0.44**	**-0.08**	**-0.09**	**0.24**	**0.00**	**-0.02**
	1.0%	8.70%	0.49	0.47	-0.08	-0.02	0.16	0.03	-0.04
	2.0%	9.26%	0.39	0.59	-0.10	0.32	-0.28	0.20	-0.12
	3.0%	10.50%	0.29	0.72	-0.12	0.67	-0.72	0.37	-0.20
Summer	0.1%	11.72%	0.37	0.62	-0.21	-0.17	0.33	0.22	-0.16
	0.5%	11.54%	0.37	0.60	-0.18	-0.11	0.25	0.19	-0.12
	0.94%*	**11.47%**	**0.38**	**0.59**	**-0.15**	**-0.04**	**0.15**	**0.14**	**-0.06**
	1.0%	11.47%	0.38	0.58	-0.15	-0.03	0.14	0.14	-0.06
	2.0%	11.87%	0.39	0.54	-0.08	0.12	-0.08	0.04	0.06
	3.0%	12.91%	0.40	0.50	-0.01	0.28	-0.29	-0.05	0.18
Fall	0.1%	8.13%	0.45	0.56	0.00	0.11	-0.13	0.05	-0.04
	0.23%*	**8.12%**	**0.46**	**0.53**	**0.01**	**0.08**	**-0.10**	**0.05**	**-0.02**
	0.5%	8.16%	0.48	0.48	0.00	0.01	-0.05	0.05	0.02
	1.0%	8.43%	0.51	0.40	0.00	-0.11	0.06	0.05	0.10
	2.0%	9.64%	0.56	0.28	-0.12	-0.30	0.28	0.06	0.24
	3.0%	11.50%	0.62	0.14	-0.20	-0.51	0.50	0.07	0.38

* These portfolios are minimum variance portfolios

Source: Authors' own creation

The portfolio compositions in all seasons are ex-post Markowitz efficient portfolios in the data period from 2013 to 2020. As an example, a mean-variance optimizing speculator aiming for a one percentage daily return in the period should hold the following portfolio:

Figure 12.12: Mean variance portfolio for 1% daily return

Composition	Instrument
57%	System price
43%	Front week futures
0%	One week to delivery futures
-6%	Two weeks to delivery futures
-9%	Front month futures
-4%	One month to delivery futures
19%	Two months to delivery futures
Sum 100%	

Source: Authors' own creation

The same interpretation may be made for seasonal mean-variance efficient portfolios as portfolio compositions are optimized based on ex-post seasonal data from 2013 to 2020. A risk averse speculator has increasing incentives to hold mean-variance efficient portfolios in seasons with low volatility than in seasons with higher volatility. The practical interpretation of this is that a risk averse speculator would prefer to hold a mean-variance portfolio during the fall as compared to holding a mean-variance portfolio during the winter. In addition, all rational speculators would invest in portfolios with equal, or higher, average return as the minimum variance portfolio. This, as no rational speculator would take on more risk for less reward.

12.5.1 Discussion: Portfolio rebalancing

Markowitz's mean-variance analysis generates portfolio compositions that are constant over time, and speculators applying the analysis on actual portfolios need rebalancing. However, the mean-variance efficient portfolios above include financially settled futures bought at specific times. Thus, the rebalancing possibilities are limited as only the system price can be bought continuously. In addition, speculators are subject to cash settlements on the futures, increasing the need of reserves in case of losses. Furthermore, Markowitz' portfolio does not consider trading costs and taxes (Munk, 2018, p. 196). All of these aspects must be considered when discussing how speculators should rebalance to maintain efficient portfolio compositions. Ultimately, the sum of the aforementioned factors entails that Markowitz' mean-variance portfolio only exists as a highly theoretical portfolio and that market participants would encounter great difficulty in replicating such a portfolio.

One common rebalancing strategy is to set time points, i.e. rebalancing the portfolio each quarter or annually. However, this strategy has earned critics from experts such as Larry Miles, principal at Advice Period (Brown, 2017).

"Rebalancing based on a particular month of the year makes no sense (…). It's like saying, 'I'm going to drive in a straight line for 11 miles and then, in the 12th mile, I'll turn right.'" (Larry Miles, 2017)

An alternative rebalancing strategy is based on how markets evolve, thus, rebalancing the portfolio accordingly. If efficient portfolio weights are off with a pre-determined percentage, i.e. 5%, rebalancing should be conducted (Brown, 2017).

Considering these rebalancing strategies, rebalancing limitations, and weekly and monthly financial settlements of futures contracts, it can be argued that Nordic power speculators aiming for mean-variance efficient portfolios should consider rebalancing more often than speculators aiming for mean-variance efficient stock portfolios. One reason for this is that Nordic power speculators must focus on both portfolio compositions and reserve accounts. However, every speculator should individually assess their risk profiles, transaction costs, and performance goals when assessing how rebalancing should be conducted. This, as there is no universal response to the complexity of the rebalancing optimization.

12.6 Discussion: Importance of data period when constructing hedging strategies

In the previous sub-chapters, hedging strategies for both power producers and -suppliers, as well as mean-variance efficient portfolios for speculators have been outlined. Various strategies are possible to employ to reduce risk in the case of suppliers and producers, whilst speculators may earn profits due to risk-taking. However, these strategies are retrospectively tested in the time period ranging from the 1st of January 2013 through the 31st of December 2019. Returning to the case of Metallgesellschaft, the authors Edwards and Canter (1995), highlight the importance of the data period selected to determine a hedging strategy.

Edwards and Canter (1995) examines the historic futures prices of both copper and soybeans, two commodities with a long trading history, from 1965 to 1994. In the *figure 12.13* the rollover[13] gains/losses from continuously hedging the copper price from 1965 to 1994 are presented in three ten-year periods.

Figure 12.13: Summary statistics for Copper (1965 – 1994)

Summary Statistics for Copper (1965 - 1994)

	1965 - 1974	**1975 - 1984**	**1985 - 1994**
Mean rollover	1.47	-0.94	1.65
Mean of all rollover gains	2.64	1.15	3.87
Mean of all rollover losses	-0.48	-1.03	-0.53
Cumulative rollover gain	88.03	-56.6	97.6
Frequency of a rollover gain	62%	30%	49%

Source: Authors' own creation

As can be seen from *figure 12.13*, the three time periods differ greatly in rollover returns, where the first period (1965 – 1974) experienced a positive mean rollover due to the fact that the market was in backwardation in 62% of the time (Edwards & Canter, 1995). In the following ten-year period, the backwardation rate dropped to 3% which yielded a net negative rollover loss. In the third period (1985 – 1994), rollover gains and losses were quite different from the previous ten-year period. Thus, this data suggests that in the futures market, any ten-year period of rollover returns are poor predictors of the futures rollover return[14].

The findings from Edwards and Canter (1995) have significant implications with regards to the time period chosen as a benchmark to outline a hedging strategy. This thesis has analysed the period from 2013 throughout 2019 and on this basis highlighted profitable hedging strategies. Should, however, the data period in question not be representative for the future power market, as Edwards and Canter

[13] Rollovers are calculated by Edwards and Canter (1994) by using the three-day rollover rule which entails they sell the front month contract three days prior to the last trading day and simultaneously buy the two-month contract. The rollover gains or losses are the front month price minus the two-month contract price, reported in cents per pounds. Their data source for futures was Knight Ridder.

[14] The same holds true for soybeans, please advise appendix 11 for the rollover Summary Statistics for Soybeans

stipulates, the hedging strategies might not be as profitable as expected. An illustration of how the data period chosen might influence the statistics is the consideration of weekly futures indices. The reader recalls that throughout the data period, the standard deviation counterintuitively rose as time to delivery increased, as described in *Section 9.2.4 Weekly futures*. However, this phenomenon was explained by extreme outliers in 2019, and when adjusted for the 2019 extreme values, the expected trend of falling standard deviation when time to maturity increased, presented itself. It must therefore be noted that the authors of this thesis acknowledge that the hedging results will vary with the data period chosen, and that other data periods might yield different results.

12.7 Summary of hedging

The previous paragraphs have answered the sub-question "*How can a hedging strategy be structured using the findings about derivative pricing premiums on the market?"*. This was accomplished by outlining the fundamentals of hedging and how power producers and -suppliers might structure their hedges to mitigate risk. This thesis defined optimal hedges as offsetting, which entailed that all price risks were mitigated through hedging positions. Therefore, any position not being offsetting, were defined as speculative, which was represented in the summary statistics with higher standard deviations and returns. Ultimately, as many companies who utilize hedging as an integral part of their business, also have trading departments, investment strategies for speculators were outlined. These entailed both mean- and minimum variance portfolios, created to capture the optimal risk/reward relationship.

Finally, a discussion on this thesis' hedging findings related to the demise of Metallgesellschaft in the 1990s was held. There, the importance of ensuring that the data period on which the hedging strategy is based upon, accurately depicts the future, was highlighted. As this historically has not been the case, one could argue that a hedging strategy based upon historic returns may not perform significantly better than operating solely in the spot market.

13. Discussion: Market efficiency in the Nordic power market

Chapter 10 - Forward premium analysis concluded that systematic forward premiums were present on the Nordic power market. In addition, results from hedging strategies proved that market participants including futures in their portfolios may end up paying less for a less risky portfolio compared to market participants holding portfolios without futures. These findings contradict with Eugene F. Fama's efficient market theory (1969) as evidence of a systematic forward premium may be seen as the presence of a consistent alpha in the market. Furthermore, the efficient market hypothesis states that future spot prices should be fully explained by futures prices in efficient markets. The unbiased forward rate hypothesis regression conducted in *Section 10.4 Unbiased forward rate hypothesis* rejected the hypothesis of futures prices being unbiased predictors of future spot prices, indicating that the Nordic market for power futures may be inefficient.

Researchers providing evidence against market efficiency on futures markets in the past have come up with the following potential explanations for market inefficiencies: (1) There is a risk premium present in the market (He & Hong, 2011), (2) futures prices do not reflect all available public information (Beck, 1994), (3) agents are inefficient when conveying new market information (Kaminsky & Kumas, 1990), (4) there is a lack of arbitrage opportunities (Crowder & Hamed, 1993), and (5) there continuously exist arbitrage opportunities (Brenner & Kroner, 1995). This thesis has proven that risk premiums in terms of forward premiums are present in the financial market for Nordic power. However, considering the market complexity, the recent introduction of new market regulations, and delisting of DS futures, there may be a reason to believe that the potential market inefficiency can be explained by factors related to futures' ability to reflect information, and agents' method to conveying new market information. Thus, supported by past academic studies on the Nordic power market, there is reason to believe that the market will face increasing efficiency in the future when (1) derivative products have stabilized in the market, and (2) market participants and agents gain more experience and increase their market knowledge and communication skills.

14. Conclusion

The thesis aimed to answer the following research question:

"Are derivative pricing premiums present in the Nordic power market, and how do these influence hedging strategies?"

By methodically answering the six sub-questions presented in *Chapter 3. Approach to research question,* readers were first provided with the theoretical framework required for the thesis investigations. Both option- and futures pricing theory were assessed, and volatility- and forward premiums defined, which later became the pricing premiums subject to investigation. Additionally, the *unbiased forward rate hypothesis* was reviewed, providing the readers with an understanding of how regressions can be used to test whether significant systematic forward premiums were present in the market.

Furthermore, considering the complexity of the Nordic power market, readers were provided with knowledge about market dynamics and -structure, products, and concepts. *Chapter 7. Definitions* outlined the importance of system operators being market operators striving to fulfill electricity area demands, resulting in physical electricity being priced using the concept of *Locational Marginal Pricing.* Readers were introduced to Nord Pool and Nasdaq, the two market participants responsible for physical electricity- and derivatives trading on the Nordic power market. Despite Nordic power derivatives being traded through Nasdaq, quoting of the system price is performed by Nord Pool and this is the reference price for all derivatives on Nasdaq.

In *Chapter 9. Descriptive statistics,* analyses of both the system price and futures prices were performed, resulting in the first quantitative indication of a potential seasonality pattern for premiums on the Nordic power market. The system price was observed consistently higher during winters and summers, and lower during falls and springs. Using findings from interviews and past research, different futures indices were created to better represent the development of futures prices and their correlation with the underlying system price. As should be expected, statistical characteristics similar to the system price were observed for the indices, indicating that futures may be unbiased predictors of futures system prices.

The research question in this thesis was designed such that market participants could benefit from related findings. Considering that both options and futures are commonly used in hedging, and that participants in the market need larger volumes of contracts to hedge their positions, *Chapter 8. Liquidity analysis* found derivatives' liquidity to be the main obstacle for derivatives being suitable for hedging. Based on qualitative and quantitative findings, options were excluded from further analyses due to poor liquidity. *Chapter 11. Discussion: Where are the options?* discussed potential explanations for the decreasing liquidity, and in doing so compared the Nordic power market with other commodity markets. Furthermore, the thesis analyzed historic liquidity on futures with different baseloads and concluded that weekly and monthly futures were the futures with highest liquidity within the data period.

With options excluded from premium investigations, *Chapter 10. Forward premium analysis* focused solely on forward premiums on weekly and monthly futures contracts. The reader was presented with findings from historical forward premium calculations on the futures indices presented in *Chapter 9. Descriptive statistics*. Historical forward premiums were found in all monthly- and weekly futures indices, except from *Index3 – Months* and *Index1 – Weeks*, indicating that derivative pricing premiums were present on the Nordic power market. Further investigation found winter (spring) to be the season with highest (lowest) historical forward premium.

Testing the significance of the historical forward premiums entailed the use of the *unbiased forward rate hypothesis (UFH)* presented in *Chapter 6. Theories*. Regressing the system price with futures indices as explanatory variables generated evidences against the *UFH* null hypothesis, stating that systematic forward premium (α) is equal to zero. Conducting the same regression on logarithmic transformed variables provided evidence against the *UFH* null hypothesis on weekly indices and on *Index3 – Months*. Furthermore, seasonal *UFH-regressions* were conducted to investigate the presence of significant systematic forward premiums within different seasons. Its findings may be directly related to historical forward premium findings as winter was the only season providing evidence against the *UFH* null hypothesis for both weekly and monthly futures. Spring rejected the null hypothesis for weekly futures.

In *Chapter 12. Hedging* the reader was introduced to the concept of risk mitigation in relation to participants on the Nordic power market. The hedging optimization was divided into three sections: *12.3 Hedging for power producers*, *12.4 Hedging for power suppliers*, and *12.5 'Hedging' for speculators.* Hedging strategies for power suppliers and -producers were designed to exploit the findings about present seasonal forward premiums on the Nordic power market. The strategies were tested ex-post with the objective of optimizing strategies based on different risk criteria; standard deviation, Value at Risk, and average cost/return. The speculator was included in the chapter as findings from interviews indicated collaborations existing between hedging- and trading departments in the market. Thus, optimal portfolios for mean-variance optimizing speculators were presented.

The introductory chapters, *Chapter 8, 9 and 10* described and analysed the first part of the research question:

> ***"Are derivative pricing premiums present in the Nordic power market****, and how do these influence hedging strategies?"*
>
> The analysis concluded that derivative pricing premiums have been present historically on weekly and monthly futures. Furthermore, systematic forward premiums on weekly and monthly futures were found significant, but with seasonal dissimilarities.

These findings were further used to answer the second part of the research question in *Chapter 12*:

> *"Are derivative pricing premiums present in the Nordic power market****, and how do these influence hedging strategies?"***
>
> Findings about present forward premiums impact both hedgers and speculators in the market as it is possible for market participants to exploit price differences on futures and the system price. As a result of the present forward premium, market participants need to assess their willingness to pay a premium for hedging positions in seasons, such as winter, with higher forward premiums. Participants may also be able to exploit the forward premium findings by constructing optimal hedging portfolios using the mean-variance framework and a preferred risk measure goal. In other words, this thesis concludes that both power producers and -suppliers should optimize their hedging strategies by considering the presence of pricing premiums on the Nordic power market and the seasonal dissimilarities.

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Interview 1: Torbjørn Haugen

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Appendix 2. Interview transcription: Interview 1: Torbjørn Haugen

TH: Torbjørn Haugen

JR: Jonas Roander

(The interview is conducted in Norwegian).

TH: Jeg håper det at hvis dere skal gjøre mer ut over dette her, så kan vi ta det litt suksessivt; det blir veldig mye hvis vi skal ta alt på en gang. Det som jeg kunne tenke meg er å ta det litt grunnleggende med hvordan Nasdaq og nordisk kraft er bygget opp?

JR: Ja, hvis du kan starte med det, så hadde det vært veldig bra; da risikere ikke vi å ha fått en feil forståelse for det vi har lest.

TH: Da tar jeg og deler skjermen min, så kan vi se på hvordan handelsforløpet er, og hva slags produkter vi handler på. Det er viktig å ha for seg hvilke typer aktører som er i finansiell handel. Vi har jo et spotmarket som er referansepris, som er *veldig* volatilt. Det er jo ganske fantastisk, men husholdningene i Norge er jo nesten mellom 70-90% helt eller delvis knyttet opp til denne spotprisen.

Hvis en da går og ser på aktører her, så er det jo i hovedsak tre typer aktører; det er de som sitter på produksjon eller tilgang til et eller annet som ønsker å binde og redusere utfallsrom framover i tid, og bruker hedger. Så er det industri eller kraftleverandører som ønsker å sikre ulike produkter framover i tid, alt etter om det er fastpris eller om det er forvaltningsprodukter eller hva det skal være. Og det siste viktige 'oljen' i dette her er tradere. Så er det slik at hvis man ser på aktørene, så er det veldig mange nordiske aktører her, men det blir mer og mer ikke-nordiske, det vil si europeiske og en del amerikanske fond og den type ting. Dere har sikkert fått det med dere, men i dette markedet her nå, er det inntil videre både forwards og futures. Jeg kan vise dere litt her; hvis dere nå ser et bilde av en handelstavle?

JR: Ja

TH: Her er altså produktene fremover i tid; her har vi dagsprodukter, uker, måneder, kvartal og så har vi årsprodukter. De som det står ENOFUT er altså futures. De som er videre her, det er forward-produkter. Det som er tilfellet er at frem til i 2016 var det utelukkende forward-produkter som ble omsatt her. Det betydde at aktørene kunne klare seg med å stille garantier i en bank hvor man kunne opprette en depotkonto der. Det var ikke noe oppgjør før produktet gikk til levering. Alt annet var inngående urealisert tap eller gevinst.

JR: Ja, nettopp

TH: Nå, grunnet etterdønninger fra finanskrisen i 2008-2009, som sa «nei, på grunn av at man med garantier kan gire opp; du kan for eksempel ha 20 prosent egenkapital, og så kan du få lov til å ta 5-gangeren i garantier». Det mente de var en viktig del av hvorfor det gikk galt under finanskrisen på ulike derivat-områder, også sier de videre at nå skal alt være futures; det vil si du må stille cash for alle daglige endringer i verdi. Og slik har det blitt i dette markedet nå.

JR: Okay. Er det derfor vi ikke finner forwardkurser. Vi har lest tidligere oppgaver som snakker om forwards, men kun funnet ENOFUT på Nasdaq. Så da gir jo det mening.

TH: Ja, det gjør det. Det her er jo egentlig bra sett ut ifra en tilsyns-situasjon, men sett i forhold til de som ønsker å drive hedging er dette enormt skadelig. Dette har gjort at aktører; spesielt veldig mange som er fundamentale som driver med hedging fremover i tid, de har sett seg om etter andre løsninger. For det er klart at; la oss forestille oss at du er produsent: Du har en selvkost på 15 øre, så sier du videre at «jeg har behov for å kunne sikre noe av det vi har her på 30 øre»; ca. Der prisen er i dag, 2-3 år frem i tid. Så stiger prisen da, etter at du har sikret, for du har da sikret forskjellen mellom 15 øre og 30 øre. Sånn at du får en gitt avkastning. Så stiger prisen til 40 øre, av en eller annen grunn, for eksempel at man får et 'tørrår' som i 2018. Da må du plutselig stille garantier, eller cash, for de 10 ørene mellom 30 og 40. For det blir da ansett som et tap. Selv om du vet at du skal produsere, når den tid kommer, og du kommer til å få cash inn fra spot. Sånn at, dette her har blitt såpass vanskelig for mange, og de ønsker ikke å gjøre det, og derfor har vi nå fått inn en ulik måte å gjøre dette på. Når du da handler på Nasdaq, har du i grunn tre måter å gjøre det; det ene er å være en direkte aktør på Nasdaq som veldig mange av våre kunder er. Det andre er å gå via en GCM bank, det vil altså si at det er en formell struktur der banken er godkjent til å være aktør på Nasdaq. Da har man sine egne posisjoner, du handler selv, men det er banken som står og stiller garantier for deg. Utfordringer med dette er jo at banken gjør jo ikke dette gratis, og spesielt norske banker og nordiske banker de er dyre på dette her. De bruker å si at det her blir samme kostnad som om du har en kassakreditt; da snakker du fort 2-3 prosent, i hvert fall. Det blir veldig dyrt.

JR: Jaja.

TH: Så kan du selvfølgelig handle bilateralt, via eksempelvis Statkraft, Vattenfall eller noe lignende. Utfordringen da er jo da at du ikke vet hva du får. Altså, du handler ikke transparent. Sånn sett, har det nå kommet inn en ny sak som er ganske attraktiv der man slår sammen det med Nasdaq og bilaterale aktører. Det er en funksjon som heter 'give-up'.

JR: Hva het den sa du?

TH: 'Give up'. Det betyr at vi, for eksempel, kan handle for en kunde på Nasdaq eller via en megler. Så gir vi det opp til den bilaterale motparten, eksempelvis en aktør vi har samarbeid med som heter Centrica; et engelsk selskap som har utspring i Danmark. Da har de akseptert å inngå en bilateral avtale med den kunden og så gir vi den opp, og så blir den lagt opp på kontoen til Centrica. Da slipper vår kunde å stille garantier, ingenting, og så får han en månedlig etterskuddsvis oppgjør, som da er enten pluss eller minus avhengig av hvordan derivatet har utviklet seg. Dette er på en måte det grunnleggende her; altså hvordan kommer kundene til Nasdaq. Hvordan stiller de garantier? Hvordan forholder de seg til en future? Det vil altså si at hvis de ikke er egenaktør, på Nasdaq, da må de stille cash automatisk selv, så kan de gå via en GCM eller bilateral motpart, da blir det i praksis som en forward.

JR: Ja, okay.

TH: Gikk dette an å forstå?

JR: Ja, det gjorde det.

TH: Bra. Dette var det grunnleggende jeg hadde tenkt til å si. Kanskje vi da skulle begynne så vidt med spørsmålene dere hadde?

JR: Ja, det kan vi gjøre.

TH: Kan ikke dere styre meg litt om hva dere ønsker å ta først? Jeg må bare si med en gang at jeg ikke er veldig sterk på opsjoner.

JR: Nei, for vi har litt spørsmål vi har slitt litt med, med tanke på datainnsamlig, men vi kan jo bare ta det når vi kommer dit. Jeg tenker egentlig at vi kan starte på toppen, så kan vi eventuelt gå i dybden på akkurat hva vi lurer på og hva vi har funnet ut, så kan du eventuelt avkrefte eller bekrefte at vi ikke er helt på bærtur. For hvis vi starter på *Generelt* da vi skriver om hva som er det underliggende aktivet så har vi jobbet oss igjennom Nord Pool, og prøvd å forstå hvordan de geografiske prisene henger sammen områder og grids. Har vi forstått det riktig når vi sier det underliggende er den kalkulerte systemprisen i Norden som er regnet uten at den har kapasitetsbegrensninger sånn som den vanlige geografiske, lokale prisen har?

TH: Helt korrekt.

JR: Okay, det er bra, for vi har gått litt frem og tilbake der om hva som faktisk er det underliggende. Kjenner du til hva som ligger bak dette tallet?

TH: Det er veldig enkelt. Altså, det som skjer er at alle aktørene som har forbruk eller produksjon, de må melde inn før kl 12:00 idag hva de skal forbruke eller produsere i fra kommende midnatt, 24 timer verdier. Og dette blir alt smurt sammen og det blir laget et priskryss per time som da gir en såkalt systempris per time.

JR: Ja, okay, ja.

TH: Når du da ser her, for eksempel at vi har 12,37, så er det snittet av de 24 timene. Når det er gjort, da går Nord Pool inn og så ser de på hvilke områder er det som har flaksehalser, så begynner de å gå opp der det er for lite og ned der det er for mye, til akkurat linjen blir full. Det blir da områdeprisen for de to områdene. Og husk på en ting; i det finansielle markedet her, så er der noe som heter EPAD. Det er altså det samme som tidligere het CFD, det er *contracts for difference*, som da man kan gå inn og handle på, og da er det altså priset etter hva prisdifferansen over periode er, innenfor de ulike områdene. Da kan du altså sikre deg, den differansen.

JR: For moro skyld, er det det Einar Aas tradet på, var det EPAD?

TH: Nei, det var ikke den differansen. Det var differansen mellom Tyskland og Norden. Så det vil si at det han hadde gjort var at han hadde solgt til Tyskland og hadde kjøpt Norden, for de historisk går veldig mye sammen. Og det har jo han tjent alle sine penger på. Nå ser du at det er en situasjon hvor det er veldig risikabelt; nå er vi jo nede i 12 euro her i Norden. Det er viktig å huske at dette ikke er en EPAD. EPAD går for eksempel på Trondheim, Oslo, København, Århus, Malmö, Sundsvall, Luleå og Stockholm. Det er ikke EPADer i alle de norske områdene. I Norge er det altså Trondheim og Oslo. Så det er måten man da kan sikre seg inn til områdene på, men det er veldig liten omsetning der, så vi sier ofte at hvis man ikke må, så skal man tørre å ligge åpent med å ta noe av den risikoen selv. Dette var forklaring på EPAD; men du hadde helt rett, systempris er avregningen av future.

JR: Ja, det er perfekt; da har vi forstått det. Neste spørsmål er da hvilke derivater er mest populære; det er da et litt vagt spørsmål sånn sett men...

TH: Nei, det er veldig greit! Hvis vi går tilbake og ser på produkter her, så er det som regel den nærmeste uken, den nærmeste måneden, det nærmeste kvartalet og det nærmeste året. Det er de som har størst likviditet og det er de som blir mest handlet.

JR: Ja, okay. For da kommer vi også til det spørsmålet som ligger nede på *Futures*, vi har sett at... Jeg må bare høre med Thomas, men var det sånn at... For på månedsfutures kan vi se at den handler... At kontrakten handles for eksempel, hvis vi sier februar måned, handles fortsatt (red.anm. dette intervjuet ble avholdt i februar 11.02.2020), mens hvis vi ser på kvartal og år, handles for eksempel ikke 2020 kontrakten idag.

TH: Nei. Det er en forskjell. Hvis du ser på uke, så ser du at vi handler uke 7 nå, og vi handler februar. Det er det som kalles en *average-future.* Det vil altså si at da handler vi en pris der du tar inn de kjente verdiene av februar, så langt, og en forventning på de resterende dagene. Når du da handler det, det blir ikke mye omsatt der nå, men det setter seg en pris, som du da kan handle på. Det vil altså si 13,13 (red.anm. prisen på en februar kontrakt), det er snittet frem til og med dagen idag, altså de 11 første dagene, også er det en forventning på de resterende dagene.

JR: Okay, så det vil si at hvis 13,13; du vil kjøpe den kontrakten med forventningen om at systemprisen skal bli høyere.

TH: Eller lavere. Eller at du for eksempel har en standard variabelpris ut til mine sluttkunder. Jeg har bare dekket inn 50%; nå ønsker jeg å kjøpe resten av februar for å være sikker på at jeg kan ha en sikker gevinst resten av denne måneden.

JR: Ja, okay. Så det er derfor man ikke kan kjøpe en dagsfuture idag, det går ikke fordi den ikke er average priset den heller? Så det er kun uke og måned, men siden kvartal, år og dag, ikke er average, så selges ikke den i inneværende måned eller uke.

TH: Nei. Det gjør den ikke. Men du kan da som sagt hedge deler av resterende uke. Det kan da enten gjøres her, på uken din her, eller så har du da dagskontrakter. Så du ser at morgendagen, 12.02.2020 ligger på 13,1340. Den kan handles inntil et kvarter før levering, så den går jo ikke an å handle lenger nå.

JR: Hva er forskjell på day-ahead versus morgendagens futurekontrakt, hva er prisen mellom de to?

TH: Nei det er akkurat det samme. Dette er systempris, og du ser den prisen som kommer her kl. 12:42 er den samme futuren. Så her handler du day-ahead for neste dag.

JR: Okay, så det er basert på det som har kommet inn fra kl: 10 til 12 i dag, med de neste 24 timene etter midnatt.

TH: Ja, du kan si at 10 – 12 har jo kommet før da, dette kan du begynne å handle kl. 08:00 i dag. Og du kunne jo handle det i går og dagen før. Du kan jo handle flere dager fremover i tid. Du handler vel, 9 dager faktisk, fremover.

JR: Ja, okay. Perfekt. Da er det greit. Da kan vi bare gå videre.

TH: Joda, jeg kan prøve å si littegrann om opsjoner og hva som er typisk...

JR: Ja, nei, første gang vi ble interessert i å skrive denne oppgaven, så leste vi en oppgave som gikk på det med volatilitetespremium på markedet i form av å se på opsjoner og realisert volatilitet vs. Implisert volatilitet. Når vi har begynt å gjøre litt research har vi funnet ut at opsjoner kanskje ikke er like populært lenger.

TH: Nei, det var det før, men det var blant tradere. Svært lite aktuelt som en del av en hedging faktisk. Og det er fordi det er så billig å handle det underliggende at man velger det i stedet. Jeg tror også at opsjonskunnskapen nok er for dårlig i dette markedet her. Også er det mange som har gått skoene av seg, sånn som i 2002 og andre tidspunkt med stor volatilitet, så har det vist seg at volatiliteten ikke har holdt. Så, derfor tror jeg mange har gått på en smell, og få har tjent penger på det, og derfor har det dødt hen.

JR: Vi ser nå; vi har fått tilgang til portalen til Montel, mye av dataen vi har fått tak i nå er via MontelNews, og der ser jeg at det trades spesielt OTC trades det fortsatt opsjoner, men ikke så mange som tidligere.

TH: Nei, og det cleares lite. Det er mest OTC.

JR: Hvis du skal si litt om hva motivasjonen bak de som faktisk forsetter med det nå.

TH: Nei, det er jo trading. En måte å gire litt på; i stedet for å handle underliggende, og spesielt når man har dårlig likviditet så ønsker man ofte å bruke opsjoner som en måte å gire på. Dere skal og vite at det som handles slik er i all hovedsak europeiske opsjoner med forfall torsdagen før eller noen torsdager før levering. Men, det som faktisk er et produkt som kanskje hadde vært en reell pris på, er såkalte asiatiske opsjoner på månedsbasis. Fordi, at det passer egentlig ganske godt med typen standard variabelpriser og en del priser til sluttkunder, men ser og det at de blir for dyre. Rett og slett at volatiliteten er for høy, så man får det ikke til å gå ihop. Man handler derfor underliggende i stedet.

JR: Det er godt å få avklart, for vi er litt usikre på hvor mye vi skal dykke inn i opsjoner kontra det å bare se på futures, men da får vi i alle fall inntrykket at det helt klart futures som er tingen. Vi kan jo egentlig bare gå videre, hvor ville du anbefalt oss å hente ytterligere date hvis...

TH: Ring Nasdaq i Oslo.

JR: Vi har vært i kontakt med Nasdaq, men de har sendt oss en ITCH-fil; jeg vet ikke om du kjenner til det? Det er en historisk fil som er kodet, og de skriver videre at de ikke har tid til å filtrere dataen for oss. De har visstnok gitt oss det vi vil ha, men vi klarer ikke åpne den.

TH: Nei, det vet jeg faktisk ikke, jeg trodde kanskje det fantes en FTP-server som man kunne koble deg opp mot..?

JR: Nei, vi fortsetter å sjekke, vi er jo i kontakt med dem.

TH: Jeg kan dessverre ikke hjelpe dere der. Jeg ville ikke brukt så mye tid på det, i hvert fall ikke slik som det ser ut nå.

JR: Da kan vi egentlig bare hoppe til *Futures*, nå har vi jo gått igjennom mange av spørsmålene som var der, men på punkt nummer 5, så er det jo spørsmål vedrørende marginer.

TH: Ja, hva tenker du på da? Marginer som i handelskostnaden er?

JR: Ja, eller, det var et spørsmåls om lå litt på om det ikke var finansielt settled hver eneste dag, men nå blir den jo det. Så kanskje mer den utviklingen der at...

TH: Altså, jeg er ikke sikker på om jeg skjønner det, men er det risikopremie du snakker om?

JR: Ja, det er kanskje en annen måte å si det på.

TH: Ja, den skal jo gjelde. Hvis vi tenker på teorien, så skal jo de som er ute her for å handle derivater, som ønsker å sikre seg. Det skal jo ha en kostnad. Og den kostnaden skal på en måte være traderen sin gevinst ved å gå imellom her. Og den varierer veldig. Skal man på en måte anskueliggjøre hva risikopremiumet er, så tror jeg man skal gå og se litt på hvordan aktørstrukturen ut i dette markedet. Da kommer man inn på betraktninger rundt produsenter, kraftleverandører og tradere. Hvis man ser på hvem som har store hedgingsbehov her, er det produsentene som har det. Litt av grunnen til det er at veldig stor andel av produsentene er offentlige, det vil si at de har eiere som ønsker forutsigbarhet på dette her. Derfor så er de villig til å betal en ganske høy premie på å sikre seg. Sluttkundesiden, eller da, kraftleverandørsiden har på langt nær samme behovet. Storindustri har som regel langsiktige kontrakter med aktører. 10, 15, 20 år, og det er svært lite, eller betydelig mindre fastpris i dette systemet, enn det er fastpris. Det er stort sett Sverige som har fastpris, mens i Norge er det ingenting; Danmark er det lite og mindre i Finland. Det betyr at kjøpssiden, den underliggende kjøpssiden er liten. Det betyr at det er traderene som må inn og ta risikoen her. De vil jo ha betalt for dette. Så er det én ting til som er viktig; sammenlignet med eksempelvis olje eller andre råvarer, så er det stor forskjell på hvordan prisene varierer. Her har jeg bare laget en kurve som viser spotprisen ifra 2003 og frem til 2019. Da ser dere her at den variasjonen er jo så enormt stor, ifra år til år og fra måned til måned, at det er veldig vanskelig å si hva er faktisk en risikopremie her. Fordi at man kan handle et år tre år før, og så kan det være en svært stor risikopremie den ene veien, så plutselig får du et tørrår eller et våtår, og så hopper prisen vanvittig den ene aller andre veien. Og så fremstår det som et fantastisk kjøp eller et vanvittig dårlig kjøp med en høy premie. Og det er ganske vanskelig å si. Men det jeg har prøvd å ta frem her, og så kan dere konkludere selv egentlig; hvis du tenker det at du her i 2003 er dette den høyeste prisen som året 2003 hadde før levering. Dette er den laveste fastprisen som år 2003 hadde på Nasdaq før levering. Her er spotprisen, og her er den såkalte tre-års indeks. Det vil altså si at du går inn og handler hver eneste dag, et like stort volum frem til året starter. Altså sammenlign dette med et aksjeindeksfond. Da ser du altså at den treårs-indeksen er den som er laget her. Og da ser du at når det er stigende marked, ja, da er den bedre en spot, og så når du da snur og får lavere spotpriser, ja da ser du at da går markedet ned. Men det som er litt spesielt, og kanskje et lite svar på spørsmålet ditt; her har vi altså sett på 16 år, så er treårs-indeks 1,7 euro billigere enn spot. Kanskje kan man da konkludere med at over de 16 årene, så har altså risikopremien for produsenter, i og med at det er flere produsenter som vil sikre seg enn forbrukere, så er da den på 1,7 euro. Teoretisk sikkert litt tvilsomt, men det er i hvert fall en konklusjon man kan dra.

JR: Det er jo noe av det vi har lyst til å sjekke opp, og gå i dybden på, for å se om vi kan få noen konklusjoner på det. Det er spennende å se den indeksen der. Det var egentlig det vi vill ha svar på; mange av de spørsmålene her har du fått dekket eller klargjort på andre måter enn hva vi hadde tenkt. Punkt nummer seks, om en markedet har merket et fall i likviditet som følge av en større aktør som bortfalt i 2017.

TH: Ja, du kan si at det vil jeg svare todelt på. Vi har jo hatt en betydelig fallende tendens lenge før den tid. Jeg vil si det at hvis man går tilbake til 2000-2008 så hadde man et veldig stort innslag av amerikanske hedgefunds inn i dette markedet. Og andre amerikanske aktører. Vi hadde flere store finansielle aktører som var inne for å trade. Så vil jeg si at det store fallet kom jo i forbindelse med overgangen til futures, fordi det betydde at mange prøvde å finne andre måter å handle på, og de klarte ikke å opprettholde likviditet og mange trakk seg ut av markedet. Det er klart at det hjalp ikke med Einar Aas-saken; for det første var han veldig stor og en veldig viktig bidragsyter til likviditeten. Så det har preget det også, men jeg vil si at hovedgrunnen her er at mange store aktører prøver å skumme fløten ved å handle mellom her. Det andre er at vi fikk overgangen til futures som gjorde at mange hedget mindre.

JR: Så hopper vi videre til hedgingen og hva slags strategier man bruker, spesielt med tanke på stack-and-roll fungerer på markedet.

TH: Det skal jeg ikke uttale meg, men jeg kan fortelle hva vi gjør. Vi har et søsterselskap som heter Wattsight. Der er vi da inne og har veldig tunge analyser, de er en 25-30 analytikere som jobber på heltid med å finne ut hva prisen skal bli, ut ifra et kvarter frem i til og helt frem til 25 år. Så vi bruker det her til å se på været, det får vi inn online, når det blir publisert i London eller Redding; vi har det som går på tilsikt, vi har kullkraft, gasskraft, hvordan det håndteres. De kjører tunge modeller; vi får alle disse produktene frem i tid og får en forventning, vi har markedet, differensen og bruker mye det til å handle på. Vi ser at enten det er sikring av produksjon eller om det er langsiktig sikring av forbruk, så blir det her med indeks mer og mer aktuelt. Jeg kan love dere at å slå denne indeksen over tid, det er beintøft. Hadde jeg for eksempel vært en sluttkunde som har et forbruk av en viss størrelse, der kostnaden ikke utgjør mer enn 2,3, 4 prosent av totale kostnadsbildet, jeg ville ikke duset på og tatt en sånn treårs-indeks. Jeg vil si det at indeks er vanlig, en annen ting som er viktig i dette er hvordan man håndterer risiko. Det som er vår filosofi er at man i et konglomerat av et selskap ofte ulike interesser og ulike risikopolicier. Kanskje har man ulike aktører på forbruksiden og man har tilgangssiden man skal håndtere. Det som er viktig er at man er nødt til å samle risikoen i en portefølje og styre den med en stop-loss og en maks-risiko. Det å operere med risiko i alle sammen gjør at det blir veldig uoversiktlig og lite anvendbart. Det vi gjør når det gjelder risiko er å samle dette her, og alle disse under-porteføljene de handler med, i en handelsportefølje, og så er det de som styrer det ut mot markedet; Nasdaq. Så er det sånn da at, 'hva mener man med risiko'? Det må aldri være tvil. Går man ut i oljemarkedet sier man at det å sikre seg har en risiko, det er det som er risiko. Men for oss er det 110% stikk motsatt. Altså har du tilgang på 100 GWh og du har sikret 90, så er risikoen din 10. Det er ikke det du har sikret. Vår definisjon på risiko er den åpne posisjonen som ligger og flyter med spotprisen, altså markedsprisen; ikke det du har sikret. Sikring er å sikre forskjellen mellom selvkost du har og den markedsprisen som finnes, for å ha en forutsigbarhet. Når vi treffer en aktør så har vi to spørsmål til den; har du krav til resultater i et enkelt-år? Er svaret nei, skal du selge eller kjøpe i spot. Er svaret 'ja, vi trenger forutsigbarhet', da må du inn med en eller annen sikringsstrategi som tilsier at du må minske utfallsrommet fremover i tid. Gjelder det samme ja på resultat ifra år til år, fremover i tid, ja så må du da stacke sikringshorisonten videre fremover. Hva er det du sikrer? La oss si du er en sluttkunde eller en industri, så er det i prinsippet fire ting du sikrer. Kraftforbruk i systempris, det er jo det du gjør på Nasdaq. Så er det sånn at du har valuta hvis du skal ha det tilbake i norske kroner, må du ha en valutatermin som du kan ta via en bank eller hva det skal være. Husk på én ting; snakker man flere år frem i tid, da er det altså et påslag på valutatermin som er gitt av rentedifferensen mellom EUR/NOK. Eurorenten er jo negativ til null, mens vi har et par prosent. Så det vil si at skal du handle 2023, og du er industri, så får du ikke en EUR/NOK på 10,2, du får en 10,2 * 1,5 prosentpoeng påslag for hvert år. Så husk på det hvis dere skal inn og regne på noe.

JR: Ja, det er viktig, tusen takk.

TH: Områdeprissikring er den EPADen som du eventuelt må sikre, og så har du det som går på el-sertifikat; jeg vet ikke om dere bryr dere om det, men det er jo sånn at enhver, utenom tungindustrien i Norge, må kjøpe el-sertifikat tilsvarende 18 til 20 prosent av forbruket sitt. Det er altså en grønn avgift, markedsbasert, som er laget for å finansiere fornybar energi. Nå har det blitt så billig å bygge ut fornybar energi at den er i ferd med å gå mot null. Så egentlig kan dere glemme den litt, men jeg ville bare ta den med.

JR: Ja, den er der, men trenden er at den går mot null, eller utgående

TH: Om den ikke er utgående er den i alle fall verdiløs, for å si det sånn. Det var det.

JR: Jeg bare går igjennom spørsmålene for å sjekke... Når det kommer til tidspunkt for hedgning, du nevnte at det normalt er det mest likvide derivatet er den nærmeste perioden. Er det også sånn i hedging og er det lett å se mønstre der ut ifra volum?

TH: Nei, det er veldig vanskelig å lese; de fleste har handelsbord som gjør at de er flink til å gjøre dette når det er naturlig.

JR: Ja, okay så det er en analyse som skjer kontinuerlig.

TH: Ja, og som sagt mange kjører veldig, om ikke fullt ut indeksrelatert, så i hvert fall en slags form for indeks. De kjøper ganske lite over tid. Så er det selvfølgelig slik at hvis noen som er veldig mye ute og skal kjøpe, så kan det jo hende at man drar opp markedet litt, og da vil mange selge. Da får du en stor omsetning en dag eller et tidspunkt.

JR: Jeg tror egentlig vi har fått dekket mye av de spørsmålene vi har i denne omgangen.

Intervjuet avsluttes med hyggelig konversasjon irrelevant til underlaget på oppgaven.

Appendix 3. Interview themes interview 2: Torbjørn Haugen

Interview 2: Torbjørn Haugen

Theme 1: Forward premium findings
- Premium on monthly indices
- Premium on weekly Indices

Theme 2: Market participants
- Typical buyer of power futures
- Typical seller of power futures
- Incentives to buy and sell

Theme 3: Futures settlement structure
- How is a contract settled?
- Who gets the premium?

Theme 4: Why do options have low liquidity?

Appendix 4. Interview transcription: Interview 2: Torbjørn Haugen

JR: Jonas Roander

TH: Torbjørn Haugen

TK: Thomas Kilaas

(Interview is conducted in Norwegian).

JR: I første omgang ønsker vi en forståelse av forwardpremium kalkulasjonene våre. Hvorfor man i noen tilfeller finner et positivt forward premium på markedet og hvorfor et negativt premium noen ganger oppstår.

TH: La oss begynne litt med selve futuresene. Det er sånn her at det største fokuset er på inntil tre år. Også har man veldig mange som kjører en rullering, eller indeks på dette. Husk på at man har fundamentale aktører og traders. I et normalt velfungerende marked er det sånn at hvis man skal ha et velfungerende marked må man omsette det fysisk underliggende 7 til 10 ganger. I det nordiske kraftmarkedet er det fysiske underliggende ca 400TWH per år. Det vil si at skulle man ha et velfungerende marked så burde man ligge et sted mellom 2.5 til 3k TWH per år. Der er vi ikke nå. Da vil vi oppleve at den variasjonen vil være mye tettere opp mot levering og kanskje tettere på spot og sånn sett ha en annen risikopremie. Men det som er spørsmålet ditt her som er viktig å ha med seg det er jo når du spør hvordan man kan forklare tilfeller hvor futurespris er dyrere enn spot. Vi er akkurat inni dette her nå i en veldig typisk fase. Husk på at spotprisen gjenspeiler hvordan kortsiktige fundamentale forhold endrer seg. Hvis du tenker deg nå for eksempel kvartal 2 i 2020. Den som går fra april og i mai og juni. Når vi sto i desember måned da hadde vi en hydrologi som var ganske normal. Vi hadde en CO2 som var på 20 og vi hadde gass- og kull priser som ikke var så langt unna det de er i dag. Så får vi altså en ekstrem mild og bløt vinter som endrer hydrologi med 10% av årsvolumet for hele Norden. Altså 35 TWH. I tillegg har CO2 falt fra 25 og til 16. Da har altså spotprisen gått ned i 10EUR. Og der ligger også kvartal 2. Da må dere huske på at forventingene som var og handelen gjennom 2017, 2018 og 2019 for kvartal 2 gjenspeiler at det er relativt normale forhold og kanskje til og med litt anstrengt. Spotprisen er altså en ren fundamental dag til dag sak, mens når du ser på premiumet.. og jeg vet ikke hva dere ser på, men når dere ser på en futures, hva ser dere da faktisk på? Gjennomsnittlig handel på periodens levetid?

JR: Altså det er noe annen research på markedet også. Det vi nå har gjort er at vi har laget indekser med bakgrunn i forskjellige tidspunkter. Vi fokuserer kun på måneds og ukeskontrakter da vi fant ut at de er mest likvide. Kvartal er også likvid, men da har man litt for få datapunkter til at man kan knytte noen gode analyser med mindre man går ekstremt mange år tilbake. Det vi nå egentlig har gjort er at vi har laget en indeks som ser på prisen på for eksempel en ukeskontrakt på siste tradingdag før faktisk uke, også har vi sett på den vektede prisen om du står i dag og kjøper neste ukes kontrakt og står i dag og kjøper kontrakten om 2uker. Også vekter man de 50/50. Siste kontrakten er gjort både på uke og månedskontrakter hvor man står i dag og kjøper futures som gjelder 1, 2 og 3 perioder frem. Også har vi vektet disse.

TH: Ja okay, men da må vi gå litt tilbake. På ukes kontrakter så kan dette her fungere, men sånn dere sikkert forstår fra hva jeg sa i stad så er det veldig problematisk å kjøre spot mot kvartal og år. Det vil ikke gi noen mening fordi at forutsetningen når du har handlet på futureskontrakter eller forwardkontrakter er helt annerledes enn det som er den faktiske tilbud og etterspørselen ved levering i spot. Så kan du si at det som fungerer sånn noenlunde er spot mot neste uke og kanskje uken etterpå. Fordi da er alt av værmeldinger og sånne ting kjent. Spesielt når du går bakover i tid når man hadde lite vind og solkraft så ville det være veldig preget av kullpris og en forventet kullpris, CO2pris og en forventet hydrologisk utvikling. Ikke minst i magasiner og snø og vann. Men nå får du en stor overlagring både på kontinentet og i Norden. Vind og sol som er uregulerbart og som da kun er avhengig av værmeldingen som ikke er så veldig mye å stole på utover de neste 10 døgn. Og da vil dette kunne endre seg veldig fort og sånn sett vil du få en helt annen utvikling for underlaget for spotberegningen kontra hva forventningen var på ukesfuturen.

JR: Hvis vi sier at det er lettere å forutse / det vil være mindre differanse mellom spot og futures hvis vi for eksempel kjøper en kontrakt i dag og sammenligner den med hva average spot vil være neste uke på grunn av at man har mer info om vær blant annet. Når vi ser tilbake fra desember 2019 til 2013 så er summen av premiumet vi har regnet positivt i de fleste tilfeller. Så fra 2013 til 2019 er futures i gjennomsnitt dyrere enn spot. Selv om vi ser på en kontrakt som starter allerede om tre dager.

TH: Ja, men det som er en annen ting som vi kan gå tilbake til. La oss la det her ligge litt også tar vi noen av de andre spørsmålene dine. Kan dere ta opp mailen jeg sendte til dere?

JR: Den har vi klar.

TH: Fordi at når dere ser på år 2013 til 2019 så er det klart at den er preget av at man der har hatt fallende spotpriser stort sett hele veien, med unntak av siste biten. La oss begynne med det grunnleggende som jeg også tror jeg nevnte sist gang også. I dette markedet når det gjelder hedging fram i tid. Tradere er stort sett fokusert på nærmeste uke, måned, nærmeste kvartal og år. Det er der likviditeten er, og det er der fokuset er for tradere. Også er det sånn at veldig mange av de som driver hedging har et fokus på eksempelvis tre år. Og det er av naturlige årsaker et større fokus på å sikre seg tilgang enn kjøp. Det skulle tilsi at det er et negativt premium. Hvis du ser de 15-16 årene som vi har. Skjønner dere den kurven?

JR: Ja, den ene viser spot og den andre futures, også viser den siste grafen differansen mellom futures og spot.

TH: Og dette er altså en treårsindeks og det ses at det ikke finnes noen korrelasjon mellom spot og indeks fra år til år. Så er det de to intervallkurvene som altså er den dyreste fastpris og billigste fastprisen man kunne handle i gjeldende år. Dette her gir et veldig godt innblikk i at det ikke finnes en sammenheng mellom futures- og spotpris, for futures er en forventet spot med normale eller små avvik, mens spoten er en helt annen og nær beregning av en balanse. Det er det samme i oljemarkedet egentlig, men der er det mye mer forutsigbart hva forbruket er og hvor mange tankere som er ute og sånne ting. Så hvis du ser på 15 og 16 år så ser man at 1.7 EUR er risikopremien, og den kan i stor grad bli knyttet opp mot at det er så mange flere selgere enn kjøpere i dette futures markedet.

JR: Fordi det vi da er litt forvirret rundt er at når vi ser på 2013-2019 så får vi da på både uke og månedskontrakter, som samstemmer med tidligere research, så er konklusjonen at futures er dyrere enn spot. Og hvis det er det vi har funnet ut så sliter vi med å forklare hvorfor noen vil ta en futures posisjon gitt at man over en lang periode vil tape i gjennomsnitt.

TH: Når det gjelder hvorfor man gjør dette så er det rett og slett fordi at det er høy volatilitet og ekstremt mye av kraftproduksjonen i Norden er offentlig, og de har et veldig stort behov for forutsigbarhet på resultat. Derfor så har de sikringsstrategier som tilsier en relativt høy andel sikring. Spesielt Sverige og Finland har det. I Norge så er det noe mindre fordi man har en sak som heter grunnrente. Kjenner dere til denne?

JR: Nei

TH: Grunnrente er et generelt begrep i økonomien. Du skal beskatte av det som har en ekstremavkastning, og det har historisk vannkraftproduksjon hatt. Det er dyr kraftutbygning som er nedbetalt, men som har en svært lav driftskostnad. Litt den samme diskusjonen som på laks. Det som er viktig å ha med seg i den norske vurderingen er at der er det en grunnrente som faktisk er en grunnrenteskatt som nå er på 37% og den er løpende beregnet etter spotpris. Det vil si at når man har stor variasjon i volum, som fra år til år om det er tørt eller vått, og man har tilsvarende motsatt korrelert pris så er det svært risikofylt å sikre 100%. Så det de fleste gjør er at de gjør en beregning på sine anlegg om hva som over tid gir den høyeste avkastningen. Dermed vil de fleste norske kraftprodusenter sikre mellom 50 og 60%. og det er fordi at, til tross for at de sannsynligvis ønsker å sikre mer, vil ikke det være optimalt over tid. Da kan vi gå tilbake. For nå har jeg konkludert med at det er et stort behov for sikring av tilgang, men det er tilsvarende lite behov for sikring av forbruk.

Det er det nesten bare industrien som gjør. I Norge er 97% av alle forbrukere, private og smånæringer, tar spotrelaterte produkter. Det betyr dermed at det er en stor skjevhet av hvor mange som ønsker å kjøpe og selge i dette markedet her. Nesten uavhengig av produkt. Det gjør da at det er et stort antall tradere som må være kjøpere i dette markedet her, og de vil jo ha en premie for å gjøre dette. Dermed er de veldig forsiktig med å kjøpe for dyrt, noe som tvinger kraftprodusentene å selge på en lavere pris enn hva deres forventning kanskje er. Og det er dermed en forklaring på hvorfor man over tid at en average futures indeks er ca. 5% lavere enn gjennomsnittlig spot. Ble dette forvirrende?

JR: Nei, det er veldig godt forklart og det vi forventet av våre funn, men vi har jo funnet ut at vår futures indeks er høyere enn spot, noe som samstemmer med tidligere research, så kan vel det da betegnes som et avvik da egentlig?

TH: Ja, men nå har jeg jo forklart det som foregår på en treårsindeks. Så er det viktig å ha det klart for seg at når man snakker 1, 2 og 3 uker frem i tid og kanskje månedsprodukter da har man egentlig det motsatte. Og hvorfor det? Jo, Hvis man ser på uke og månedsprodukter så er produsentene da i stor grad ferdig hedget. Men hvem er det da som kjøper? Jo det er de kraftleverandørene som skal sikre sin standard variabel eller kortsiktige kontrakter. Så der er det stikk motsatt. Der vil man se, som dere sannsynligvis har funnet ut, at det er et fokus på kjøp, og der vil man få en positiv premie.

TK: Kunne du kanskje gjentatt det? Veldig bra at du har en forklaring, men gjerne gjenta forklaringen.

TH: Ja det kan jeg. Altså hvis du tenker at ca. 30% av Norges privathusholdning har en standard variabel kraftpris. Dette er et produkt som kan endres med en 2ukersvarsel. Det gjør dermed at man kan sikre 2uker frem i hvert fall minimum ……(mistet kontakten)….. Om gangen, rullerende. Og det er fordi at man nå har sagt prisen ut til kunde og de handler inn og da har man en forutsigbarhet og leveranse. Det er altså en forutsigbar margin på kontrakten. De setter dermed prisen i forhold til markedet og er 100% interessert i å kjøpe og dekke inn dette for å hedge seg. Igjen ser vi da at det er svært lite produksjon som vil handle, så da er man igjen avhengig av at det er tradere som er motpart. De vil ikke selge uten å få en premie og sånn sett vil man da sikkert over tid finne ut at det er en høyere futures pris enn spot på nærmeste uke og nærmeste måned. Den vil du ikke finne tilsvarende på nærmeste kvartal og nærmeste år.

JR: Det forklarer mye av det vi har lurt på.

TH: Altså det underliggende hedgingbehovet er grunnleggende for hvordan man finner de ulike premiumene her. Men dere er nødt til å bruke en eller annen form for indeks her, for det å se på enkeltuker og enkeltmåneder blir galt. Fordi den fundamentale situasjonen i spot den overlagrer den risikopremien mange ganger og sånn sett så vil den drukne i den.

JR: mhm, vi har jo indekser og vi vektlegger i hovedsak 3uker rullerende med forskjellige prisberegninger sånn at man har en indeks som ser på kun 'last price' på siste trading dag i en uke, men vi har også indekser som ser på gjennomsnittlig pris over en tidsperiode og en indeks som ser på prisen med høyest volum. Sånn at man hvis man kjøper neste ukes kontrakt så vil indeksen som ser på høyest volum se på denne uken og se på hvilken gjennomsnittspris som har blitt handlet mest. Dette for å få en variasjon og forskjellige prisinnregningskriterier.

TH: Godt, jeg har et kvarter til, og dere lurer på hvordan et futuresoppgjør fungerer.

JR: Ja, det bygger litt på at vi prøver å forstå det at futures kan være dyrere enn spot også.

TH: Det har ingenting med oppgjør å gjøre, så lenge dere er tydelige på at dere med spotpris snakker om systempris. Og da er det sånn som at med en vanlig futures at det er daglig oppgjør og daglig utveksling av cash opp mot en depotkonto. Mot sluttkurs hver dag. Frem til mars 2016 var dette forwards, og grunnen til at dette ble omgjort var at etter finanskrisen så bestemte myndighetene at man skulle gå over til å ikke få lov til å handle forwards fordi dette ga gearing. Et ekstremt negativt tiltak for markedet fordi dette gjorde at alle som driver langsiktig hedging må ha et voldsomt cashbehov istedenfor å kunne bruke bankgarantier som pant. Så det har gjort at i redsel for at tradere skal gå utover rammene sine, så har de på en måte ødelagt hele hedgingmarkedet eller i hvert fall gjort det vanskeligere og svært negativt. Så det som kom inn i stedenfor var såkalte GCM banker (general clearing member banker) som er vanlig i veldig mange andre markeder, men det er her svært dyrt. Det har også gjort at hedgingene har blitt mer kostbart grunnet transaksjonskostnader enn det har vært tidligere. Men dere er klar over hvordan futureskontrakter gjøres opp?

JR: Ja, eller det spørsmålet lå der vel først og fremst for at vi skulle være helt sikre på hvem som får differansen mellom futures og spot. Den som selger en futureskontrakt vil få differansen mellom futures og spot, og omvendt?

TH: Ja, det er 100% et nullsumspill.

TK: Kan vi gå tilbake til det kortsiktige markedet bare for å avslutte det. Vil det da være slik at de som primært handler måneds og ukeskontrakter er strømleverandører, mens lenger kontrakter er strømprodusenter?

TH: Helt korrekt.

TK: Og i begge tilfeller er det typisk tradere som tar den andre siden av handelen?

TH: Ja, men det trenger ikke å være rene tradere, det kan godt være produsenter eller kraftleverandører med en egen tradingaktivitet, men poenget er at de som er motparten i hedgingbehovet er i stor grad tradingrelaterte porteføljer.

TK: Vet ikke om det er noe du har kjennskap til, men vil man se et tilsvarende mønster i andre råvarer? Eks. olje?

TH: Det kjenner jeg ikke til, men det som har blitt veldig vanlig innenfor kraft uansett hvilket land og type kraftportefølje man ser på, så er det et betydelig skille mellom hedgingportefølje og trading. Tidligere var det mer vanlig å si at man venter med å sikre fordi man tror prisene skal opp. Det man gjør i dag er at man kjører en indeksrelatert sak mot hedgingen, også har man en egen tradingaktivitet ved siden av der man evt. Avviker fra det. Det er jo selvfølgelig helt korrekt, og sånn sett så er det ubarmhjertig for en trader å ha det sånn, men man skiller jo hva man tjener penger på å ikke.

JR: Godt, men da er vi vel ferdig og kan avslutte den delen der. Jeg føler i hvert fall jeg har fått den forståelsen jeg søkte.

TH: Vi har ikke vært innom opsjoner da.

JR: men før vi går dit, så har jeg et siste spørsmål på futures. Du snakket litt om det, men hvis man ser på ukes og månedskontrakter og ser på premium årlig så ser vi at både på ukesbasis og månedsbasis med 1uke, 2 og treukerskontrakter er det ekstremverdier i 2019. Altså futures er dyrere i 2019 enn hva det har vært tidligere år.

TH: Det har rett og slett med at man hadde en svak hydrologi og en veldig sterk CO2 pris. Det gjorde at engstelsen for at spotprisen skulle gå i vei på oppsiden og dermed så oppsto det en større oppside eller nedside i utfallsrommet på en spotpris og sånnsett var da kraftleverandørene villige til å betale en høyere premie for å lukke inn den gevinsten ut mot kunde.

JR: og dette gjaldt også for ukes- og månedskontrakter?

TH: Ja, og om du ser på nå og tilbake til nyttår så vil du finne det stikk motsatte.

JR: Ikke sant, men vi har avgrenset oss og forholder oss til desember 2019 som siste kontrakt, men det hadde vært spennende å se på. Men takk, da vet vi hvorfor resultatene i 2019 har vært som de har vært. Men ja, raskt om opsjoner. Du ser jo hva vi stiller av spørsmål der også.

TH: Ja du kan jo si at når det gjelder opsjoner så er det så lite likviditet at det ikke er noen som lenger bruker opsjoner i hedging. Hvis vi tenker, som jeg nevnte tidligere, at om man har europeiske opsjoner som hedgingsintrument er lite anvendelige. Det er fordi at om man tenker Q1 nå, så vil man ha måttet løse den inn den tredje torsdagen i desember. Det ville i prinsippet ikke gitt deg noe som helst fordi man ikke aner hvordan fremtiden ser ut. Og når ting endrer seg sånn så vil premium være høye på opsjonene og for det andre så gir det ikke kjøperen noe særlig. En opsjonstype som er attraktiv i kraft er såkalte asiatiske opsjoner, som for eksempel på månedsbasis så beregner den premium på bakgrunn av hva den gjennomsnittlig blir levert på. Den gir en effektiv hedge, men den blir så kostbar at det er svært få som ønsker å bruke den. På produksjon er det ikke noe man vurderer en gang. Til en viss grad er det noen som bruker den på standard variabel, men hvis du hadde sett på hva premium på en årskontrakt på en årskontrakt er på månedsbasis kontra det å handle løpende månedskontrakter så hadde man over mange år sett at den premien hadde vært altfor høy. Så derfor, en kombinasjonen av at opsjoner er instrumenter som ikke er egnet for sluttkundebiten, kombinert med at premien er svært høy for de instrumentene som er attraktive, så tørker dette markedet ut. Når dere spør om hvilke aktører som handler opsjoner nå, så tror jeg det i stor grad er tradere som ønsker å geare sine posisjoner på produkter de ikke klarer å gjøre det med ordinære futures.

JR: Ja, okay. For jeg har sett litt på open interest via Nasdaq, og nå er det ca. 200 opsjoner som er listet, men det er bare 14 av de som faktisk har open interest/vært handlet. Noe som gjenspeiler det du sier.

TH: Jeg vil også si det at størstedelen av opsjonsvolumet er garantert ikke clearet. Totalt sett så er det ca. 10 aktører som er store på opsjoner og dermed bilaterale opsjoner, og de handler da fram og tilbake også jevner de ut en nettoposisjon som de gjør opp økonomisk i etterkant. Så jeg vil si det at å i hvert fall se på opsjoner i kraftmarkedet uten å ha oversikt over det bilaterale vil være nesten meningsløst.

JR: Vi avgrenser oss fra det i oppgaven, men trenger en grunn til å avgrense oss fra det.

TH: Kan anbefale en person som heter Karsten Engen. Kontaktinfo kan jeg sende på mail. Det kan være at han har en annen holdning til dette.

JR: setter veldig stor pris på det! Men nå er tiden der den skal være, så du får ha en god dag.

TH: Takk for det, og det er bare å ringe om det skulle være noe mer dere lurer på eller dere vil at jeg skal kommentere på.

JR: Takk! Som avtalt så sender vi over oppgaven når det nærmer seg.

TH: God helg!

Appendix 5 – Interview transcription: Knut Rabbe Nasdaq OMX

Knut Rabbe is the sales executive at Nasdaq Commodities. He led the change in market making from DS Futures to Futures. The following are excerpts from mail correspondence and a phone interview.

Mail dated 11th of March 2020

«Vi flyttet volumet gradvis over til future i sammenheng med at våre market makere startet å kvotere i Future kontraktene i stedet for DS Future kontraktene. I dag handles mer enn 95% av volumet i future kontraktene og resten i DS future (97,7% i 2020 se figur under)»

Mail dated 12th of March 2020

«Jeg ville tatt en prat med noen av de større aktørene i markedet som Statkraft, Vattenfall, Ørstedt for å få mer informasjon om opsjonsmarkedet. Det var et veldig likvid marked men er nå nesten ikke eksisterende. Derimot gjøres det nok noe opsjonsvolum bilateralt og dette bør markedsaktørene kunne svare bedre på.»

Phone call 12th of March 2020

TK: Thomas Kilaas **KR:** Knut Rabbe

TK: Var det bortfallet av DS Futures som medførte fall i likviditet i Opsjoner?

KR: De har prøvd å aktivere volumet, men folk er ikke interessert. Han tror det har noe med kunnskap å gjøre. De mistenker at det er lav bilaterale handel. Generelt har markedet blitt redusert ganske betydelig. Det var mange som hadde mye kunnskap om dette før, både meglere og tradere, men de har ikke fått opp interessen. Mange av meglerne har forsvunnet ut i andre markeder. Mye kunnskap har forsvunnet ut. AXPO er interessert i alle fall.

TK: Finnes det spekulanter på markedet?

KR: Det er noen igjen, men det er forholdsvis små. Det nordiske markedet er til enhver tid oversolgt. Store produsenter som er selgere i markedet, og det er ikke nok kjøpere. Mange handler går bilateralt. Bilaterale 10-15 års kontrakter. Elkem er en typisk kjøper av lange kontrakter. Det er noen som får øynene opp for muligheter her. De hedger seg 2-3 år frem i tid. Og det går som regel greit. Utover det, så er det ikke.

TK: Hvordan har likviditeten fra DS-futures til futures vært?

KR: Binde kapital pga. volatilitet fjerner muligheten for likviditet i lange kontrakter. Statelig og kommunale selskaper 'kan ikke' stille garantier (pga. optikk.) Tradingvolumet har gått ned betraktelig for hele markedet.

Appendix 6 – Nordic system price extreme values

Prices							
Highest values	**Elspot**	**Date**	**Month**	**Lowest values**	**Elspot**	**Date**	**Month**
1	199.97	21/01/16 08:00	January	1	1.14	25/12/15 02:00	December
2	199.94	21/01/16 17:00	January	2	1.15	26/07/15 05:00	July
3	198.29	01/03/18 08:00	March	3	1.18	26/07/15 04:00	July
4	168.64	21/01/16 09:00	January	4	1.27	25/12/15 03:00	December
5	160.03	19/01/16 17:00	January	5	1.38	23/06/13 06:00	June
6	160.00	21/01/16 07:00	January	6	1.39	26/07/15 06:00	July
7	150.08	21/01/16 18:00	January	7	1.52	26/07/15 03:00	July
8	149.95	21/01/16 16:00	January	8	1.70	23/06/13 05:00	June
9	127.32	29/11/17 17:00	November	9	1.72	25/12/15 01:00	December
10	120.08	19/01/16 16:00	January	10	1.93	26/07/15 07:00	July

Appendix 7 – Regression & Newey-west corrected outputs: Last settlement price: *Index1 - Weeks*

Regression outputs for other indices and futures criteria can be generated using the do-files found in file 6, 7 and 8, with associated Stata browse-files.

<u>**Standard regression Output:**</u>

```
reg Sysprice Index

      Source |       SS           df       MS      Number of obs   =       363
-------------+----------------------------------   F(1, 361)       =   5086.82
       Model |  30272.8304         1  30272.8304   Prob > F        =    0.0000
    Residual |  2148.39286       361  5.95122677   R-squared       =    0.9337
-------------+----------------------------------   Adj R-squared   =    0.9336
       Total |  32421.2232       362  89.5613902   Root MSE        =    2.4395

------------------------------------------------------------------------------
    Sysprice |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       Index |   .9478424   .0132896    71.32   0.000     .9217076    .9739772
       _cons |   1.762152   .4503793     3.91   0.000     .8764556    2.647849
------------------------------------------------------------------------------
```

Newey-west corrected output for the standard regression:

```
Regression with Newey-West standard errors          Number of obs     =        363
maximum lag: 3                                      F(  1,        361) =    3659.65
                                                    Prob > F          =     0.0000
```

Sysprice	Coef.	Newey-West Std. Err.	t	P>|t|	[95% Conf.	Interval]
Index	.9478424	.0156681	60.50	0.000	.9170302	.9786546
_cons	1.762152	.4967977	3.55	0.000	.7851713	2.739133

Standard regression: Logarithmic transformation:

```
. reg log_sysprice log_Index
```

Source	SS	df	MS
Model	35.6654129	1	35.6654129
Residual	2.2922906	361	.006349835
Total	37.9577035	362	.104855534

```
Number of obs     =        363
F(1, 361)         =    5616.75
Prob > F          =     0.0000
R-squared         =     0.9396
Adj R-squared     =     0.9394
Root MSE          =     .07969
```

log_sysprice	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
log_Index	.965775	.0128865	74.94	0.000	.9404331	.991117
_cons	.1205816	.0444312	2.71	0.007	.0332051	.2079581

Newey-west corrected output: logarithmic regression:

```
. newey log_sysprice log_Index, lag(15)

Regression with Newey-West standard errors          Number of obs     =        363
maximum lag: 15                                     F(  1,        361) =    2414.68
                                                    Prob > F          =     0.0000
```

log_sysprice	Coef.	Newey-West Std. Err.	t	P>|t|	[95% Conf.	Interval]
log_Index	.965775	.0196538	49.14	0.000	.9271248	1.004425
_cons	.1205816	.0689871	1.75	0.081	-.0150855	.2562486

Seasonal dummy regression output:

```
. reg Sysprice Index dummyspring dummysummer dummyfall

      Source |       SS           df       MS      Number of obs   =       363
-------------+----------------------------------   F(4, 358)       =   1280.18
       Model |  30302.6951         4  7575.67378   Prob > F        =    0.0000
    Residual |  2118.52811       358  5.91767629   R-squared       =    0.9347
-------------+----------------------------------   Adj R-squared   =    0.9339
       Total |  32421.2232       362  89.5613902   Root MSE        =    2.4326

------------------------------------------------------------------------------
    Sysprice |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       Index |   .9532903    .013639    69.89   0.000     .9264678    .9801128
 dummyspring |   .7895544   .3651904     2.16   0.031     .0713664    1.507742
 dummysummer |   .5261838   .3710021     1.42   0.157    -.2034336    1.255801
   dummyfall |   .2848326   .3623098     0.79   0.432    -.4276904    .9973556
       _cons |   1.183899   .5461245     2.17   0.031     .1098835    2.257914
------------------------------------------------------------------------------
```

Newey-West seasonal dummy regression output:

```
. newey Sysprice Index dummyspring dummysummer dummyfall , lag(3)

Regression with Newey-West standard errors      Number of obs     =        363
maximum lag: 3                                  F(  4,        358) =     981.72
                                                Prob > F          =     0.0000

------------------------------------------------------------------------------
             |             Newey-West
    Sysprice |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       Index |   .9532903   .0157982    60.34   0.000     .9222213    .9843593
 dummyspring |   .7895544   .4189112     1.88   0.060    -.0342816     1.61339
 dummysummer |   .5261838   .4485685     1.17   0.242    -.3559765    1.408344
   dummyfall |   .2848326   .4187083     0.68   0.497    -.5386044     1.10827
       _cons |   1.183899    .670126     1.77   0.078    -.1339793    2.501777
------------------------------------------------------------------------------
```

Logarithmic seasonal dummy regression:

```
. reg log_sysprice log_Index dummyspring dummysummer dummyfall

      Source |       SS           df       MS      Number of obs   =       363
-------------+----------------------------------   F(4, 358)       =   1416.01
       Model |  35.7011857         4  8.92529642   Prob > F        =    0.0000
    Residual |  2.25651782       358  .006303122   R-squared       =    0.9406
-------------+----------------------------------   Adj R-squared   =    0.9399
       Total |  37.9577035       362  .104855534   Root MSE        =    .07939

------------------------------------------------------------------------------
log_sysprice |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   log_Index |   .9709279   .0133058    72.97   0.000     .9447605    .9970952
 dummyspring |   .0266801   .0118909     2.24   0.025     .0032953    .0500648
 dummysummer |   .0162222   .0121789     1.33   0.184     -.007729    .0401734
   dummyfall |   .0065978   .0118161     0.56   0.577    -.0166399    .0298356
       _cons |   .0904849   .0476715     1.90   0.058    -.0032665    .1842364
------------------------------------------------------------------------------
```

Newey-west corrected output: seasonal dummy Logarithmic regression:

```
. newey log_sysprice log_Index dummyspring dummysummer dummyfall, lag(15)

Regression with Newey-West standard errors      Number of obs     =        363
maximum lag: 15                                 F(  4,        358) =     832.95
                                                Prob > F          =     0.0000

------------------------------------------------------------------------------
             |             Newey-West
log_sysprice |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   log_Index |   .9709279   .0189185    51.32   0.000     .9337225    1.008133
 dummyspring |   .0266801   .0093937     2.84   0.005     .0082063    .0451538
 dummysummer |   .0162222   .0108614     1.49   0.136    -.0051379    .0375823
   dummyfall |   .0065978   .0092541     0.71   0.476    -.0116015    .0247971
       _cons |   .0904849   .0673234     1.34   0.180    -.0419141     .222884
------------------------------------------------------------------------------
```

Seasonal regression output – Winter:

```
. reg Sysprice_winter Index_winter

      Source |       SS           df       MS      Number of obs   =        90
-------------+----------------------------------   F(1, 88)        =    554.24
       Model |  6602.24956         1  6602.24956   Prob > F        =    0.0000
    Residual |   1048.2869        88  11.9123511   R-squared       =    0.8630
-------------+----------------------------------   Adj R-squared   =    0.8614
       Total |  7650.53645        89  85.9610838   Root MSE        =    3.4514

------------------------------------------------------------------------------
Sysprice_w~r |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Index_winter |   .8871105   .0376817    23.54   0.000     .8122261     .961995
       _cons |   3.523575   1.380958     2.55   0.012     .7792098    6.267939
------------------------------------------------------------------------------
```

Seasonal regression output – Spring:

```
. reg Sysprice_spring Index_spring

      Source |       SS           df       MS      Number of obs   =        91
-------------+----------------------------------   F(1, 89)        =   1774.42
       Model |  6094.86822         1  6094.86822   Prob > F        =    0.0000
    Residual |  305.701677        89   3.4348503   R-squared       =    0.9522
-------------+----------------------------------   Adj R-squared   =    0.9517
       Total |  6400.56989        90  71.1174432   Root MSE        =    1.8533

------------------------------------------------------------------------------
Sysprice_s~g |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Index_spring |   .9601792   .0227942    42.12   0.000     .9148876    1.005471
       _cons |   1.755577   .7466375     2.35   0.021     .2720242     3.23913
------------------------------------------------------------------------------
```

Seasonal regression output – Summer:

```
. reg Sysprice_summer Index_summer

      Source |       SS           df       MS      Number of obs   =        91
-------------+----------------------------------   F(1, 89)        =   2624.96
       Model |  9927.58147         1  9927.58147   Prob > F        =    0.0000
    Residual |  336.597106        89  3.78198995   R-squared       =    0.9672
-------------+----------------------------------   Adj R-squared   =    0.9668
       Total |  10264.1786        90  114.046429   Root MSE        =    1.9447

------------------------------------------------------------------------------
Sysprice_s~r |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
Index_summer |   .9919329   .0193607    51.23   0.000     .9534637    1.030402
       _cons |   .5786222   .6024257     0.96   0.339    -.6183848    1.775629
------------------------------------------------------------------------------
```

Seasonal regression output – Fall:

```
. reg Sysprice_fall Index_fall

      Source |       SS           df       MS      Number of obs   =        91
-------------+----------------------------------   F(1, 89)        =   1509.75
       Model |  6338.97165         1  6338.97165   Prob > F        =    0.0000
    Residual |  373.683658        89  4.19869279   R-squared       =    0.9443
-------------+----------------------------------   Adj R-squared   =    0.9437
       Total |  6712.65531        90   74.585059   Root MSE        =    2.0491

------------------------------------------------------------------------------
Sysprice_f~l |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  Index_fall |   .9711103   .0249929    38.86   0.000       .92145    1.020771
       _cons |   .8675703    .870073     1.00   0.321    -.8612461    2.596387
------------------------------------------------------------------------------
```

Appendix 8 – Descriptive statistics: Quarterly futures

	Index1 - Quarter	Index2 - Quarter	Index3 - Quarter
Observations	27	26	25
Mean	31.88	31.51	31.73
Std. Deviation	9.18	8.65	8.47
Skewness	0.79	0.79	0.66
Kurtosis	0.63	0.13	-0.28

Appendix 9 – Breusch-Pagan /Cook-weisberg test for *Index1 - Weeks*

Tests for the other indices and futures price criteria are conducted in Stata Do-files found in file 6,7 and 8, with the use of associated browse-files.

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: Index

         chi2(1)      =     4.16
         Prob > chi2  =   0.0415
```

Appendix 10 – Shapiro-Wilk W test for *Index1 – Weeks*

Tests for the other indices and futures price criteria are conducted in Stata Do-files found in file 6,7 and 8, with the use of associated browse-files.

Shapiro-Wilk W test for normal data

Variable	Obs	W	V	z	Prob>z
residual	363	0.87991	30.314	8.081	0.00000

***p-value 0.000 suggest that our residuals arent normally distributed**

Appendix 11 – Mean-rollover gains for soybeans

Summary Statistics for Soybeans (1965 - 1994)

	1965 - 1974	**1975 - 1984**	**1985 - 1994**
Mean rollover	5.52	-4.56	-0.50
Mean of all rollover gains	16.74	10.14	9.59
Mean of all rollover losses	-3.50	-8.91	-6.86
Cumulative rollover gain	386.12	-319.00	-34.75
Frequency of a rollover gain	44%	23%	36%