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Methods for evaluation of the Nordic forward market for electricity

ANALYSES IN ACCORDANCE WITH THE FCA GL

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Summary and conclusions

The upcoming assessments of the Nordic electricity market by the regulators can be regarded as mirroring the assessments made by market participants when these are developing and pursuing their hedging strategies. A key difference though, between the FCA GL and real hedging strategies is that market participants are concerned about all risks, not just price risks. Key features of hedging strategies in several sectors are that they are pragmatic and informal.

- Pragmatic means that risk management is a tool and not a goal per se. Companies tend to maximise profits within constraints, and risks are one group of constraints. The challenge is therefore to find the acceptable level of risk for acceptable costs. There are numerous examples of potential hedges that are not used – simply because the costs are considered too high. 'Costs' here includes both an apparently high risk premium in a contract, that the hedge may reduce negative risks but at the same time foreclose attractive profit opportunities, and the internal administrative costs of managing a complex hedge portfolio.
- Pragmatic also means that when executing the hedging strategies, risk committees are commonly involved. This reflects that market participants often do not have clear thresholds or limits dictating what to do. A frequent feature of hedging strategies is that companies tend to apply some sort of market view. This means that hedging decisions may be dependent on (internal) price prognoses.
- Pragmatic further means that many companies want to avoid fluctuating quarter and annual results because of fluctuations in the mark-to-market value of their hedges. It is important for them that their auditors approve that their hedges are qualified for hedge accounting according to IAS 39. Therefore, the choice of using proxies or not mainly depends on their auditor's view on the correlation between the proxy and the hedged item.
- Informal means that the hedging is most often not based on formal correlation or market analysis.
- Informal partly reflects the involvement of risk committees etc., but also that analyses if they are done tend to be ad hoc or tailor made, and not performed at fixed or regular intervals.

Theory and experiences show that complete elimination of risk is not optimal, but rather that hedging a fraction of the portfolio either directly or indirectly through proxies yield the "highest pay-off" to the hedger. A mean-variance approach to hedging has an important implication for the assessment of hedging opportunities in the electricity market. Using a standard mean-variance analysis the composition and performance of selected portfolios with system price and EPADs can be analysed and evaluated.

For the analysis of correlation, we suggest the regulators compare yearly and monthly average zonal prices with similar averages of the underlying for potential hedging instruments, such as SYS contracts, EPADs for the actual bidding zone or EPADs for other bidding zones, and area contracts for adjacent bidding zones like Germany, or a combination of such. A methodical challenge is that there is essentially an infinite number of potentially relevant combinations. The purpose of the analyses must be to test whether the prices in the delivery period are well correlated or not, and not to examine the changes in the value of the hedging portfolio and the hedged item during the hedging period. Hence, the approach taken in the hedge accounting literature is not relevant for measuring correlation in the regulators' assessments.

For the analysis of efficiency, we suggest three groups of analyses. All analyses rely on direct market data without the need for estimating, modelling or forecasting complex systems, which in itself would bear uncertainty.

- Descriptive measures: We suggest that analyses of traded volumes and open interest are coupled with information of trading horizons. The analyses should provide insight in trading activity per contract (year, month, etc.) and per location. Data are readily available, and the required computational effort is limited. The descriptive measures can be compared with descriptive measures regarding long-term transmission rights.
- Price measure: We suggest calculating the ex-post risk premium separately for year and month contracts, based on a comparison of the last closing price before the contracts go to delivery and the actual delivery prices. Risk premiums should be analysed for a sufficient long period of time, perhaps five years. The approach will yield insight on the market dynamics between buyers and sellers of derivatives. By observing magnitudes, directions, and significance of ex-post risk premiums across trading horizons and bidding areas, possible systematic biases in the pricing of derivatives can be identified.
- Transaction cost measure: Best bid-ask spreads obtained either from exchanges or OTC brokers will answer questions on the cost of hedging as well as the underlying liquidity. The magnitudes of the quoted bid-ask spreads will reveal the transaction costs market participants face when participating in the power derivatives markets.

Unfortunately, there are no identified thresholds for the various measures. There is no quick fix for this, and thus a separate objective for the analyses must be to gain experience with the performance of the financial market.

When preparing a final conclusion, note that there is a trade-off between good correlation and low transaction costs. When building up a hedge portfolio, It can be better to accept imperfect correlation if the alternative contracts are more liquid and/or are traded with lower risk premiums and transaction costs.

Lack of trade in some contracts might be a completely rational solution for an efficient market. Operating markets are not costless; there are only a limited number of economically justifiable futures markets.

1 Introduction

On 26 September 2016 the European Commission adopted its regulation (EU) 2016/1719 establishing a guideline on forward capacity allocation (FCA). The regulation entered into force 17 October 2016.

The FCA GL requires for two kinds of decisions that the regulators assess whether the electricity forward market provides sufficient hedging opportunities in the concerned bidding zones (Article 30 (3). The first decision is not to issue long-term transmission rights (LTTRs) on a bidding zone border (Article 30 (1). The second decision is regarding introduction of LTTRs if LTTRs do not exist on a bidding zone border (Article 30 (2). The assessment shall include at least a consultation with the market participants about their needs, a correlation analysis and an analysis of whether products offered are efficient. FCA GL leaves it to the regulators to decide the details of the methods for such analyses.

The Nordic energy regulators are committed to carry out such an assessment, which shall identify whether the electricity forward market provides sufficient hedging opportunities in the concerned bidding zones. To prepare the assessment, the Norwegian Water Resources and Energy Directorate (NVE) in cooperation with the Swedish Energy Market Inspectorate (Energimarknadsinspektionen), the Finnish Energy Authority (Energiavirasto), and the Danish Energy Regulatory Authority (DERA) commissioned this study. The task for this study has been to evaluate different criteria/indicators relevant for the assessment of hedging opportunities in the Nordic electricity market and to provide insight of hedging activities from other, comparable sectors (mainly commodity markets). The objective for the study was to present a justified suggestion on the specific method/s to be used by the regulators in their evaluation of the financial electricity markets as required in the FCA GL. While this report thus presents proposals for methods, there are no attempts to assess the hedging opportunities in different parts of the Nordic electricity market.

One of the scopes for the FCA GL is to ensure that market participants have sufficient hedging opportunities for electricity price risks. The two relevant key terms in this respect are *sufficient correlation* and *efficient hedging* instruments, neither of which are precisely defined in the regulation. The correlation issue deals with the market participants' challenge to identify forward contract(s) that can be used to hedge price volatility, and to analyse if suggested contracts are suitable for hedging the price risk. The efficiency issue addresses the concern for market participants that the hedge may be too costly. The most important factors are liquidity, relative size of risk premiums and (other) transaction costs.

Our starting point for this study is that the assessments the regulators are about to do, correspond to what (rational) market participants do when developing their hedging policies/risk management strategies. In this sense, the regulators' assessment mirror the market participants' analyses – except that the regulators to a larger degree must be able to present their methods explicitly. We note that while the FCA GL focuses on hedging of price risks, market participants have a broader perspective and objective for their hedging strategies.

Our approach has thus been to examine the methods and procedures actually applied by market participants, based on our own and others' practical experience from various markets, and combine this with relevant academic literature. It is clear that the market participants' methods are less formal and explicit than the regulators may have wished for. Furthermore, there are generally no formal (and external) requirements to the market participants' assessments.

The report thus follows the same structure: First, we present market participants' hedging strategies and methods. Their objective can generally be described as reducing risks to acceptable levels (sufficient correlation) at acceptable costs (efficient products). We continue in chapter 3 by exploring how correlation analysis should be structured properly to reflect the challenges faced by market participants, and proceed in chapter 4 with methods to evaluate contract efficiency. There is a rich academic literature about measuring efficiency, particularly in financial and commodity markets (stocks, grains, etc.). Applications in electricity markets are less frequent, and our approach has been to focus on methods that reflects market participants' perspectives while limit ourselves to methods that have been applied in analyses of electricity markets and that are not too computationally complex.

2 Acceptable risk levels at acceptable costs – hedging strategies in practice

In this chapter we will explore different features of hedging strategies in different industries. The aim is to provide a realistic background for analyses of whether current markets provide sufficient hedging opportunities to electricity market participants. We start with a short and general description of hedging purposes, and end with a closer look on current hedging strategies in various industries.

The FCA GL requires the regulators to assess whether the electricity forward market provides sufficient hedging opportunities in the concerned bidding zones. The assessment shall include at least a consultation with the market participants about their needs, a correlation analysis and an analysis of whether products offered are efficient. The FCA GL leaves it to the regulators to decide the details of the methods for such analyses.

Within accounting, there is already some 'global rules' for analyses of forward markets, where practice has developed into generally accepted standards for how to perform correlation analyses and how to evaluate the results of the various tests. A key question is if some of these accounting standards are transferrable to the regulators' tasks. There are some clear parallels in the scope of these analyses, and previous discussions initiated by the Nordic regulators have also raised the issue explicitly. We have therefore inserted a section discussing the relevance of these global accounting standards.

A common feature of all markets is that perfect hedges only exists in text books and theoretical examples. Even if there is perfect correlation between the underlying of a financial contract and the price of actual deliveries, the efficiency of hedges relying on that particular contract is likely to be less perfect due to volume variations. Market participants are generally faced with a mixed challenge; they must consider the appropriateness of available financial prices as well as the impact from other types of risk; volume risk, legal risk, operational risk, regulatory risk, etc.

2.1 Theoretical perspectives to hedging

Futures markets for agricultural commodities have been in operation for more than a hundred years, and agricultural commodities dominated futures markets for a long time. There is a vast literature on the functioning of agricultural futures markets, their role for price discovery and as a risk management tool. The purpose of this section is to give an overview of some of these issues as they pertain to hedging (and their relevance for forward electricity markets).

The traditional hedging theory emphasizes the risk avoidance potential of futures markets (Alexander, 2008). The futures markets are viewed as a mechanism through which price risk can be transferred from one set of agents to another. Keynes (1936) set forth his theory of normal backwardation in which the hedgers are willing to pay a risk premium to reduce their price risk, while the speculators are willing to enter the futures market only if the expect to collect a premium. The hypothesis of backwardation has been subject to extensive testing starting with Telser (1958) refutation in his study of wheat and cotton markets. This conclusion has been mainly been maintained in the literature (Fama & French, 1988; Carter, 1999). Furthermore, the traditional view holds that the purpose of hedging is to remove all risk from the hedging portfolio (Alexander, 2008).

The traditional view of hedging as insurance was challenged by Working (1953 b, a) who argued that the hedger does not seek primarily to avoid risk but one who hedges because of an expected return from the trading activity. The mean variance view of hedging was introduced by Johnson (1960) and Stein (1961), and extended to producers by McKinnon (1967) and Anderson and Danthine (1983). In this approach, hedging is the process of simultaneously choosing futures positions and cash positions in order to construct a portfolio of assets (Carter, 1999; Alexander, 2008). The hedger is assumed to maximize the expected value of her utility function on the basis of their means and variances, e.g. using a mean-variance objective function. This mean-variance approach to agricultural risk management, including hedging, has been incorporated into textbooks since the 1970s (Anderson, Dillon, & Hardaker, 1977; Tomek, 1972).

Portfolio hedging has been extended to proxy hedging where there are no forward or futures markets for some commodities (Ederington, 1979; Alexander, 2008). Furthermore, the locational basis risk has been explored for a number of commodities and locations (Carter, 1999). An early, and typical, study by Bobst (1973) concluded that hedging is as effective in areas without delivery points as in areas with delivery. He argued that the continued effectiveness of the hedging opportunity depends upon liquidity in the futures market and stable spatial price patterns.

The mean-variance and portfolio approach to hedging shows that complete elimination of risk is not optimal, but rather that hedging a fraction of the portfolio either directly or indirectly through proxies yield the “highest pay-off” to the hedger (Ederington, 1979; Williams J. , 1986). The mean-variance approach also has an important implication for the assessment of hedging opportunities in the electricity market. Using a standard mean-variance analysis (Alexander, 2008) the composition and performance of selected portfolios with system price and EPADs can be analysed and evaluated.

The number of active organized futures markets is small compared to the potential number of commodities, grades, locations and future periods. Many see the lack of futures markets as a failure of the market system itself (Arrow, 1978). However, as operating markets are not costless there are only a limited number of economically justifiable futures markets (Williams J. , 1986).

The number of economically justifiable markets is where the marginal benefits of a market equals the marginal costs of operating said market.

2.2 Objectives for hedging strategies

The primary objective for market participants is normally to maximise profits, typically within constraints related to factors like risk exposure, among other things. This leads to an objective for risk management, in general terms, to reduce risks to acceptable levels at acceptable costs. This has two implications:

1. There is generally no point in eliminating all risks and aim for the perfect hedge – investors expect their companies to take some (specific) risks, and customers pay accordingly. If all risks are hedged, there is in a sense no business because then your suppliers and/or customers can do your job better than you do it yourself.

2. The cost of hedging matters. Thus if the available hedges (or some extra hedges) are too costly, meaning that accepting them eliminates all profit opportunities, the question is essentially if you can accept operating without such hedges. If the unhedged risks are unacceptable, the market participant has no future in the industry.

Hence, for most market participants the objective of hedging is to have someone else to absorb those risks that they cannot or will not absorb themselves. The hedging strategy must ensure that the exposures to crucial risks are within acceptable limits, set by the owner and/or the management.

Note that regarding the cost of hedging, there might be two alternative explanations if a hedge appears as costly. If the risk is high, the cost of insurance is also higher, as compared with a situation with low risk. It simply might be costly to offer the hedge. For electricity contracts, this means that the properties of the probability distributions for electricity prices to a large extent determine the hedging costs. The more volatile the day-ahead prices are, the costlier it would be for someone to guarantee a fixed price instead of the volatile day-ahead price. Alternatively, (or in addition), the insurance market might be inefficient. If, for instance, there is only one supplier of insurance, the chances are high that the price for insurance is also high. It can be hard to distinguish between these two possible explanations, but it is obvious that to the extent the cause of costly hedging is related market behaviour and market design, it is worthwhile to consider measures to improve the situation.

Further, hedging retailing, which is a low margin business, is hardly comparable to hedging generation, which is high risk and potentially high reward business. Retailers offering fixed price contracts (or contracts where prices cannot be adjusted easily on a short notice) want to hedge their sales to end-users in order to reduce or manage their price risk. Generators are typically more eager to secure some of their expected profits forward. Industrial customers have another situation. Electricity can be an important part of their costs but their main business is the products they produce and sell. Thus different market participants have different requirements for hedging.

Note also that what matters for market participants is not only the price risk, which is the key issue in this report, but the total impact of volatile prices, uncertainties regarding volumes (supply and/or demand), as well as numerous risks and uncertainties related to other factors (legal risks, counterparty risks, operational risks, etc.). The fact that the financial situation of the market participant also impacts the demand for hedging, adds complexity to this picture.

International Financial Reporting Standards (IFRS) are designed as a common global language for business affairs so that company accounts are understandable and comparable across international boundaries. The European Union decided in 2002 that from 2005 IFRS would apply for the consolidated accounts of the EU listed companies. IFRS are the rules to be followed by accountants to maintain books of accounts which are comparable, understandable, reliable and relevant for international users. This objective is rather different from objectives for hedging strategies among market participants in the electricity sector.

One of the key principles in IFRS is that derivatives such as power derivatives should be booked at mark-to-market value. Changes of the mark-to-market value between periods should have immediate effect on the profit and loss account (P&L). IAS 39 (IAS is short for International Accounting Standards) provides an exemption from this rule for **qualified** hedging portfolios. The external auditor may accept hedge accounting if the company can demonstrate a close correlation between the value of a hedging portfolio and the value of a hedged item. If changes in both are well correlated, hedge accounting can be 'granted'. Companies seeking acceptance for hedge accounting must therefore present a correlation analysis, and subscribe to a rather 'mechanical' hedging strategy (explained further below).

Many companies with listed stocks or bonds consider hedge accounting as important and prefer to avoid explaining volatility of results due to changes in the mark-to-market valuation of their hedging portfolios. The original objective for hedging power costs was in fact for many industrial users to avoid volatility of results because of volatility of power costs. If the preferred hedging strategy by such a company is not accepted for hedge accounting by its auditors, the company chooses often between ending its use of power derivatives or to adapt its hedging in such a way that hedge accounting is accepted by the auditor.

The situation is different for a company with electricity as its main business. Such a company will in any case have to explain to the stock market how the volatility in the electricity market affects its results. Also, the financial analysts following the company are often well-informed about the electricity market. Such a company can perceive more freedom of action to not perform hedge accounting if its preferred hedging strategy is not accepted by its auditors. Industrial consumers with only a few main owners can also perceive more freedom of action. If the management can communicate the benefits to the main owners, possible over-reactions in the stock market are not so deterrent.

Art. 30 (4) of the FCA GL focuses on price risks, whereas both the hedge accounting rules and normal hedging strategies focus on risks. ‘Risks’ are clearly a much broader term than price risk. If, for instance, the hedge contract is an electricity base load futures contract, and the hedged item is a power plant with utilisation time around 4000 hours, the correlation between the value of the hedge contract and the hedged item may be weak even if the hedge contract has the relevant local prices as its underlying. If this arrangement does not pass the auditor’s correlation tests, the auditor may not allow hedge accounting. The problem is then not that the correlation of prices is insufficient (it may in fact be perfect), but that the volume is different in the contract and for the power plant.

The term mechanical hedging strategy refers to a hedging strategy not depending on e.g. the current price level. The alternative is a dynamic hedging strategy, and implies that hedges are not executed unless the responsible decision maker is comfortable with the price level of the hedge contracts. A dynamic hedging strategy could also mean that the hedge portfolio is reversed in the event of beneficial price movements and re-established when prices have ‘settled’ at a more comfortable level. A mechanical strategy does not allow for such flexibility, but has to be executed at predefined intervals or events.

2.3 Hedging strategies in the Nordic electricity market

Traditionally (i.e. before re-regulation started in the 1990s), bilateral physical contracts were used for buying and selling electricity. Fixed-price contracts protected customers from the risk of increasing prices whereas generators were protected from the risk of reduced prices. Retail sales were often an integrated part of the business for generators. There was also physical trade between generators on a case-by-case basis. Acquisition of cross-border capacities were a prerequisite for cross-border trades. In several jurisdictions, utilities also enjoyed monopoly rights that effectively protected them from price risks and other types of risks.

The rise of organised day-ahead markets in the 1990s has opened up opportunities for other buying and selling strategies. Consumers and retailers can buy their electricity in the day-ahead market and generators can sell electricity in the same market. Physical trading in the day-ahead market instead of bilateral physical contracts facilitates competition on equal terms and cost reductions for most participants since all participants in the day-ahead market meet the same price irrespective of their size. The drawback is that volatile day-ahead prices lead to substantial price risks. Long-term contracts can be used for hedging of such risks.

Nord Pool was established in 1993 as an organised day-ahead market for Norway. Brokers started quickly to develop a standardised contract for OTC trading. The point of delivery was normally Smestad (the transformer outside Statnett's head office in Oslo at the time), and contracts were settled physically. However, more and more market participants found that physical delivery at Smestad wasn't convenient. The physical settlement meant heavy administrative burdens for companies with portfolios of several hundreds of contracts. Another problem was that Norway was divided in several bidding zones and changes in the bidding zones occurred frequently.

Contracts with a Norwegian system price as the reference price therefore became more popular and Nord Pool started to list such contracts. The Norwegian system price was calculated by Nord Pool in the day-ahead market auction as the price that would have been the clearing price if there were no congestions between the Norwegian bidding zones.

Nord Pool was transformed to a Norwegian-Swedish power exchange in 1996 when Sweden reformed its electricity market. Finland joined Nord Pool in 1998, Western Denmark in 1999 and Eastern Denmark in 2000. The system price as the reference price for financial contracts has gradually been expanded from a Norwegian system price to a Norwegian-Swedish system price, to a Norwegian-Swedish-Finnish system price and finally to a Nordic system price.

Thus for twenty years, hedging of the basic price risks has been concentrated around system price contracts. The liquidity in the market for system price contracts grew very fast until 2002. Many non-Nordic companies joined Nord Pool and started extensive trading. The volume in cleared Nordic financial contracts was over 3 000 TWh in 2002. Together with the volume in the day-ahead market, this corresponded to a churn rate of 9. The collapses of Enron and TXU Europe led to an exodus of most US power companies from Europe in 2003. The volume in cleared Nordic contracts dropped to under 2 000 TWh in 2003.

System price contracts are baseload contracts for days, weeks, months, quarters and years. Figures for trading activity and open interests in the different maturities indicate that volume variations within a week are normally ignored in the hedging portfolios. Volume variations within longer time frames are usually hedged by building a portfolio of contracts for different periods, e.g. larger hedge volumes during winter than summer.

The system price can be interpreted as a price for a virtual Nordic zone, but it is not by any means a price for a physical point of delivery. Physical deliveries are settled against the price for a specific bidding zone. The consequence is a remaining risk for a difference between the system price used for basic hedging and the physical bidding zone price. Market participants, in particular retailers and consumers in Sweden, Finland and Denmark, wanted a possibility to also hedge the difference between the local bidding zone price and the system price. CfDs (later EPADs) were therefore introduced in 2000. An EPAD (Electricity Price Area Differential) is a financial contract to hedge the average difference between a bidding zone price and the Nordic system price. EPADs are available as baseload contracts for months, quarters and years.

The differences between zonal prices and the system price are less volatile than the system price itself if measured in absolute terms (EUR/MWh). Changes in prices and price expectations that trigger changing the content of the hedging portfolios result normally in buying or selling system price contracts, while the portfolios of EPADs are kept more stable.

EPAD contracts are named after a major city within the relevant bidding zone, so that Århus corresponds to DK1, Copenhagen to DK2, Helsinki to Finland, Luleå to SE1, Sundsvall to SE2, Stockholm to SE3, Malmö to SE4, Oslo to NO1 and Tromsø to NO4. Currently, there are market makers for the two Danish areas, the four Swedish areas and for Finland (as well as for Latvian and German EPADs).

There are no EPAD contracts listed for the Norwegian bidding zones NO2, NO3 and NO5 and there is little request for such contracts from retailers and industrial consumers. One reason is that average differences between the system price and Norwegian area prices are smaller than the differences between the system price and Danish, Finnish or Swedish area prices. This reflects that Norwegian hydro production has normally high short-term flexibility. The system price is therefore most often near to Norwegian area prices.

The overall feedback in studies of the Nordic market is that none of interviewed market participants want to replace the basic hedging in system price contracts with basic hedging in different area price contracts. The combined liquidity in system price contracts is seen as essential and they fear fragmented liquidity if there are different area price contracts. Market actors in all price areas benefit from the high liquidity in the financial contracts linked to the system price.

Interviews with market participants, for this project and for previous projects, reveal that hedge accounting is common among industrial customers. But many Nordic electricity generators and retailers do not bother to obtain hedge accounting. Generally, they can easily explain revenue volatility caused by a hedging strategy to their stakeholders. However, auditors may still demand that the companies pursue rather mechanical hedging strategies, with limited flexibility to adapt to market views. This has the interesting consequence that low liquidity of the hedging instrument is not necessarily an issue – once the hedge is established as a short or long position in a specific contract, the mechanical strategy requires the company to keep the contract and let it go to delivery.

Interviews also confirm that the basis for any Nordic hedging portfolio is a carefully examined position in SYS contracts. The role of the SYS part of the portfolio is to provide protection from the major price movements that tend to affect all market areas. For the reminder of the price risks, two kinds of analyses are applied – similar to the logic of the FCA GL art. 30. If an EPAD exist for the relevant bidding zone, there is one set of analyses to consider the performance of said EPAD: cost of hedging, risk premium and liquidity. If the relevant EPAD is considered not good enough, a second set of analyses is applied to determine if alternative EPADs or the system price alone have sufficient correlation with the relevant zonal price.

The approach in the correlation analyses varies among market participants. Some seem to follow an approach consistent with what auditors require when considering hedge accounting and IAS39, while others evaluate correlation more along the scheme suggested in chapter 3. Some of the interviewees have not made any explicit correlation analysis during the past five years, but regularly decides on whether to hedge their area price risks.

The decision on whether to hedge the area price risks often seem to be an application of a market view. If the risk of an unfavourable zonal price (below the system price for producers, above the system price for end users and retailers) is considered low, a seemingly attractive choice can be not to hedge the area price risk, and retain an opportunity to benefit from a favourable price difference instead. A market view is established when internal or trusted price prognoses are compared with current market prices. Correlation analyses can be integrated in the development of price prognoses. Models that only forecast local prices can be combined with correlation analyses to produce a forecast for the system price.

If the area price risks are hedged by proxies, a common concern is the remaining unhedged zonal risks in the 'home market' and some zonal risks related to the proxy. The latter group of 'external' risks can be difficult to explain to stakeholders, and might also be blurred in the hedge portfolio. It will not necessarily 'help' if the proxy contract is very liquid, traded with minimum bid/ask-spread and has a nice track record of good correlation with the local market. The problem is rather that the hedge includes risks that are not naturally a part of the hedged operation.

2.4 Jet fuel hedging strategies in the aviation industry

Jet fuel (a kerosene type fuel) is a major cost item in the airline industry. Its percentage of operating cost, which is the most common measure, varies a lot between airlines and is dependent of the route structure where the mix of short haul and long haul production has a large impact. Furthermore the aircraft fleet composition is important where newer aircraft has a distinct advantage in fuel efficiency. Another obvious relationship is the cost efficiency in other areas such as administrative overhead, labour cost and fleet commonality when fuel cost is looked upon as a percentage.

Typically this has the effect that low cost carriers like Ryanair, Easyjet and Wizz Air shows much higher percentages of fuel costs compared to operating costs than the legacy carriers such as e.g.

British Airways, Lufthansa and Air France-KLM. As an example the leading low cost carrier Ryanair's fuel cost in 2014/15 was 43 percent of its operating cost versus an old legacy carrier as SAS where the ratio for the corresponding period was 24 percent. Since fuel cost doesn't vary significantly over time between airlines this actually says more about the cost efficiency in other areas than fuel.

The overall objective mentioned by the airlines that do hedge the fuel exposure is not to profit but rather to obtain consistent protection in order to ensure ticket pricing predictability and maintaining equilibrium with the competition.

Regardless of the relative impact of the fuel cost at an airline it is still a significant cost item which needs management attention. Although logistics and distribution costs amounts to roughly 10 percent of the total fuel cost in today's market the product price has a huge impact on the overall costs. Taking the oil market volatility into account the only way of managing this cost item is to hedge a world market related portion of the fuel cost.

2.4.1 The jet fuel market and the oil market

Jet fuel is a comparatively small refined product typically representing eight to twelve percent of the refined oil barrel. Jet fuel is not an exchange traded commodity contrary to crude oil, gasoil (heating oil) and gasoline.

The pricing of physical jet fuel is predominantly published via Platts (a subsidiary of McGraw-Hill) and by OPIS who base their price assessments of reported physical trades as indices for the major trading centres such as ARA (Amsterdam-Rotterdam-Antwerp), North West Europe, US East Coast, US West Coast, US Gulf Coast and Singapore.

With the lack of exchange traded futures those who would want to directly hedge any specific jet index must resort to OTC structures.

The oil market is characterized by a high degree of volatility as illustrated in Figure 2-1.

The crack spread between jet fuel and Brent is also volatile due to fluctuating demand and variation in refinery economics. This is shown in Figure 2-2 and Figure 2-3.

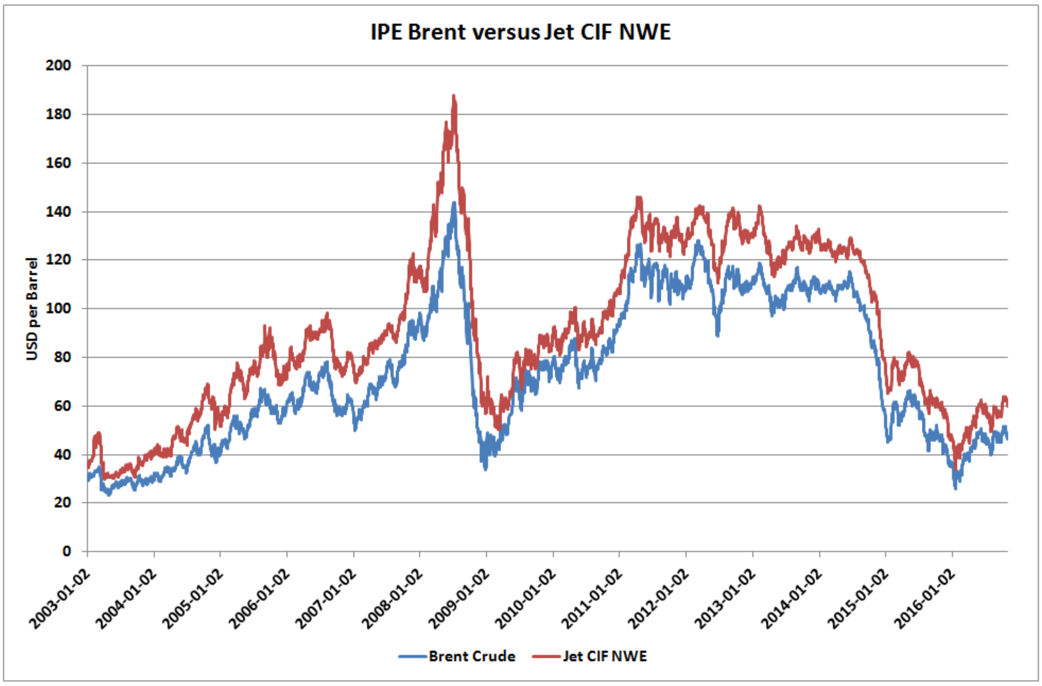

Figure 2-1 Brent and jet fuel price development

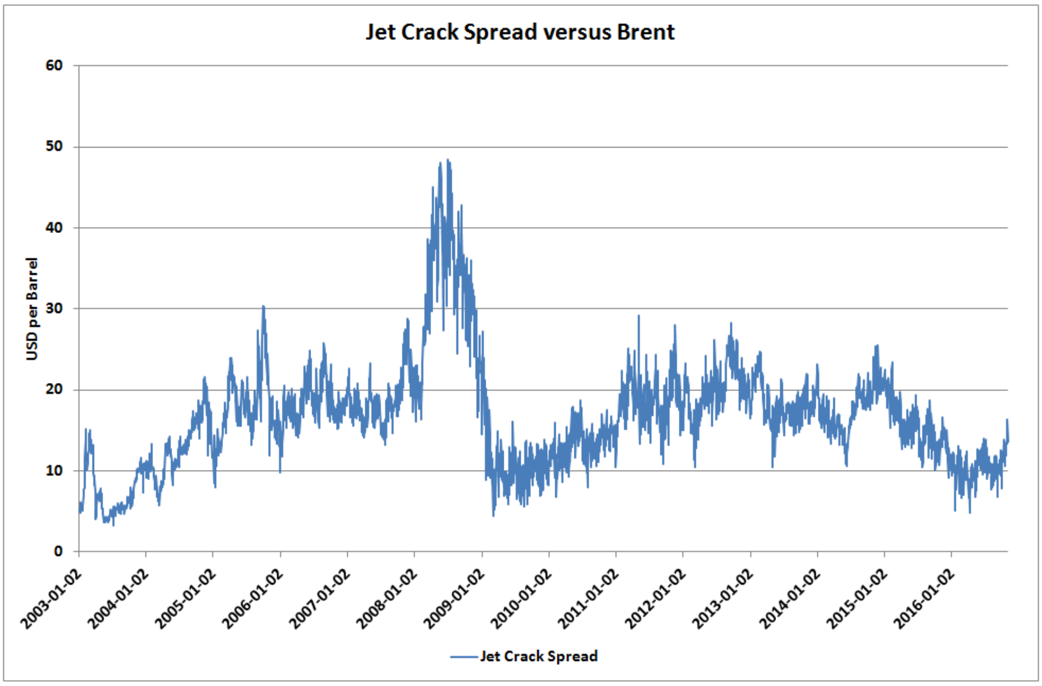

Figure 2-2 Jet Crack Spread

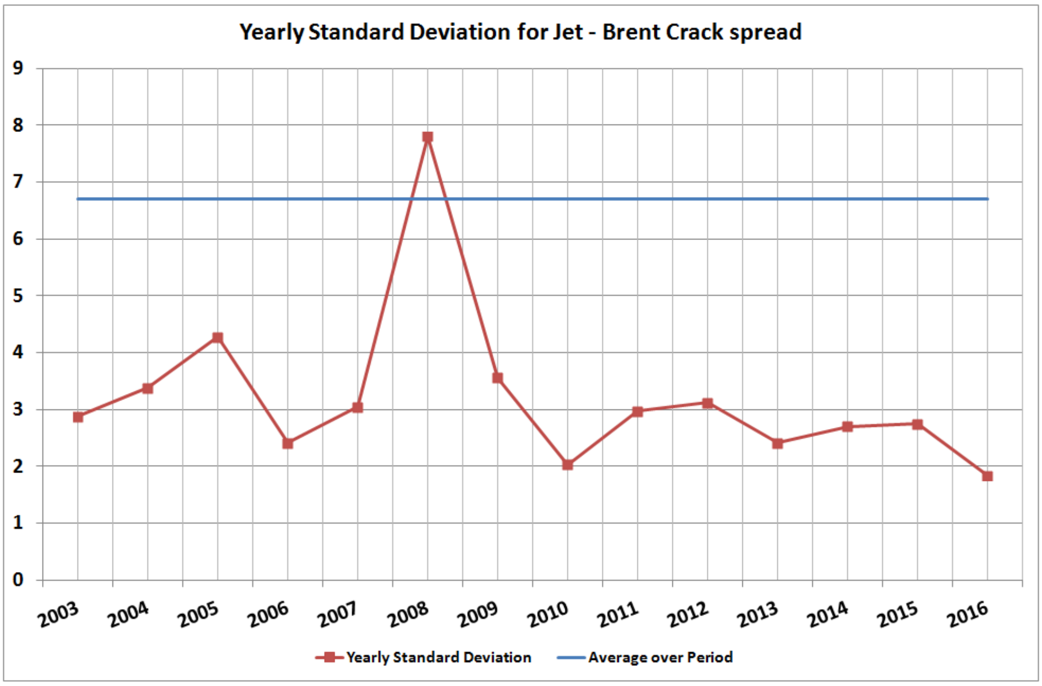

Figure 2-3 Yearly standard deviation for the Jet-Brent crack spread

2.4.2 Hedging strategies by three European airlines

2.4.2.1 Airline A

This airline is hedging the jet fuel, amounting to approximately 1.3 million metric tons of estimated consumption per annum. The purpose is to obtain predictability when pricing its products, i.e. tickets to the market.

The hedging policy is determined by the board and can be revised yearly. The policy states that 40 to 80 percent shall be hedged forward on a 12 months rolling basis with an option to hedge an additional 50 percent for months 13 to 18. How the percentages are applied over the time horizon is decided by its Fuel Committee chaired by the CFO and with representatives from treasury, the physical fuel purchasing department and the commercial department. The hedges are executed and monitored by treasury.

The policy sets no limit for premium cost; the amounts spent are at the Fuel Committee's discretion.

There is a high degree of freedom to use a broad range of instruments but selling call options net is explicitly forbidden. Typically the hedges used are a mix of OTC swaps, outright call options and zero cost collars (see illustrations in Figure 2-5 to Figure 2-7).

Proxies are allowed and historically IPE Gasoil has been used. Currently all hedges are in jet (Jet Fuel CIF Cargoes NWE) which is this airline's index that prices its physical fuel at its home market. The airline has a significant amount of physical fuel priced on other indices in the US and Singapore but this basis risk is currently ignored in order to minimize administration and transaction complexity.

Use of IPE Brent is also allowed but this is further discussed below in connection with accounting.

Any deviation from the policy has to be approved by the board.

This airline has around ten counterparties approved by the treasury that they can trade with under certain limits and this is deemed to be sufficient. All currently approved counterparties are banks; the rating of the two major trading oil companies Shell and BP are not meeting the airline's rating requirement. Since the number of counterparties is relatively small and well known, no brokers are used since they are only perceived as an additional cost providing little if any value.

Benchmarking and subsequent hedge accounting is performed based on IAS 39. The interpretation by the auditors is that sufficient correlation is obtained by hedges in jet and IPE Gasoil but that a hedge in IPE Brent does not qualify for hedge accounting. This is the reason why Brent hedges are not used although they are allowed by the hedging policy.

The oil market is consistently monitored and the decision to take the desired hedge transaction to the market is based on perceived opportunity and the policy's requirements. There are no indications that any sophisticated simulations and technical analysis is done within the airline.

Hedge transactions are "tendered in the market" i.e. several providers are asked to submit their offers and the most competitive offer is accepted.

2.4.2.2 Airline B

The second airline is the largest of the three studied airlines. It has a similar approach to hedging as airline A above.

The predictability of the oil price component is the objective for hedging the about 10 million metric tons of estimated consumption.

The hedging policy is set by the executive management and not by the board. The executive management also decides on any deviations recommended by the Fuel department, which is responsible for executing the policy and also for purchasing the corresponding physical fuel.

The policy states that 50 percent shall be hedged on a 24 month rolling basis with a maximum of 80 percent of any one month. Additional hedges for additional 12 months are allowed with the same percentages. Additional hedges for large charter contracts are also made if the contract revenue is fixed.

This airline is using proxy hedging as defined by the policy by using OTC swaps, call options and zero cost collars in IPE Brent.

This use of proxy hedging means that this airline is ignoring the basis risk between crude oil and jet (the jet crack spread). Although the crude oil price movements over time mirror the jet fuel price movements, the crack spread fluctuates a lot due to fluctuating demand and variation in refinery economics, see Figure 2-2. Upon a direct question it states that it is comfortable with that basis risk exposure. The main reason for proxy hedging is that the comparatively small jet market is illiquid long term (long term meaning after one year forward) whereas the much larger crude oil market provides sufficient liquidity up to five years forward.

Airline B is more exposed than airline A above to jet pricing based on indices in other regions than Europe. This exposure in other regions is ignored although the policy allows hedging in WTI (West Texas Intermediate). WTI is the US equivalent to the European benchmark Brent crude oil and provides a better correlation to US jet indices.

This exposure was handled by the previous hedging policy which was different to the present in that the jet fuel crack spread was hedged in addition to Brent for the next 6 months forward for 25 percent of the consumption on average with the highest coverage in prompt months (Figure 2-4).

The airline has around twenty counterparties approved by its treasury available and the higher number is probably explained by this airline's own credit rating and their own rating requirements. Although the banks are in majority they also trade with the oil industry. Brokers are not used due to the same reasons as explained above for airline A.

Also this airline performs hedge accounting based on IAS 39. However, their auditors are surprisingly enough satisfied that IPE Brent hedges provide sufficient correlation to the jet fuel price.

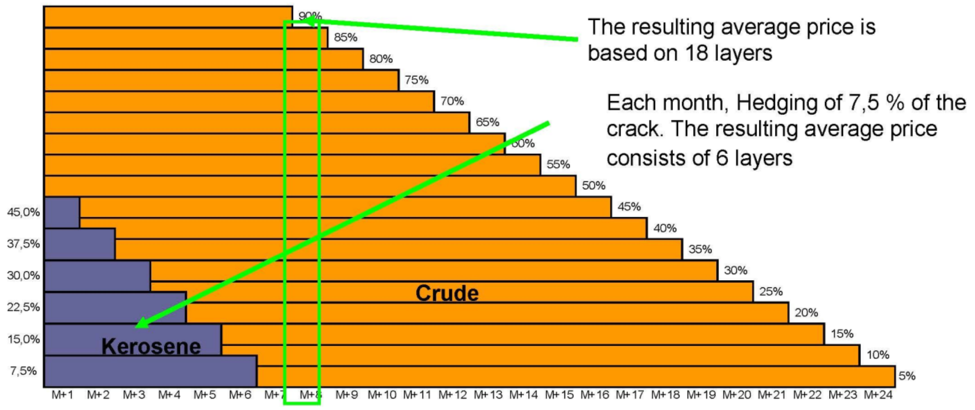

Figure 2-4 Mechanic hedging strategy for jet fuel crack spread

Same as airline A above they consistently monitor the oil market and the decision to take a desired hedge transaction to the market is also based on perceived opportunity and the policy's requirements. Although this airline has larger dedicated resources to fuel it does not seem that sophisticated simulations and technical analysis are done.

The transaction is instead "tendered in the market" i.e. several providers are asked to submit their offers and the most competitive offer is accepted. This seems to be the current standard business model in the airline industry.

This airline also highlighted the competitive situation versus other airlines; "if our competitors did not hedge we probably wouldn't either".

2.4.2.3 Airline C

This airline has recently undergone restructuring, staff reductions and changes of staff in fuel management and finance. It was much less forthcoming than the other two to share their policy and their market behaviour which is why the below is mostly derived from their latest published annual report.

The airline has reduced its hedging of the about 1 million tons it consumes due to extensive hedging losses in calendar 2015.

The hedging horizon is 24 months forward with declining percentages over time and is regulated by the hedging policy approved by the directors and delegated to a Financial Risk Committee.

Contrary to the two other airlines they have historically hedged with a mix of jet, Brent and gasoil for their European jet consumption and heating oil for the US portion. However, if this strategy is still used is unclear.

Instruments used are the industry standard OTC swaps, call options and zero cost collars.

Interestingly this airline does not use hedge accounting but books the fair value of its hedges to the profit and loss account. This indicates that this airline has not gotten approval from the auditors to use hedge accounting depending on the commodities they are hedged with. Another reason is possibly that the airline has two major owners and that they are not concerned with variations in the profit and loss account caused by hedges.

2.4.3 Comments from the banking industry

As an additional source of information about hedging strategies of airlines, we have also interviewed a derivative trader in one of the major US banks' commodity branch. The bank is one of the world's largest commodity derivative providers.

The low-cost segment of the airline industry is generally hedged to a higher degree than the legacy carriers which is not really surprising given the former's low-cost offer to the travelling public.

Products commonly used are primarily Brent but also gasoil and jet are used.

If jet is chosen, the home market index is commonly used and the basis risk versus other regional indices is generally ignored.

However, the trend of using proxies is definitively towards using Brent *if* hedge accounting with Brent hedges are accepted.

There seems to be no standard view on this and a rumour says that a large airline obtained hedge accounting acceptance from one country branch of an auditor whereas this was not accepted by a different country branch of the same auditing firm.

Credit risk is a huge issue for the hedge providers. Given the financial state of the airline industry a lot of carriers cannot hedge due to their rating and/or perceived financial status.

One way of resolving the credit issue is to embed the oil derivative with a CDS (Credit Default Swap) on the airline provided that a CDS on the specific airline actually exists. Obviously this adds to the cost of the derivative but it does provide an ability to hedge for a less financially stable airline.

The following charts outline the three types of hedging instruments that are common in the airline industry. The first is a fixed price structure by means of jet swaps. The second is to get a price cap by the use of call options and the third is to use a combination of two options in order that results in a zero cost collar.

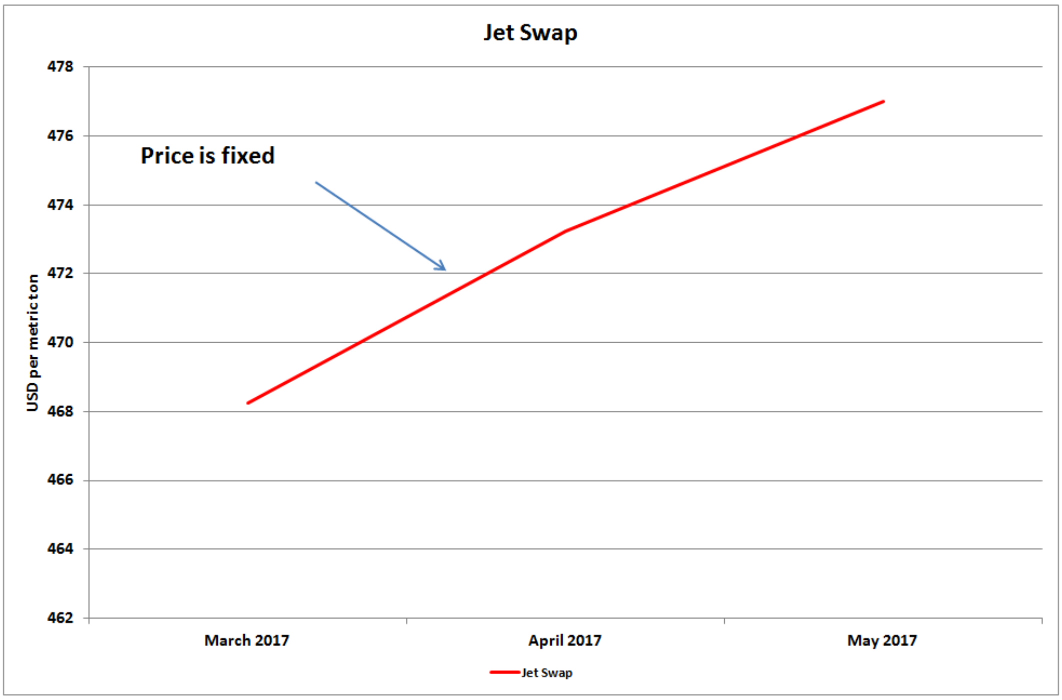

Figure 2-5 Fixed price structure by means of jet swaps

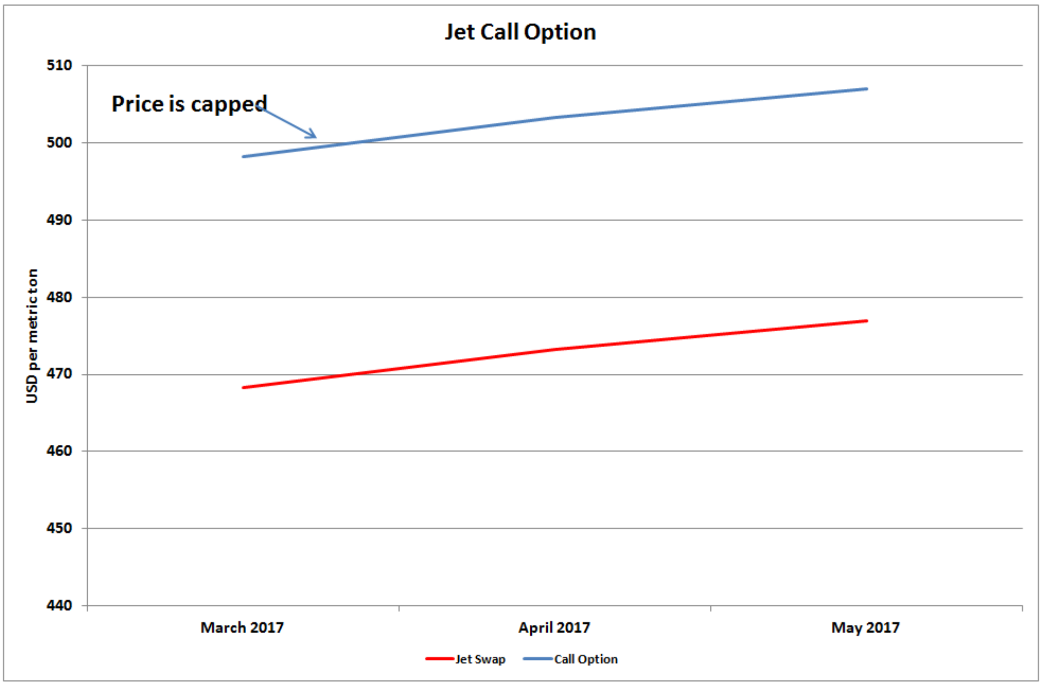

Figure 2-6 Price cap by jet call options

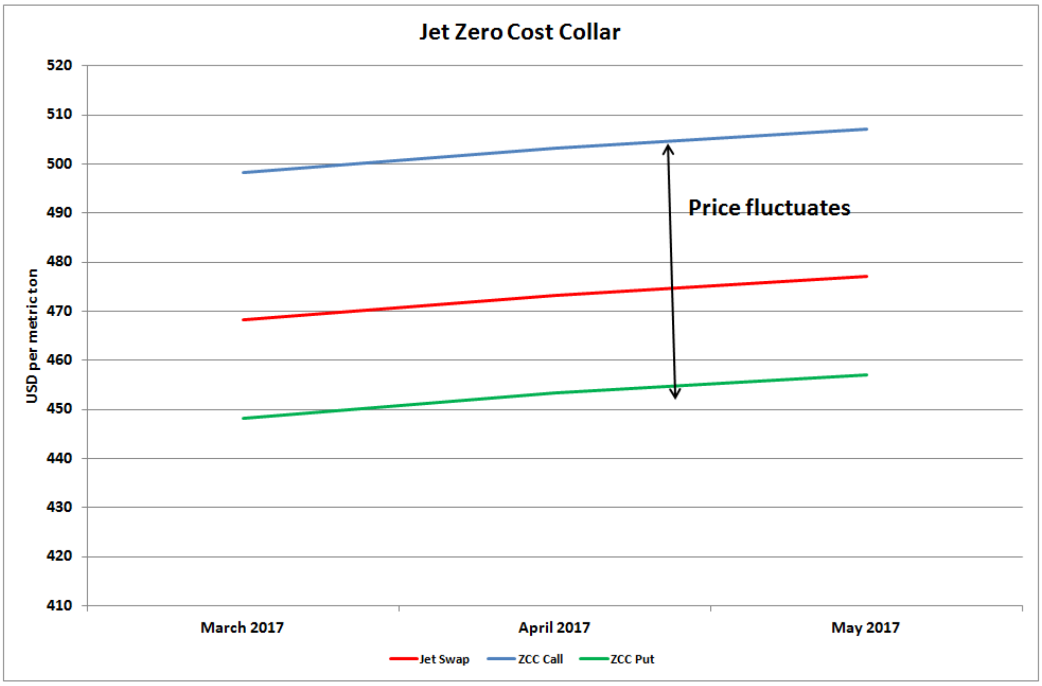

Figure 2-7 Cap and floor established by a zero cost collar strategy

2.4.4 Summary and similarities with the electricity market

The hedging choices and hedging strategies for jet fuel are surprisingly similar to the choices and strategies applied by industrial customers in the Nordic electricity market. Jet fuel is an important cost item in the airline industry as electricity is for electricity-intensive industries. The relationship between Jet and IPE Brent as illustrated in Figure 2-2 above can be seen as a similar relationship as the relationship between the system price and the zonal prices.

Jet fuel is not directly exchange traded. An airline wanting to hedge has a choice between a very liquid proxy as Brent, a liquid proxy as gasoil or heating oil, or rather illiquid, at least long-term, OTC swaps in jet fuel. There is also a possibility to combine very liquid basic hedging in Brent with supplementary hedging in short-term OTC crack spreads between jet fuel and Brent.

An industrial customer in the Nordic market has a choice between a very liquid proxy as the system price, a liquid proxy as a combination of system price and an EPAD for another more liquid bidding zone. There is also a possibility to combine very liquid basic hedging in system price with supplementary hedging in a perhaps illiquid EPAD for its own bidding zone.

Most airlines and most industrial customers in electricity want to avoid fluctuating quarter and annual results because of fluctuations in the mark-to-market value of jet fuel hedges and electricity hedges. It is very important for them that their auditors approve that their hedges are qualified for hedge accounting according to IAS 39. Therefore, the choice of using proxies or not mainly depends on their auditor's view on the correlation between the proxy and the hedged item.

All three airlines purchase physical fuel in different world regions priced on different indices, but two airlines base all hedging on the home market index. The remaining basis risk is ignored in order to minimize administration and transaction complexity.

Given the experiences of the oil market crash in late 2008 the decision on the execution of the hedging policy – and not only the policy itself – has increasingly involved executive management directly or indirectly via a hedging committee.

The 2008 market development has also led to several airlines, primarily in the US, have stopped hedging their jet fuel.

Another common reason for not hedging is the lack of credit with the banking community.

2.5 Hedging strategies in the aluminium industry

The Norwegian metals industry is a significant buyer of electricity. Electricity may count for as much as 30 – 40 % of the total costs. Investments in this sector have quite long time horizons, often beyond 20 years. Investments are thus associated with considerable risks, also regarding electricity costs.

A well-known player in this market is Norsk Hydro. Some of the general features of their hedging philosophy are publicly known. One of the objectives for the hedging activities is to support Hydro's attractiveness in the capital market. Hydro wants to be recognised as an industrial, not a financial company. This implies that they cannot hedge all risks, both at the input and at the output side. As investors invest in Hydro in order to be exposed to the risks in the aluminium market, it would have been counterproductive to hedge the sale of aluminium.

But on the supply side, Hydro is well known for its long horizon in hedging. Hydro was among the pioneers in developing the Norwegian hydropower resources. With full ownership to power plants, Hydro has largely internalised major risk factors for the cost side. In 2011, Norsk Hydro purchased the Brazilian company Vale S.A.'s aluminium business, thereby also gaining control over Hydro's supply of bauxite. Norsk Hydro seems to pursue similar (at least to some extent) hedging philosophies in the markets for power and for raw materials.

As Hydro's annual power consumption in the Nordic region is significantly higher than their own power generation, Norsk Hydro is also 'constantly' looking for long term power contracts. This is not a minor challenge as their potential counterparts, the utilities, have similar concerns in their hedging philosophies – selling power contracts with relatively fixed prices or price formulas for a decade or two implies that their owners not necessarily get what they are expecting as owners of utilities. Nevertheless, it is well known that Hydro every so often have signed 20 year contracts for annual quantities of up to 1 TWh.

Hedging horizons of 20 years or more are far beyond all exchange based financial markets. Hydro's only option is thus to negotiate bilateral contracts with counterparties they trust. In such deals, they may or may not agree on a delivery point or reference price at the location of Hydro's factories. Either way, EPADs or SYS contracts are not particularly relevant for their hedging strategy. However, the 'problem' is not the price behaviour or the efficiency of the contracts, but the much short time horizon for the organised and transparent market places.

The example of Norsk Hydro illustrates that financial contracts may be irrelevant for some hedging requirements even if the contracts were performing perfectly in all other aspects than time horizon. The example also illustrates that the hedging opportunities are not limited to contracts listed at exchanges and cleared by clearing houses. Interestingly, the situation for companies in similar situations, with hedging horizons of many years rather than a few years, is not improved or addressed by the FCA GL.

2.6 Conclusions

Key features of hedging strategies in several sectors are that they are pragmatic and informal.

- Pragmatic means that risk management is a tool and not a goal per se. Companies tend to maximise profits within constraints, and risks are one group of constraints. The challenge is therefore to find the acceptable level of risk for acceptable costs. There are numerous examples of potential hedges that are not used – simply because the costs are considered too high. 'Costs' here includes both an apparently high risk premium in a contract, that the hedge may reduce negative risks but at the same time foreclose attractive profit opportunities, and the internal administrative costs of managing a complex hedge portfolio.
- Pragmatic also means that when executing the hedging strategies, risk committees are commonly involved. This reflects that market participants often do not have clear thresholds or limits dictating what to do. A frequent feature of hedging strategies is that companies tend to apply some sort of market view. This means that hedging decisions may be dependent on (internal) price prognoses.
- Pragmatic further means that many companies want to avoid fluctuating quarter and annual results because of fluctuations in the mark-to-market value of their hedges. It is important for them that their auditors approve that their hedges are qualified for hedge accounting according to IAS 39. Therefore, the choice of using proxies or not mainly depends on their auditor's view on the correlation between the proxy and the hedged item.
- Informal means that the hedging is most often not based on formal correlation or market analysis.
- Informal partly reflects the involvement of risk committees etc., but also that analyses, if they are performed, tend to be ad hoc or tailor made, and not performed at fixed or regular intervals.

3 Measuring relevance of hedge instruments

The first analysis called for in article 30 (4) is whether appropriate (effective) hedges for day-ahead price risks are available for market participants. If EPADs or other local financial contracts are available, the appropriateness of these hedging opportunities is not an issue – these are by construction effective hedges. A short or long position in an EPAD in combination with a system price contract will perfectly eliminate any price risk in the contract period. The same holds for short or long positions in e.g. Dutch, German or British futures contracts.

The analytical challenge comes if there are no local financial contracts available or if the local financial contracts are considered inefficient (see chapter 4). Market participants with hedging demands will then eventually look for proxies – i.e. other contracts, either by themselves or in combination, that potentially could provide appropriate hedges (Alexander, 2008). For a Nordic bidding zone, that could be an EPAD for another bidding zone with comparable behaviour of day-ahead prices. Alternatively, one could look for a combination of several contracts, such as two EPADs, one EPAD and one local futures contract, or any other combination that appears to provide appropriate hedge.

It is not required that the proxy is for an adjacent bidding zone. The important issue is whether a short or long position in the proxy provide sufficient hedge for the market participant. As this is a financial matter, the physical location of the proxy is not an issue. It is the behaviour of the prices that matters.

In this chapter we discuss how to determine if available proxies have sufficient correlation with a zonal price. We start with a mathematical approach to describe the volatility of the revenue for a market participant with different choice of hedging instruments. The relevant methods for quantitative assessments follow immediately from the mathematics.

3.1 The correlation analysis depends on the hedging strategy

A practical interpretation of price risk is to which extent the revenue varies with fluctuating prices. A common measure of such variations is the standard deviation of the revenue. If the revenue is fully determined by the prices in hedging contracts, the impact of short-term price variation is eliminated, and the standard deviation is low. To prepare for an analysis of how to measure hedge effectiveness, we start with some mathematics derivations to study the revenue in some detail.

3.1.1 Hedging with the relevant EPAD

Consider a power plant with delivery in bidding zone z. Let z_t represent the (average) price in period t in bidding zone z and s_t represent the system price in period t. Let us define the *zonal difference* as the difference between zonal price z and the system price s. The underlying for an EPAD is the zonal difference:

$$d_t^z = z_t - s_t \tag{1}$$

The zonal price in period t can thus be written as

$$z_t = s_t + d_t^z \tag{2}$$

Let us assume the owner considers hedging the output from the power plant by selling a SYS contract and an EPAD for zone z. The market price at the time of hedging is $\hat{S}$ for the SYS contract and $\hat{Z}$ for the EPAD. Settlement of the hedging contracts during the delivery periods yields the following payment:

$$\hat{S} - s_t + \hat{Z} - d_t^z \tag{3}$$

The total payment to the power plant is the sum of the physical delivery and the settlement of the hedge:

$$z_t + \hat{S} - s_t + \hat{Z} - d_t^z = s_t + d_t^z + \hat{S} - s_t + \hat{Z} - d_t^z = \hat{S} + \hat{Z} \tag{4}$$

As we can see, the final revenue is constant and independent from both the actual zonal price and the system price. The standard deviation of the delivery prices during the hedging period is thus zero. Thus there is no need to worry about correlation or effectiveness of the hedge if there is an EPAD available.

3.1.2 Hedging with another EPAD

Alternatively, the owner considers using the EPAD for zone x. Using the same principles for notation, the settlement of the hedge can now be written as

$$\hat{S} - s_t + \hat{X} - d_t^x \tag{5}$$

The total revenue will now be the sum of the hedge prices and the spread between the zonal differences.

$$z_t + \hat{S} - s_t + \hat{X} - d_t^x = s_t + d_t^z + \hat{S} - s_t + \hat{X} - d_t^x = \hat{S} + \hat{X} + d_t^z - d_t^x \tag{6}$$

The spread between the zonal differences, $d_t^z - d_t^x$, is equal to the spread between the zonal prices

$$d_t^z - d_t^x = z_t - s_t - (x_t - s_t) = z_t - x_t \tag{7}$$

As the prices in the hedge contracts, $\hat{S} + \hat{X}$, is a constant when the hedge is made, the standard deviation of the revenue depends on the correlation of the zonal prices. Mathematically, the variance of the revenue equals

$$Var(\hat{S} + \hat{X} + z_t - x_t) = Var(z_t - x_t) = Var(z_t) + Var(x_t) - 2Cov(z_t, x_t) \tag{8}$$

The standard deviation is the square root of this expression. The correlation between z and x is defined as the ratio of their covariance and the product of their individual standard deviations;

$$Corr(z_t, x_t) = \frac{Cov(z_t, x_t)}{\sigma^z \cdot \sigma^x} \tag{9}$$

This can be rearranged, such that $Cov(z_t, x_t) = Corr(z_t, x_t) \cdot \sigma^z \cdot \sigma^x$, and then we can see how the correlation metric fits into the calculations.

If z and x are perfectly correlated, the covariance equals the product of the individual variances, which also are equal. In that case, the variance, and thus the standard deviation, of the revenue is zero. If z and x are not correlated at all (correlation coefficient and covariance equal to zero), the negative element on the right-hand side in Equation 8 is zero, which clearly makes the variance and standard deviation larger than if z and x are perfectly correlated. Finding a good proxy thus implies searching for the X in the setup here that minimises the variance.

The mean-variance and portfolio approach to hedging (section 2.1) shows that complete elimination of risk is not optimal, but rather that hedging a fraction of the portfolio either directly or indirectly through proxies yield the "highest pay-off" to the hedger.

3.1.3 Other hedging strategies

Another hedge strategy would be to rely on SYS contracts only, in which case the relevant correlation to study is that between the actual delivery price z and the system price s. Hence, the approach is quite similar to the analysis of a hedge relying on an EPAD for another zone than the delivery zone.

A variant of the above hedging strategy is to combine several EPADs. That corresponds to replacing X with a weighted average of other contracts. The principles are still the same.

A further variant would be to compose a hedge portfolio mixing both SYS contracts, EPADs and financial contracts for other areas, e.g. the German or the Dutch area.

3.2 Correlation analysis in practice

The equations above raise some important questions. One is about time resolution, another is about what is considered as 'good' or sufficient correlation. We start with describing Nordic trading volumes and hedging volumes for different contract durations. We continue discussing whether to rely on the practice that stems from hedge accounting tests and study the correlation between changes in prices from one period to another, or alternatively study the correlation between the prices directly as the equations tell. Finally, we discuss practical details, such as which prices are relevant and how to detail time resolution.

3.2.1 Trading volumes and open interest for different contract durations

Figure 3-1 shows for different contract durations how cleared trades (TWh per month) has developed during 2013-2015 in the Nordic market. As far as we know, all OTC trade in the Nordic region is cleared. Quarterly and yearly contracts have the highest traded volumes. The volumes in weekly and daily contracts are nearly negligible.

Figure 3-2 shows a fairly stable level of open interest – the total open interest fluctuates between 250 and 300 TWh. A striking difference when comparing the two diagrams is that while yearly and quarterly contracts are traded in approximately similar volumes, the yearly contracts have a much higher share of the open interest. This indicates that in the Nordic region, the yearly contracts are more used for hedging, while speculative traders tend to focus on quarterly contracts.

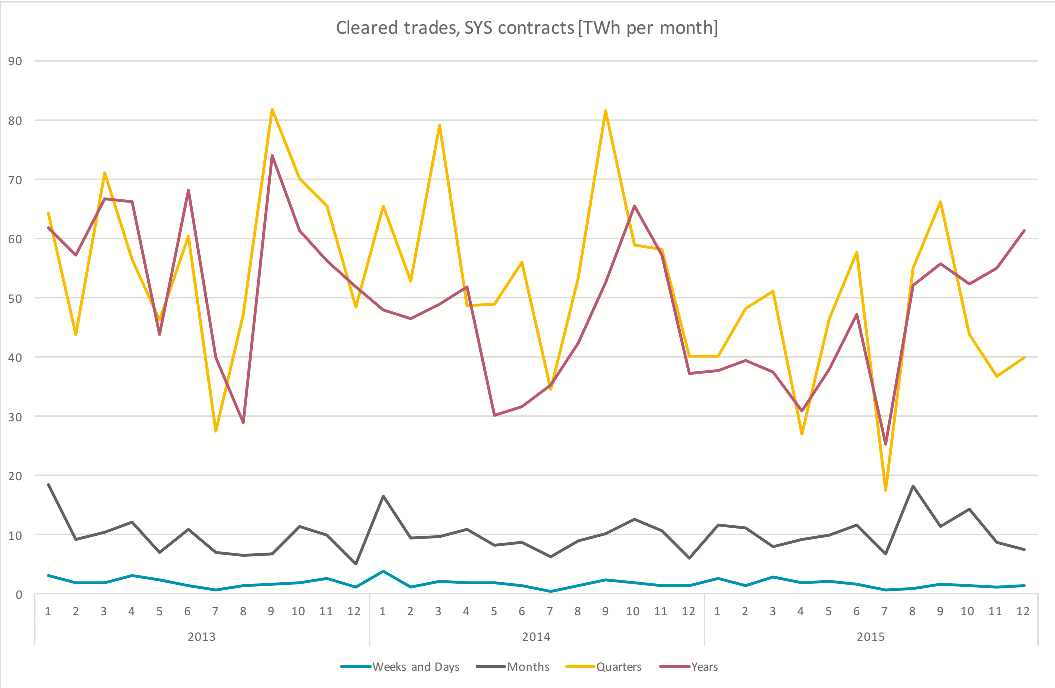

Figure 3-1 Traded volumes for different durations, Nordic SYS contracts (Data source: Nasdaq)

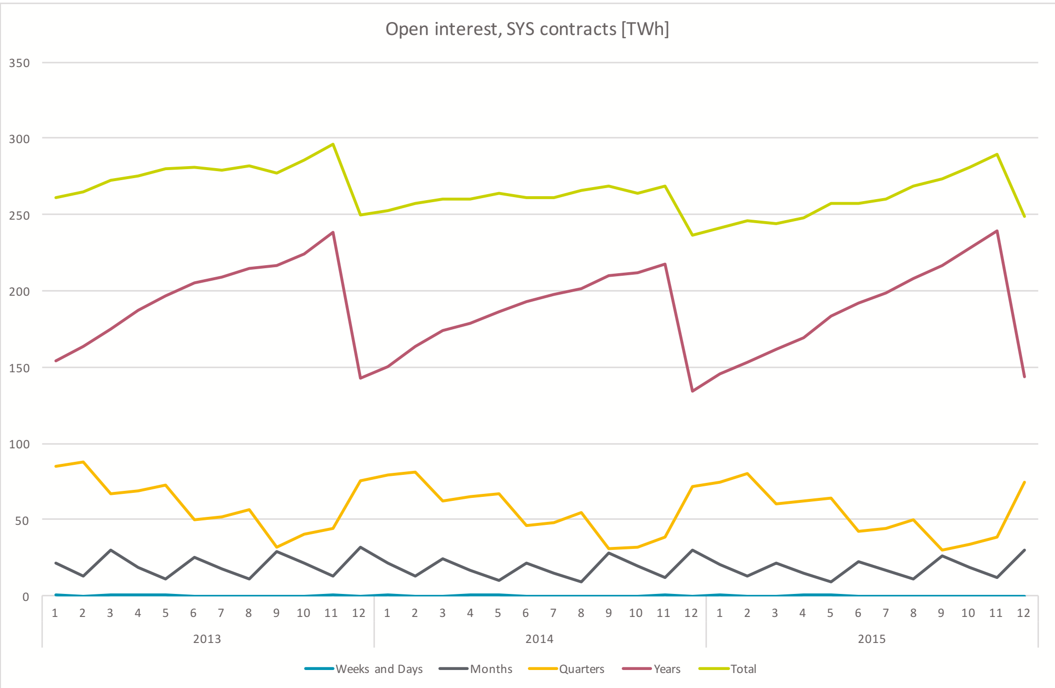

Figure 3-2 Open interest in Nordic SYS contracts (Data source: Nasdaq)

Figure 3-1 and Figure 3-2 reflect the trade of system price contracts. Similar diagrams for EPADs are provided below.

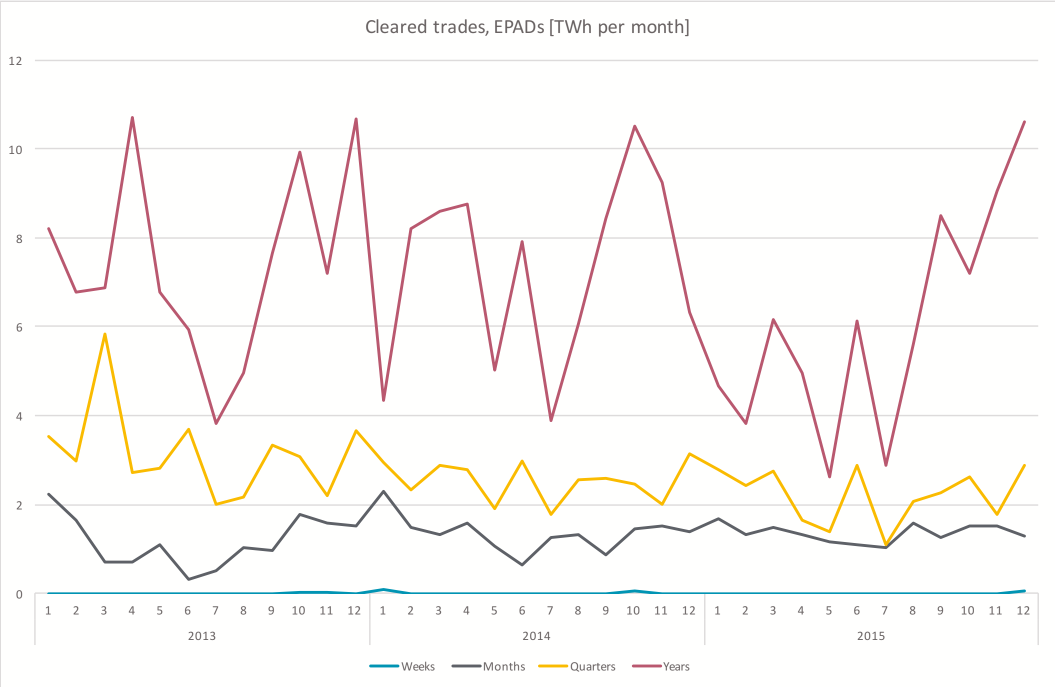

Figure 3-3 Traded volumes for different durations, EPADs (Data source: Nasdaq)

A striking difference between this figure and figure 3-1 is that while quarterly and yearly SYS contracts are traded in similar volumes, the trade in EPADs is dominated by yearly contracts. Further, comparing Figure 3-2 and Figure 3-4, we can see an almost identical distribution of open interest (on different durations) on EPAD and SYS contracts. Taken together, this suggests that while the system price contracts are popular for trading, the primary use of EPADs is for hedging.

From both diagrams of open interest, it is also fairly easy to see how open interest in yearly contracts are turned into open interest in quarterly contracts before year end (the cascading effect), but the total open interest is fairly stable.

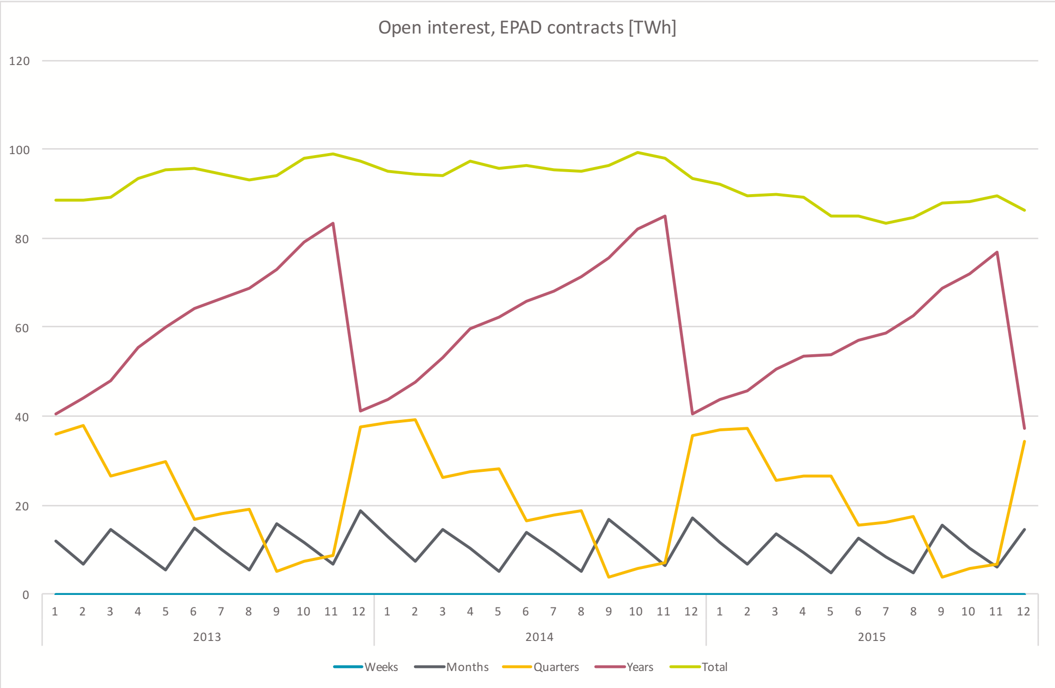

Figure 3-4 Open interest in EPADs (Data source: Nasdaq)

3.2.2 Correlation between prices or price changes?

The correlation tests in the accounting literature are comparing the changes in mark-to-market values of a hedged item and a portfolio of hedging contracts (Finnerty & Grant, 2003; Hailer & Rump, 2005). The reason is of course that the starting point for the accounts is that all contracts should be booked at mark-to-market value. This applies in particular to derivatives that are listed at exchanges with publicly known and accepted price quotes. IAS39 allows for an exemption from this general rule if the mark-to-market values of the two (the hedged item and the hedging portfolio) are sufficiently correlated. The exemption implies that a decrease in the value of e.g. the hedge portfolio does not have to be booked against the profit and loss account because the loss also reflects a similar gain in the value of the hedged item (and vice versa). Without an exemption, the loss on the hedge portfolio must be booked immediately, while the corresponding gain in the hedged item cannot be booked due to the general principles of cautious accounting. The correlation tests must therefore focus on comparing the changes of prices from one period to the next.

The hedging decisions in the electricity market have a different perspective and objective. The objective is generally to reduce the volatility of revenue or costs due to the volatility of day-ahead prices. And with proper hedging contracts, the market participant can 'replace' the volatile day-ahead prices with fixed prices for longer periods. There will still be volatility in revenue or costs with such hedging, but the volatility will be lower and the prices will be more predictable.

This objective or strategy is reflected in the math in the previous section. There it follows immediately that what matters is the correlation between the average delivery price of the hedging horizon and the average of the underlying for the hedging contracts over the same period.

Another way to explain this is that once the hedge is made, it does not matter if the market prices for the hedging period changes. If a market participant has sold at say 20 EUR/MWh for next year, and the market price for such contracts increases to 21 EUR/MWh the day after, this increase has no impact on the future revenue. The hedged volume will only receive 20 EUR/MWh. The increase from 20 to 21 EUR/MWh is relevant only for a mark-to-market valuation, not for predicting the future revenue.

The scope for the correlation analysis must therefore be to compare a given zonal price with the underlying for appropriate hedging portfolios. The concern is whether the prices in the delivery period are well correlated or not, and not whether changes in the value of the hedging portfolio and the hedged item during the hedging period are correlated. Thus the approach in accounting tests is not relevant in this context.

3.2.3 Which prices should be compared?

It follows from the beginning of this chapter that if the relevant EPAD is considered efficient, there is no need for a correlation analysis. The delivery price and the underlying for a hedge based on a SYS contract and the said EPAD are the same. The correlation analysis becomes relevant if the local EPAD is considered inefficient or there is no local contract available, and a proxy is considered instead. The analytical problem is then that there can be an infinite number of proxies, or potentially relevant hedge portfolios. The focus in the literature is on a mean-variance hedging with a minimum variance criteria (Alexander, 2008).

A hedge portfolio can consist of SYS contracts in combination with several EPADs, and can also include e.g. German or Dutch contracts. If we consider a hedge for e.g. SE1, one alternative could be to use the Helsinki EPAD. Another alternative would be to use the Stockholm EPAD. We could also combine them with x % of the volume hedged by the Helsinki EPAD and 100 minus x % hedged by Stockholm. And we might as well consider including the Tromsø EPAD in addition to Helsinki and Stockholm – or instead of Stockholm.

In practice, we can see only two realistic approaches for the regulators to search for potentially relevant proxies. One is to ask market participants which contracts they consider relevant in their hedge portfolios. The other is to search systematically through a limited set of alternative combinations. In doing so, the analytical challenge is 'reduced' to find the combination of contracts the demonstrates the best correlation with the local price to be hedged.

This leaves us with the two initial questions: What time frames should be compared, and is it possible to define a threshold to distinguish between sufficient and insufficient correlation?

3.2.4 Time resolution and time horizon

Nordic trading volumes and hedging volumes for different contract durations are briefly described in section 3.2.1. Hedging horizons are apparently somewhere between a month or two (short-term retail contracts) and up to 3-5 years. Some producers had hedged too much in advance to benefit from the relatively high prices in 2010 and 2011, and think that this was not only unlucky but also undesirable. Thus currently, some of them might be a bit reluctant to hedge too far out in time. This partly also explains why hedging strategies among generators often are flexible. Typically, the strategy states that between x and y % of the expected generation should be sold one year ahead, and further that between z and v % should be sold out two years ahead, etc. (x and y are then larger than z and v, respectively).

Except for the long term industries, like metals, industrial customers have somewhat similar hedging horizons, but frequently less flexible. Retailers also generally have a more mechanical approach and a hedging horizon corresponding to the duration of their fixed price sales contracts.

For those with a horizon of several years it is generally the average price per year that matters, while the quarterly and even monthly averages are more relevant for retailers. We cannot see any reason to study averages over shorter time periods, such as weeks. Hourly prices are anyway totally irrelevant.

A practical approach would be to study both yearly and monthly averages. This also enables a comparison with LTTRs which are yearly and monthly contracts. An issue with yearly averages is that we may have insufficient data points to do a proper analysis. An alternative could therefore be to study quarterly or half-yearly averages instead of yearly.

The next issue is how many time periods the analysis should consider. A company considering a hedge is essentially concerned about future delivery prices, not the past ones. But it is the history that is known and it might tell quite a lot about what may happen in the future. Simply comparing the average prices for the last year is clearly misleading, particularly if the hedging horizon indicates that yearly averages is the relevant time resolution. Including all available price history or putting equal weight on the recent years as on the oldest observations might also be misleading. A proper correlation analysis therefore relies on a balance between not looking too far back and not missing realistic but not frequent incidents (black swans).

A practical solution could be to look some years back but also study previous correlation scores. Suppose as an example that we study the past 48 months, and that we calculate the correlation coefficient between two price series. We can then go one month back and repeat the calculation. We can repeat this and study how a 48 month correlation figure has developed over time.

3.2.5 No thresholds

The last and perhaps the trickiest question is where to draw the limit for a sufficient hedge. The beauty of the principles from hedge accounting is that there is a norm. To qualify for hedge accounting, the correlation coefficient must be at least 0,8. Market participants in the electricity sector may hedge at lower correlation rates without having to comply with the IAS39 if they do not apply hedge accounting. Thus it seems fair to assume that a ratio below 0,8 can also be sufficient. 0,7 is clearly better than e.g. 0,5, but is 0,5 sufficient? And would hedging by a proxy with a correlation coefficient of 0,5 be worse than not hedging the zonal price risk at all?

One might ask market participants what thresholds they apply (if any) or would prefer the regulators to apply, but experience suggests that market participants look for protection from unfavourable outcome of the zonal price difference and are thus more concerned about how they consider the probability for future price movements, rather than relying on a correlation test. Market participants may also have vested interests in the regulators' evaluation after such a survey or consultation.

Ultimately, whether to apply and where to define a threshold must be a decision by the regulator(s). However, we recommend that knock-out thresholds are not used. Possible thresholds should only be treated as indicators in the analysis. It is the overall results from correlation analysis, efficiency analysis and consultation that is important.

3.3 Summary of suggested method

The mean-variance approach to hedging has an important implication for the assessment of hedging opportunities in the electricity market. Using a standard mean-variance analysis the composition and performance of selected portfolios with system price contracts and EPADs can be analysed and evaluated.

We suggest the regulators compare yearly and monthly average zonal prices with similar averages of the underlying for potential hedging instruments, such as SYS contracts, EPADs, and contracts for adjacent bidding zones like Germany, or a combination of such contracts. A methodical challenge is that there is essentially an infinite number of potentially relevant combinations. The purpose of the analyses must be to test whether the prices in the delivery period are well correlated or not, and not to examine the changes in the value of the hedging portfolio and the hedged item during the hedging period. Hence, the approach taken in the hedge accounting literature is not relevant for measuring correlation in the regulators' assessments.

4 Evaluation of contract efficiency

Article 30 (4) b in the FCA GL calls for an analysis of whether the products or combination of products offered on forward markets are efficient. In this chapter we discuss the choice of methods to analyse efficiency of contracts relevant for hedging Nordic electricity price risks. There is a rich literature on measuring contract efficiency in financial markets, and thus a large number of alternative approaches for the regulators' analyses. We outline the potentially most relevant liquidity and efficiency measures for electricity derivatives contracts, discuss their benefits and limitations under different circumstances (such as geographical region), conclude on which methods the regulators should apply, and provide technical guidance on their assessment and interpretation.

We distinguish between three general classes of liquidity and efficiency measures, here described as 1) Descriptive measures (trading horizon, traded volume, and open interest); 2) Price measures (risk premium, long- and short-run market efficiency, and Amihud); and 3) Transaction cost measures (bid-ask spreads, and Roll's measure). The objective is not to provide an exhaustive list of all possible efficiency measures or try to identify a single empirical proxy that could capture all aspects of efficiency. Instead, we discuss in-depth application of a few methods and proxies empirically applicable to the Nordic electricity markets.

Most of the measures discussed in this chapter evaluate a single contract type that can be studied in the context of a particular bidding zone and over time (e.g. quarterly baseload futures in Finland over a year). Portfolios or combinations of contracts are discussed only partially. The reason for this approach is simply to avoid too complex explanations. It should be noted that if a particular contract later identified as mis-priced or too costly would be used in a portfolio, the negative aspects of such contract can be reduced but they will not simply disappear by pooling the contract with other hedging contracts.

Based on the detailed discussion in this section, our recommendation is to use less computationally intensive liquidity measures which are more operational. The recommended liquidity measures are all of the descriptive measures, risk premium from the price measures, and bid-ask spreads from the transaction cost measures. A brief summary of all the measures discussed in this chapter are presented in Table 4-1.

The chapter is organised as follows: Section 4.1 provides a brief introduction to concepts of liquidity, market efficiency, and derivatives pricing in electricity markets. We continue in section 4.2 with the descriptive measures and in section 4.3 with price measures. Transaction cost measures are discussed in section 4.4. An overview of our recommendations is presented in section 4.5.

Table 4-1 Summary of efficiency and liquidity measures

	Measure	Interpretation	Assessment	Pros	Cons
Descriptive measures	Trading horizon	Measures product design	Descriptive analysis	Evaluation of hedging possibilities against individual contract time frames	Not a direct measure of efficiency or liquidity
	Traded volume	Measures liquidity	Descriptive and time series analysis	Data availability (daily returns and volume)	Partial measure of liquidity
	Open interest	Measures liquidity and importance for hedging	Descriptive analysis	Dynamic measure of liquidity and importance for hedging	Partial measure of liquidity
Price measures	Risk premium	Measures hedging pressures	Time series analysis	Computationally straightforward	Needs further disentanglement
	Amihud	Measures liquidity	Time series analysis	Data availability (daily returns and volumes); allows studying time series effects of liquidity	Not well defined for power derivatives markets
	Long-and short-term market efficiency	Measures overall market efficiency	Time series analysis	Data availability; allows testing overall market efficiency in short-and long-run	Analytical complexity; more reliable estimates for shorter maturity contracts due to smaller forecast errors
Transaction costs	Bid-ask spread	Liquidity measure with pronounced effects on transaction costs	Descriptive and time series analysis	Measures the costs of hedging for market participants	Limited data access and availability of OTC bid-ask spreads (except for regulators)
	Roll's measure	Measures transaction costs	Time series analysis	Infers a measure of effective bid-ask spreads simply from market prices	Relative ease of access to bid-ask spreads from market data

4.1 Background on liquidity, efficiency and power derivatives pricing

A financial asset is perceived *liquid* by market participants when they can quickly sell large amounts of the asset without negatively affecting its price. Typical qualities of a liquid asset are 1) small transaction costs, 2) easy trading and timely settlement, and 3) large trades having only limited impact on the market price. Additionally, the following five characteristics are associated with liquid markets (Sarr & Lybek, 2002):

1. Tightness – low transaction and implicit costs
2. Immediacy – speed with which orders can be executed; efficiency of trading, clearing, and settlement systems
3. Depth – existence of abundant orders above and below the current trading price
4. Breadth – orders are numerous and large in volume with minimal impact on prices
5. Resiliency – quick flow of new orders correcting order imbalances

Some liquidity and efficiency measures also rely on the assumption of *market efficiency*. The efficient market hypothesis in its strong form (Fama E. F., 1970) stipulates that security prices fully reflect all available information, and in its weak form (Fama E. F., 1991) that the deviations from the strong efficiency are within information and trading costs. In general, returns are close to unpredictable (Cochrane, 1999), following a random walk. The theory also holds that prices are rationally determined, e.g. companies correctly assess their risks, and any discrepancy between the spot and derivatives prices will be arbitraged away. Nonetheless, past evidence (Fama & French, 1988; Campbell & Shiller, 1988) suggests that returns can be reasonably well predicted for longer-horizons (years) but less so for short-horizons (daily, weekly, and monthly).

Electricity derivatives cannot be priced in accordance with the traditional theory of storage, because electricity is economically non-storable. Instead, the price of electricity derivatives is determined by *expectations* and *risk preferences* of market participants (Dusak, 1973; Breeden, 1980; Cootner, 1960). Hence, the variation in electricity derivatives prices is driven entirely by the expectation of the future spot price $E(S_T \mid \boldsymbol{\Omega}_t)$ during the time of delivery (T) conditional on the information set $\boldsymbol{\Omega}_t$ available at time *t* plus a risk premium, see Equation 10. The risk premium represents an equilibrium compensation for bearing the price risk for the underlying commodity, i.e. electricity (Longstaff & Wang, 2004, p. 1887).

$$F_{t,T} = E(S_T \mid \Omega_t) + \pi_t \tag{10}$$

When evaluating the price of a hedging instrument, a link with the underlying business conditions and fundamental factors must be established. In electricity markets, this includes, for example, the expected price volatility (price skewness), weather conditions (precipitation, wind, temperature, etc.), large generation investments or shutdowns, new transmission lines and their faults, etc.

Hence, the ultimate question, "*What is a reasonable price for a hedge?*" has to be evaluated under a given techno-economic context because this context affects the expectations and risks the market participants reflect in derivative prices. Also, the underlying micro structure of the power derivatives market, such as product design, market participants, trading systems, clearing and settlement of transactions, and accounting framework should be considered when evaluating liquidity.

4.2 Descriptive measures

We call the measures in this class descriptive because they do not require any transformation or complex computation and can be directly interpreted. The inputs for the measures in this class come directly from the market data publicly quoted by an exchange, or otherwise obtained from brokers and information providers. The first measure discussed below is trading horizon, which is an institutional micro structure factor shaping the product design (maturity) of individual derivatives. The second and third measure, namely traded volumes and open interest are volume-based measures. They are useful for measuring market significance and market breadth, i.e. the existence of numerous and large orders in volume with minimal transaction price impact. Relevant literature for this sub-chapter is presented in table below.

Table 4-2 Relevant literature

Reference	Comment
(Blume, Easley, & O'Hara, 1994)	Investigation of the informational role of volume and its applicability for technical analysis
(Sarr & Lybek, 2002)	Qualitative and quantitative liquidity measures applied to foreign exchange, money, bond, and equity markets
(Spodniak, Collan, & Viljainen, 2015)	Descriptive liquidity measures (volume, trading horizons, etc.) applied to EPAD market

4.2.1 Trading horizons

Trading horizon, understood here as a derivatives product with different timeframe/maturity, is not a measure of efficiency or liquidity per se. The trading horizon shows for different listed contracts which maturities that can be traded and cleared and is thus an indicator of hedging possibilities. In addition to bidding area segmentation, trading horizons provide a fundamental cross-sectional division for most of the efficiency and liquidity measures discussed here. By focusing on individual trading horizons over period of time and across space (bidding zones) when measuring traded volumes and open interest, greater insights into market behaviour and levels of market activity can be gained.

There is essentially no other ‘task’ or method here than simply being aware of the contract time frames when collecting information about traded volumes and open interest.

4.2.2 Traded volumes

In general, traded volumes[1], representing number of MWh sold and bought for given derivative during a specified period, provide information on liquidity and demand for a particular hedging instrument. Contracts in high demand are traded more and can be easily sold or bought whereas contracts with low traded volumes can be difficult to sell or buy.

This measure is traditionally used to measure *the existence of large number of transactions and market participants.* Hence, trading volume is mostly linked to market breadth, i.e. orders are numerous and large in volume with minimal impact on prices. Relating the traded volumes with prices for these trades, we can calculate turnover (Euro volume), see Equation 11 where P_i and Q_i are individual trades for derivative i during a given time period.

$$V_i = \sum P_i Q_i \tag{11}$$

A complementary measure for market breadth can be calculated by dividing the traded volume (Q_i) with the number of transactions, which gives the average trade size. Large average trade size indicates the existence of numerous and large trades. Small average size indicates that the contract is more used for adaption of a portfolio than for speculative trading.

To allow for greater detail in the analyses, trading volumes for each product should be structured along trading horizons and bidding zones over a number of time periods, such as years and months. Additional granularity may be gained by disentangling traded volumes by market place, such as over-the-counter and exchange. Such data structuring provides a glance into liquidity and quick overview of the market structure; which products are being most traded, in which bidding areas, for what maturity, and at which market place[2].

[1] Traded volumes are simply the Q_i in Equation 11.
[2] A link between traded volumes and market efficiency has been discussed (Antoniou, Ergul, Holmes, & Priestley, 1997; Blume, Easley, & O'Hara, 1994). If these findings were translated into

4.2.3 **Open interest**

Open interest refers to all open positions with a clearing house at a given point in time. It corresponds to the total amount of energy in derivatives contracts that have not yet been closed out by an offsetting trade, fulfilled by means of the physical delivery of the underlying asset or executed via cash settlement. An important metric to understand financial markets is the development of open interest. When a contract is bought or sold for hedging purposes, the intention is to keep the new position until the contract goes to delivery. If the contract is bought (sold) for trading purposes, the idea is most often to sell (buy) a similar contract for a higher (lower) price at a later point in time. The first of the trader's transaction will increase open interest, while the second will reduce open interest. Hence, the size of the open interest in a contract in relation to the traded volumes in the contract shows to what extent the contract is used primarily for hedging purposes or for trading.

Open interest is a more dynamic measure of liquidity compared to e.g. traded volumes, because it reflects the decrease or increase of money brought into the futures market. Open interest of individual contracts in most futures markets typically follows a pattern represented by low values when delivery period is distant, followed by a peak relatively close to delivery, and then a fall when the delivery period approaches (Williams, Peck, Park, & Rozelle, 1998). Electricity contracts used for hedging are, however, normally kept until delivery. The drops just ahead of delivery seen in Figure 4-1 represent the cascading effect (yearly contracts turned into quarterly contracts before year end, etc.), but the total open interest is fairly stable.

Similar measure of liquidity as open interest is churn rate, which is a ratio between the total traded volumes (Q_i) of power derivative *i* and the total electricity consumption (V_i) in a given period, see Equation 12. Churn rate can be understood as a number showing how many times a megawatt hour is traded before it is delivered to the final consumer.

$$CR_i = \sum \frac{Q_i}{V_i} \tag{12}$$

Churn rate might be a good indicator of trading significance, but it is less relevant as an indicator of hedging significance. The actual traded volume for a specific bidding zone consists of both

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Nordic electricity derivatives, past trading volumes, in conjunction with past returns, would provide useful information in predicting future returns. The trading volume would be mostly relevant for thinly traded derivatives, such as EPADs. To evaluate the proposed relationship, a market model should be estimated where current power derivatives returns are dependent on past returns, past volumes and measure of risk. If the past volumes would significantly contribute to prediction, trades/speculators using such measure would benefit from better quality information not contained in prices alone. Nonetheless, since the main purpose of this study is contract liquidity instead of market efficiency, we recommend using the traded volume measure for the liquidity purpose only.

EPADs and SYS contracts as well as day-ahead contracts in the Elspot market. However, 'splitting' the SYS trade between bidding zones would be complex (if possible at all[3]) and does not make sense.

Thus while we find open interest per contract as valuable information about the various bidding zones, we cannot see how churn rates can be calculated and applied by the regulators in a useful way.

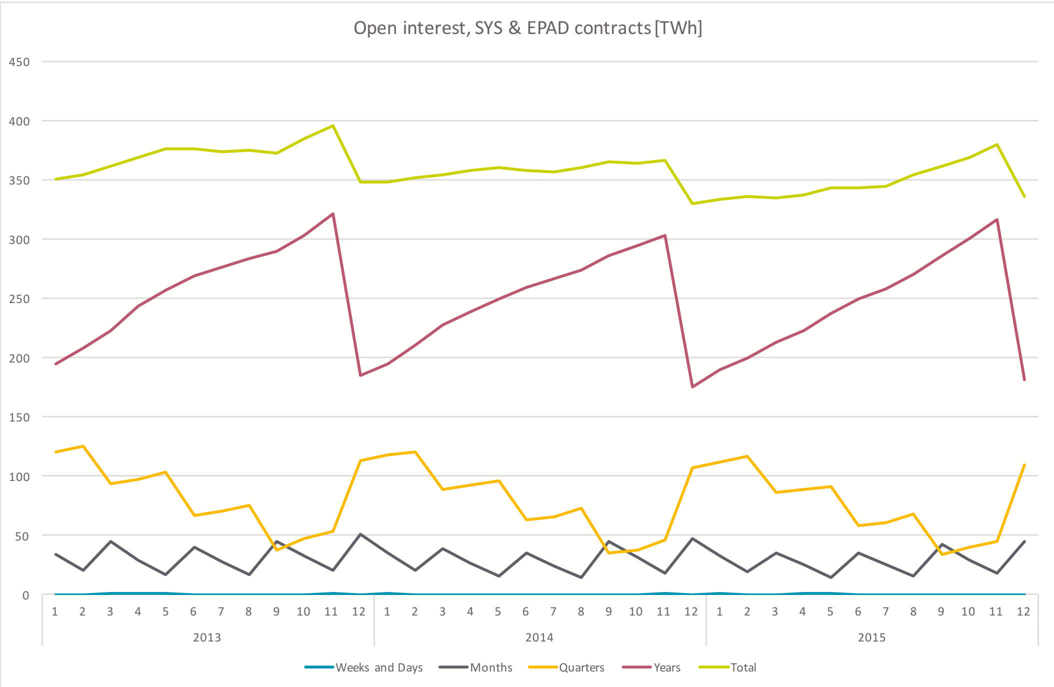

Figure 4-1 Open interest in SYS and EPAD contracts (Source: Nasdaq/EC Group)

4.3 Price measures

Price measures in this section relate to the price discovery process of determining a derivative's price through buyer and seller interaction in the marketplace. The rapidity with which market

[3] Several market participants have physical positions to hedge in numerous bidding zones and do not have to specify for which zone a particular trade is made. In fact, one trade may be intended to hedge positions in numerous zones. Market participants without physical positions may also trade without any regard for the zonal prices or the zonal structure at all.

participants react to new information, their judgement and the quality of information all affect the dynamics of the price discovery process.

We discuss three examples of price measures for power derivatives assessed cross-sectionally (trading horizons and bidding zones) and across time. The first measure estimates risk premiums as the futures-spot-bias; the second evaluates the impact of illiquidity on derivatives prices/returns (Amihud, 2002); and the third evaluates the overall long-term and short-term efficiency of the derivatives and the underlying prices. See also section 2.1 for some theoretical perspectives to the risk premium.

For the regulators' analyses, we suggest relying on the risk premium analysis described in section 4.3.1.1

Table 4-3 Relevant literature for price measures

Reference	Comment
(Bessembinder & Lemmon, 2002)	Negative relationship of spot price variance and positive relationship of spot price skewness to risk premiums
(Marckhoff & Wimschulte, 2009)	Ex-post risk premiums for CfDs (EPADs) calculated for 2001-2006, including confirmation of Bessembinder & Lemmon (2002) model
(Spodniak, Chernenko, & Nilsson, 2014)	Ex-post risk premiums for EPADs 2001-2013
(Redl, Haas, Huber, & Böhm, 2009)	Price formation of futures and forward contracts on EEX and Nord Pool, including ex-post risk premiums for Nov 2003- May 2008

4.3.1 **Risk premium**

One approach to investigate pricing accuracy of power derivatives contracts is to calculate risk premiums, which are systematic differences between the trading prices of an electricity contract ($F_{t,T}$) and the contract's expected (ex-ante) spot price when it is delivered ($E_t(S_{T,T})$). We call this systematic difference forward risk premium (Benth & Meyer-Brandis, 2009; Longstaff & Wang, 2004; Benth, Cartea, & Kiesel, 2008; Marckhoff & Wimschulte, 2009). Forward risk premiums can be understood as mark-ups or compensations in the derivatives contracts charged either by traders, suppliers or consumers for bearing the price risk for the underlying commodity (Longstaff & Wang, 2004, p. 1887).

The underlying question behind risk premiums is whether they denote a natural behaviour of risk-averse market participants willing to pay (accept) a risk premium (discount) for transferring the risk of unfavourable spot price movements (Marckhoff & Wimschulte, 2009), or whether they are a sign of market inefficiency, such as arbitrage (Borenstein, Bushnell, Knittel, & Wolfram, 2008). From the available data and empirical analysis we cannot disentangle the two directly, but we can study the magnitudes, persistency, direction, and significance of risk premiums, which then shed light on the accuracy of the market to price power derivatives. Put differently, by studying risk premiums we may assess, whether the specific power derivatives contracts are unbiased predictors of the future spot price.

4.3.1.1 Ex-post risk premium

In the forward and futures pricing literature it is a common practice to calculate the ex-ante premium in the forward price as the ex-post differential between the futures prices and the realized delivery date spot prices (Redl, Haas, Huber, & Böhm, 2009). Longstaff and Wang (2004) suggested this ex-post approach to risk premiums in electricity forward prices by using $S_{T,T}$ as a proxy for $E_t(S_{T,T})$), and Marckhoff and Wimschulte (2009) applied this proxy to calculate the ex-post risk premium for EPADs. Ex-post risk premiums are easy to calculate with readily available data, while the ex-ante approach relies on unobservable information (the expected prices).

Forward risk premium in a derivatives contract at time t for delivery at time T is equal to the derivatives price $F_{t,T}$ at time t for delivery at time T minus the average realized spot price $S_{T,T}$ between the beginning and end of the delivery period T_1 and T_2 respectively. The ex-ante risk premium is expressed by Equation 13 and the ex-post risk premium is expressed by Equation 14:

$$\pi_{t,T} = F_{t,T} - E_t(S_{T,T}) \tag{13}$$

$$\pi_{t,T} = F_{t,T} - \frac{1}{n}\sum_{h=T_1}^{T_2} S_{T,T} \tag{14}$$

The derivatives price $F_{t,T}$ can be for any type of power derivatives contract, such as system price futures or EPAD. For clarity, the ex-post risk premium calculation for EPADs is shown in Equation 15, where $EPAD_{t,T}$ represents the EPAD's price at time *t* for delivery at time *T.* The risk premium is this price minus the average realized spot difference between the zonal price P_h^{Area} and the system price S_h^{System} between the beginning and end of the delivery period T_1 and T_2, respectively.

$$\pi_{t,T}^{EPAD} = EPAD_{t,T} - \frac{1}{n}\sum_{h=T_1}^{T_2} (P_h^{Area} - S_h^{System}) \tag{15}$$

For the regulators' analysis, we suggest using the last recorded trading price $EPAD_{t,T}$ (or $F_{t,T}$ for SYS contracts or local contracts for e.g. Germany) for individual contracts in the calculations because it represents the best estimate of the expected price just before delivery starts. Risk premiums can be calculated for individual contracts (e.g. monthly Stockholm EPADs, base year futures, etc.) by taking the difference between the last trading day price of a derivative and the average spot outcome during the underlying delivery period. Risk premiums calculated for individual contracts can then be presented in yearly averages over individual trading horizons (yearly, quarterly or monthly) and bidding areas.

Note that contracts with shorter trading horizon/maturity and closest to delivery, such as daily, weekly, and monthly, will typically contain the lowest forecast errors made by market participants. Nonetheless, risk premiums for longer maturities, such as yearly contracts, can be also calculated while noting that market participants can make greater forecasting errors for longer contracts or contracts further away from delivery (e.g. monthly contract maturing three months from now).

Statistical significance of the quantified risk premium should also be tested by the t-test statistic, i.e. test whether the risk premiums are different from zero under a given level of significance. The formula for one-sample t-test is expressed in Equation 16, where $\bar{x}$ is the mean risk premium in the sample, *s* is the standard deviation of risk premium in the sample, *n* is the sample size, and μ_0 is the hypothesized population mean (e.g. zero). The sample can be all ex-post risk premiums calculated for each derivative class, such as monthly EPADs, in a given bidding zone over a year, for instance. So if we use only front-month EPADs (monthly EPAD with next month delivery) the sample size over one year would be twelve. For yearly derivatives and when using only front-year contracts (yearly derivative with next year delivery) we would need to apply the t-test on at least a four-year period, i.e. the sample size would be four (at least) because there is only one risk premium per year for yearly contracts according to the outlined methodology[4].

$$t = \frac{\bar{x} - \mu_0}{{}^{s}/_{\sqrt{n}}} \tag{16}$$

The T-test shows whether the sample and population mean are different or not. If the sampled risk premium is not significantly different from zero, there is no systematic bias in the derivatives prices compared to the underlying spot prices. Even when statistical significance of risk premium is confirmed at 5 % or lower, the magnitudes, signs, and techno-economic reasons behind these should be explored before making interpretative conclusions.

[4] An alternative methodology is to calculate the ex-post premiums on daily basis instead of averaging over the entire delivery period, see (Marckhoff & Wimschulte, 2009), which would provide e.g. 365 risk premiums for yearly derivative over a year, so t-test can be directly applied on yearly derivatives over a year. However, for operational simplicity, we recommend the simpler approach described above of just comparing the last trading day price for a derivative and the average ex-post spot outcomes.

In summary, we recommend calculating average ex-post risk premiums for individual contracts and testing their statistical significance. Comparative insights on risk premium magnitudes, directions, and significance will be gained which would expose possible systematic biases of derivatives.

4.3.1.2 Ex-post percentage risk premium

Forward risk premiums can also be expressed as percentage of the spot price at delivery. Redl et al. (2009) call this measure the futures-spot-bias. Using the definitions described in the previous section, the percentage risk premium can be expressed as:

$$\Delta_T = \frac{F_{t,T} - S_{T,T}}{S_{T,T}} \quad (17)$$

Δ_T is the relative difference between the derivatives and spot price, $F_{t,T}$ is the average of a derivatives contract traded in period t for the delivery in *T*, and $S_{T,T}$ is the average underlying spot price during the delivery period. Similarly as above, this measure could be calculated not only on the averages of entire delivery period but also on daily basis.

This ratio measures risk premiums as a percentage of the spot prices in the delivery period. Statistical significance of the quantified risk premiums can be tested by the t-test statistic. The interpretation is how many percentage points above (+ %) or below (- %) a derivatives contract was traded with respect to spot prices in the delivery period. The percentage values may ease the interpretation of risk premiums, especially across different bidding areas, but they might also confuse, as large percentage values could be driven by small or zero day-ahead zonal spread at delivery ($S_{T,T}$) in the denominator. Thus we do not recommend using a relative measure of risk premiums.

4.3.1.3 Risk premium matrix

Risk premiums are likely to vary over time, due to continuously changing market conditions. To ease the interpretation of risk premiums, we proceed with a discussion on determinants and dynamics of risk premiums.

It can be proposed that the interaction between *structural market shares* (Kristiansen, 2004) with *risk aversion* has the potential to explain both the negative term-structure and positive term-structure of risk premiums. By structural market share we mean the share of demand (consumers) and supply (producers) in the hedging position. Figure 4-2 depicts the proposed relationship in a simple xy chart with four highlighted sectors, where the vertical axis represents the risk aversion dimension and horizontal axis the market share dimension. The figure explains the sign and magnitude of risk premiums in the electricity futures contracts by focusing on four sectors in the chart.

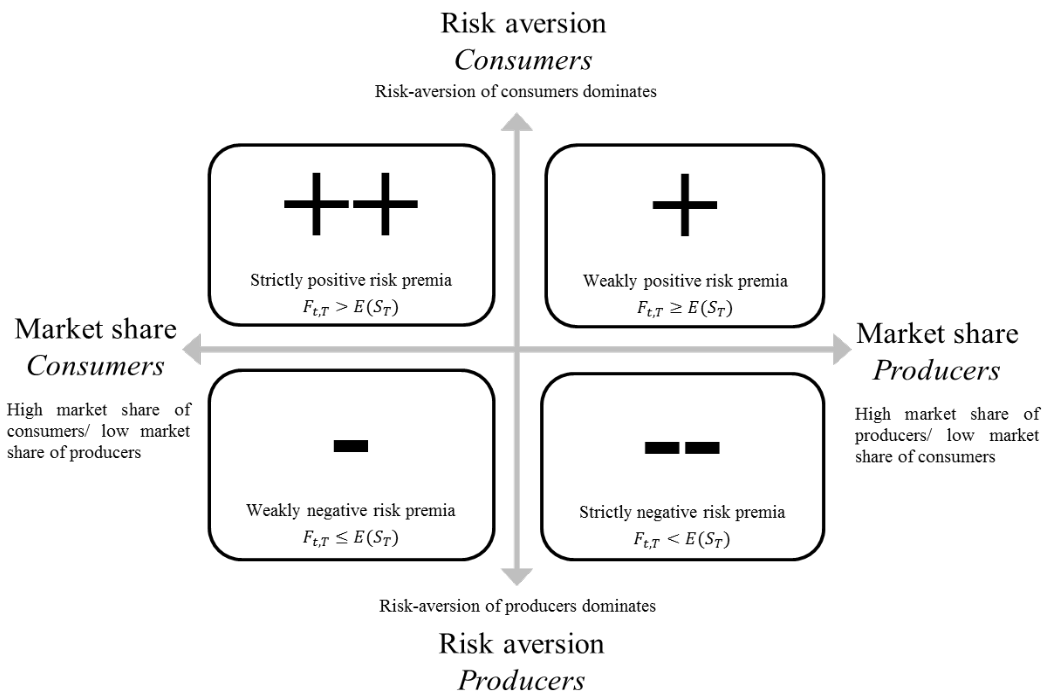

Figure 4-2 Explanation of sign and magnitude of forward risk premiums according to risk aversion and market share dimensions (Source: Spodniak, P. (2017))

The current theory generally predicts a negative term structure of risk premiums, i.e. moving from the bottom-right to the top-left corner or more generally from the bottom-half to the upper-half of the diagram during the decreasing time to maturity. This is explained by smaller number of consumers hedging longer-term positions combined with high risk aversion of producers eager to hedge their long-term profits (bottom-right sector). This is also called market power of consumers who push the futures prices below their expected delivery price (strictly negative risk premium). When coming closer to the contract delivery more consumers enter hedging positions because of increasing desire to hedge against short-term risks (top-left sector). This situation is called market power of producers who can charge a premium on the futures contract compared to the expected delivery date price (strictly positive risk premium).

Risk aversion and market shares are both influenced by many fundamental factors, such as exceptionally cold or warm weather, peak/off peak periods, high/low hydro reservoir inflows, CO_2 prices, etc. (Redl, Haas, Huber, & Böhm, 2009; Redl & Bunn, 2013). However, most of the past theoretical and empirical studies have worked with the “traditional” electricity system dominated by dispatchable generation and inelastic demand. This is hardly the case anymore. Due to changing *elasticity or flexibility* of electricity supply and demand we can expect changing dynamics (direction and magnitude) of the forward risk premium. Thus we cannot take it for granted that forward risk premiums follow the negative term structure, and hence systematically positive and negative term structures can be observed.

4.3.2 Amihud

Amihud (2002) shows that across stocks and over time, expected stock returns are an increasing function of expected illiquidity. He defines a cross-section relationship between illiquidity and stock return as:

$$ILLIQ_{iy} = 1/D_{iy} \sum_{t=1}^{Diy} |R_{iyd}|/VOLLD_{ivyd} \tag{18}$$

Where

$ILLIQ_{iy}$ is the illiquidity ratio for stock *i* in year *y*

D_{iy} is the number of days for which data are available for stock i in year y

R_{iyd} is the return on stock *i* on day *d* of year *y*

$VOLLD_{ivyd}$ is the respective daily volume in dollars

$|R_{iyd}|/VOLLD_{ivyd}$ is average ratio of the daily absolute return to the (dollar) trading volume on that day

ILLIQ is a ratio giving the absolute (percentage) price change per dollar of daily trading volume, or the daily price impact of the order flow. The positive effect of illiquidity on stock returns is then modelled by cross-sectional estimation of monthly stock returns on multiple risk and other relevant variables. The proposed relationship is that the greater the illiquidity of a security the greater the expected return, after controlling for risk and other relevant measures (stock characteristics, dividend yield, etc.).

The empirical and theoretical application of Amihud measure for electricity derivatives markets seems rather limited. In order to correctly specify a cross-sectional model for power derivatives returns, relevant measures have to be first specified. Such measures may include generation and demand structure, price volatility, hydro situation, traded volumes, etc. After relevant variables are identified, cross-section regression of power derivatives return on illiquidity may be estimated.

We do not recommend using the Amihud measure for the task of measuring illiquidity now because of the lacking empirical evidence from commodity/electricity markets.

4.3.3 Long-term and short-term market efficiency

A completely different approach to measure price formation is to test the efficient market hypothesis and study the price discovery processes of futures prices and expected spot prices (Growitsch & Nepal, 2009; Ballester, Climent, & Furió, 2016; Redl, Haas, Huber, & Böhm, 2009). Methodologically, these studies rely mainly on econometric techniques. Namely, cointegration is used for testing the efficient market hypothesis (long-run efficiency), and vector error correction models (VECM) are used for information transfer observations between the futures and spot price series (short-run efficiency).

Previous empirical studies on market efficiency in commodities markets suggest that short-term markets are not as efficient as long-term ones (Kellard, Newbold, Rayner, & Ennew, 1999; Wang & Ke, 2005; Spodniak P. , 2015). Both long-term and short term efficiencies can be tested by using daily price data for derivatives prices and the underlying spot prices for each contract maturity (daily, monthly, etc.) and bidding zone.

We do not recommend this approach for the regulators' analyses now. Despite the analytical appeal of these techniques, they are computationally intensive and their operational implementation is limited. However, the method describes a metric for market efficiency and can be useful reference to keep in mind, and is included here merely for that purpose. Further technical details in the following studies (Lai & Lai, 1991; Growitsch & Nepal, 2009; Redl, Haas, Huber, & Böhm, 2009; Spodniak P. , 2015).

There are three steps in this approach:

1. Test for stationarity
   Begin with testing whether the price series is stationary, i.e. whether its statistical properties (mean, variance, etc.) are constant over time. This is an initial step to avoid problems with statistical inferences in the next steps. Stationarity properties of daily derivatives prices and the underlying spot prices can be tested by Augmented Dickey Fuller (ADF), Phillips-Perron test (PP), and the stationarity test of Kwiatkowski–Phillips–

Schmidt–Shin (KPSS). The unit root tests, ADF and PP, hold the null hypothesis that a time series is I(1), while the stationarity test, KPSS, holds the null of I(0). If the originally non-stationary price series are found to be stationary after first-order differencing, i.e. integrated order 1 denoted by I(1)), proceed to the next step, otherwise use another metric.

2. Run cointegration test (long-run relationship)
   The hypothesis of market efficiency suggests that derivatives prices do not consistently over- or under-estimate the spot prices. Johansen's cointegration approach can be used to test whether long-run equilibrium relationship exists between the spot and derivatives prices. Johansen's procedure is based on a vector autoregression (VAR) model that allows for possible interactions in the determination of spot prices and derivatives prices. If we find that S_t (spot price at time t) and F_{t-1} (futures price *i* periods before the contract matures at time *t*) are cointegrated, we find a necessary condition for market efficiency (Lai & Lai, 1991). The cointegration test should be run on individual contract maturities (e.g. monthly, quarterly, yearly) and across bidding areas on relatively large samples. If cointegrating relationship is not found this would mean that derivatives prices provide little information about the underlying spot price movements.

3. Test the restrictions on the cointegrating parameters (short-run relationship)
   If cointegrated relationship has been found between the price series in the previous step, there also exists a corresponding error correction representation of the variables. Vector error correction (VEC) model (Engle & Granger, 1987) can be used to study the price adjustment process of short-run deviations from the long-run equilibrium. Insights gained from this exercise are detailed observations on how quickly (adjustment speed) and in which market (spot or derivatives) the correction to long-run equilibrium takes place. It may be found that one market reacts much more quickly/efficiently to new information whereas other may be weakly exogenous (Wang & Ke, 2005). Additional hypothesis of full price convergence of spot and derivatives prices in the long-run can be done by placing a restriction on the cointegrating parameter.

Reliably estimating the measures described here requires longer time series data on prices, careful model specification, and statistical software. Such analyses could also be done separately on contract prices originating from different market places, such as over-the-counter (OTC) vs. electronic trading system (ETS) to see whether different market places provide different market efficiency. Nonetheless, computational burden may outweigh the potential benefits of these techniques.

4.4 Transaction cost measures

Transaction costs have pronounced effects on the net gains to investments as well as market equilibrium returns, and thus also on hedging decisions and hedging efficiency and effectiveness. Transaction cost measures capture the costs of trading a financial asset and typically include explicit costs (such as brokerage commissions and membership fees) and bid-ask spreads. Trading costs are generally challenging to analyse empirically because they vary depending on the size of a trade, firm or time of year, for instance. Bid-ask spreads may also vary across trading platforms, such as organized exchange and OTC, where differences in, for instance, order-processing costs and information quality translate into relative differences in bid-ask spreads. In this section we discuss two transaction cost measures; the absolute bid-ask spread, and Roll's implicit measure of effective bid-ask spread.

Table 4-4 Relevant literature about transaction costs measures

Reference	Comment
(Chung, Ness Van, & Ness Van, 2002)	Comparison of execution costs (spreads) and differences in depths between Nasdaq and NYSE stocks
(Bessembinder H. , 1999)	Comparison of execution costs (spreads) between Nasdaq and NYSE stocks
(Spodniak, Collan, & Viljainen, 2015)	Comparison of bid-ask spreads in absolute and percentage values for EPAD contracts 2007-2014.

4.4.1 Quoted bid-ask spread

The quoted spread is the difference between a market maker's bid and ask quotes. The best quoted bid-ask spread is the difference between the highest bidding (buying) price and the lowest asking (selling) price. The bid-ask spread is a direct measure of liquidity with more pronounced effects on transaction costs for market participants. The bid-ask spread reflects i) order-processing costs; ii) asymmetric information costs; iii) inventory-carrying costs; and iv) oligopolistic market structure costs (Sarr & Lybek, 2002). Generally, the smaller the bid-ask spread, the more liquid and possibly efficient the market. Conversely, large spreads can cause high search and delay costs. Bid-ask spreads vary throughout time, contract maturities, areas, trading arena (OTC vs. exchange) and depend on the market participants' perception of risks.

While market makers generally commit themselves to ensure bid-ask spreads are within agreed limits, the actual market spread may vary both within each day and over time. Also, there may be a large discrepancy between their quotes and the market participants' willingness to pay or accept, especially when the market is very thin.

When assessing the bid-ask spread, it is quite important to include all trading platforms in the analysis. If the trading frequency is low, the spread in offers on exchange screens may be large, making it beneficial to ask an OTC broker for assistance in finding the 'real' bid-ask spread. If the trading frequency is high and the spread in offers on the screen is very low, there is no benefit from taking time to ask a broker for assistance. This also explains why brokers tend to have small market shares in very liquid contracts.

To calculate an average bid-ask spread (BBO_{it}) for a derivative *i* during a time period *t*, divide the sum of differences between the best ask A_{it} and the best bid B_{it} price for a derivative *i* during time *t* by the number of relevant time intervals *N* in the sample, see Equation 19.

$$BBO_{it} = \frac{\sum(A_{it} - B_{it})}{N} \tag{19}$$

The average bid-ask spread is often calculated from daily frequency data which would quote the day's best bid (the highest buying offer) and the day's best ask (the lowest selling offer) among other data, such as volume traded or number of contracts traded. Average bid-ask spread should be calculated for individual contracts, i.e. trading horizon and bidding area from exchange or OTC data. The averages can also be reported on aggregate level for individual bidding zones over individual years or months.

For trading assessments, the relevant time interval is often a day or an hour but can be even shorter. For hedging assessments, the relevant time interval is often longer than a day such as a week or a month. Hedging strategies describe often a monthly development of hedging positions. However, for retailers there is usually a requirement for back-to-back hedging of the system price if a new substantial fixed price contract is received, while the requirement for hedging the zonal risk is less urgent. This is due to the fact that the volatility, measured in EUR/MWh, is smaller for EPADs than for SYS contracts.

In accordance with the actual hedging practices in the Nordic market, there are a few issues to consider when assessing the bid-ask spread in the Nordic market.

1. Data availability
   EPADs are mostly traded OTC. The market share for Nasdaq is around 20 %. Trading behaviour also suggests that there are better sources for bid-ask spreads than exchange data. We suggest the regulators approach the large OTC brokers and explore the opportunities to obtain bid-ask statistics from one or more of them. If such data are made available to the regulators, there is no need to estimate the bid-ask spread by means of e.g. Roll's measure.

2. Time resolution
   The EPAD market is a 'slower' market than the SYS market. Market participants seem to take into account that getting the correct long or short position in an EPAD is not a

matter of seconds or minutes. The generally have time for an OTC broker to search for a better deal than the one immediately available at Nasdaq. This generally implies that the best bids and asks are not necessarily available instantaneously. Thus it is not necessarily the daily bid-ask spread that is the relevant measure of the transaction cost. We suggest a weekly approach, where the best bid-ask spread per week is interpreted as the relevant cost.

3. Time horizon
   The bid-ask spread changes over time, and thus an average over time must be applied. As with the correlation analyses, there is a balance between having sufficient observations to cover the realistic possible outcomes and not including past observations that bears no relevance for the periods ahead. It seems reasonable to apply a one-year time horizon as this will include 52 weekly observations.

4. No thresholds
   There is generally no accepted level of bid-ask spreads that is considered 'good' or efficient. In competitive markets, it seems fair to assume that whatever the bid-ask spread actually is, it is a measure of actual costs and thus efficient, whereas in less competitive markets, one might suspect that whatever the level of the bid-ask spread, it is not necessarily efficient. Whether consulting with market participants can reduce this informational problem remains to be seen.

4.4.2 **Roll's measure**

Roll's measure is a method applied in stock market research to *infer* effective bid-ask spread directly from a time series of market prices. The effective spread differs from the quoted spread outlined in section 4.4.1. The effective spread is the difference between the price at which the *market maker/dealer* buys (sells) a security and the price at which he or she subsequently sells (buys) it (Smith & Whaley, 1994). Since quoted bid-ask spreads for power derivatives can be quite effectively collected from exchanges and some OTC brokers, we assume the costs in estimating effective bid-ask spreads exceeds the possible benefits.

Nonetheless, we briefly outline the technical details and background of this measure as a reference point for future analysis. Roll (1984) estimates the effective bid-ask spreads from the serial covariance of the changes in price. The measure is specified in Equation 20:

$$\mathrm{S} = 2\sqrt{-\mathrm{Cov}(\Delta \mathrm{P}_t,\ \Delta \mathrm{P}_{t-1})} \tag{20}$$

The first-order serial covariance in price changes is inversely related to the effective bid-ask spread. This implies that the effective spread can be inferred from the sequence of price changes simply by computing and transforming the serial covariance. Two assumptions must hold: 1) the asset is traded in an informationally efficient market, and 2) the probability distribution of observed price changes is stationary (at least for short intervals). Both assumptions can be tested independently or they are the part of the long-term and short-term market efficiency measures discussed in section 4.3.3 above.

4.5 Summary of suggested efficiency measures

The suggested set of analyses comprises three broad and non-exclusive classes of measures that are operational and computationally less restrictive. The analyses rely on direct market data without the need for estimating, modelling or forecasting complex systems, which in itself would bear uncertainty.

The recommended liquidity measures are all of the descriptive measures, ex-post risk premium from the price measures, and bid-ask spreads from the transaction cost measures. The descriptive measures, namely traded volumes and open interest partially but reliably proxy the liquidity of a contract. By using these measures, regulators gain insight into the breadth of the market (traded volumes) as well whether the primary purpose of the contract is trading or hedging (open interest).

We recommend calculating the ex-post risk premium as a measure of contract efficiency because greater insight on the market dynamics between buyers and sellers of derivatives can be gained. By observing magnitudes, directions, and significance of ex-post risk premiums across trading horizons and bidding areas, possible systematic biases in the pricing of derivatives can be identified.

Finally, bid-ask spreads obtained either from exchanges or OTC brokers will answer the questions on the cost of hedging as well as the underlying liquidity. The magnitudes of the quoted bid-ask spreads will reveal the transaction costs market participants face when participating in the power derivatives markets.

Unfortunately, there are no identified thresholds for the various measures. There is no quick fix for this, and thus a separate objective for the analyses must be to gain experience with the performance of the financial market.

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