NTNU
Norwegian University of
Science and Technology

Faculty of Social Sciences
and Technology Management
Department of Industrial Economics
and Technology Management

MASTER THESIS

for

STUD.TECHN. EIRIK TANDBERG OLSEN AND GAUTE EGELAND SANDA

Field of study	**Financial Engineering** Investering, finans og økonomistyring
Start date	15th January 2010
Title	**Hedging policies in electricity companies – A multi-company study** Empirisk analyse av hedgingstrategier i kraftselskaper
Purpose	Scandinavia has one of the most mature electricity markets in the world. This allows electricity companies to hedge by trading of financial dericatives at Nord Pool. This thesis will perform empirical analyses on the hedging policies and practices of electricity companies in the Scandinavian market.

Main contents:

1. Gather data from relevant companies and perform analyses on
    a. how their hedging programs are structured.
    b. whether the hedging policies has added value.
2. Identify industry practices for hedging with financial instruments.

Monica Rolfsen
Deputy Head of Department

Stein-Erik Fleten
Supervisor

MASTEROPPGAVE

___________semester 200_

Student____
Institutt for industriell økonomi og teknologiledelse

ERKLÆRING

Jeg erklærer herved på ære og samvittighet at jeg har utført ovennevnte hovedoppgave selv og uten noen som helst ulovlig hjelp

_____________________________________ _________________________
Sted dato

____
Signatur

Besvarelsen med tegninger m.v. blir i henhold til Forskrifter om studier ved § 20, NTNU's eiendom. Arbeidene - eller resultater fra disse - kan derfor ikke utnyttes til andre formål uten etter avtale med de interesserte parter.

MASTEROPPGAVE

___________semester 200_

Student____

Institutt for industriell økonomi og teknologiledelse

ERKLÆRING

Jeg erklærer herved på ære og samvittighet at jeg har utført ovennevnte hovedoppgave selv og uten noen som helst ulovlig hjelp

_____________________________________ _________________________

Sted dato

____

Signatur

Preface

This Master Thesis was performed during the spring of 2010 at the Norwegian University of Science and Technology (NTNU), Department of Industrial Economics and Technology Management.

This thesis is written in LaTeXwith TeXnicCenter as user interface. The data management and analyses have been performed using Microsoft Excel 2007.

We want to thank Professor Stein-Erik Fleten for valuable hints and constructive feedback. We also want to thank the liaisons in the participating companies for placing themselves at our disposal. The data they have provided are of a sensitive character and of academic interest. Further, we also thank the Power Data Services at Nord Pool for historical market data and the Norwegian Water Resources and Energy Directorate (NVE) for historical production data.

Trondheim, 3^{rd} of June 2010

Eirik Tandberg Olsen	Gaute Egeland Sanda

Hedging policies in electricity companies - A multi-company study*

Gaute Egeland Sanda† Eirik Tandberg Olsen

Department of Industrial Economics and Technology Management,
Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

June 2010

Abstract

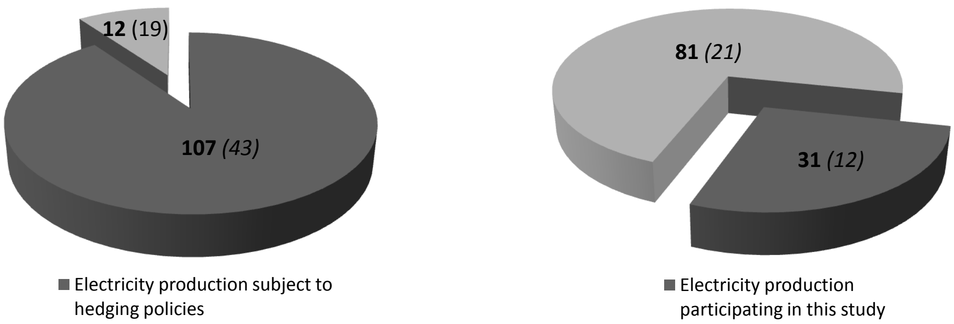
We analyze the risk management trends in commodity markets based on production and transaction data, and written policies of 12 Norwegian commodity producing companies. Our scope is hedging of physical electricity production by power derivatives at the largest electricity market in the world: the Nordic Power Exchange. The companies either have a Cashflow at Risk (C-FaR) approach, a hedge ratio approach or no explicit approach in their hedging policy. We find that the derivative cashflows constitute substantial profits to the companies. Hedging contributes to reducing the C-FaR for ten of the companies - corresponding to reduced downside risk - while only two companies achieve significant reduction in cashflow variance. These findings are surprising considering that hedging is expected to give zero expected profit and smooth the earnings function. Analyses indicate that the electricity companies alter their hedging behavior seasonally without having support for such behavior in their written policies. Overall our findings reveal that selective hedging practices (incorporation of market view in hedging decisions) are extensive among the companies - both sanctioned in their written policies and indicated by substantial profits from hedging along with virtually no volatility reduction.

1 Introduction

Companies bear operational risks which are non-diversifiable for stakeholders. These risks are associated with 'nonlinear costs' - related to among others a convex tax function, default risk and stakeholder risk aversion - and risk management can add value to the company by reducing these nonlinear costs (Smith and Stulz, 1985). Hedging is a common risk management method, both for individuals - e.g. fix the interest rate of a mortgage - and firms - e.g. fix a currency's exchange rate. Hedging protects the company from uncertainties in the underlying markets and allows them to manage the firm's value independently of market variations. Froot et al. (1993, p. 1629) state that "hedging adds value to the extent that it helps ensure that a corporation has sufficient internal funds available to take advantage of attractive investment opportunities".

*This paper is prepared as the result of a Master Thesis at the Norwegian University of Science and Technology (NTNU), Department of Industrial Economics and Technology Management. We want to thank Professor Stein-Erik Fleten for valuable hints and constructive feedback. We also want to thank the liaisons in the participating companies for placing themselves at our disposal. The data they have provided are of a sensitive character and of academic interest. Further, we also thank the Power Data Services at Nord Pool for historical market data and the Norwegian Water Resources and Energy Directorate (NVE) for historical production data.

†Corresponding authour. E-mail: gautesanda@gmail.com.



(a) (b)

Figure 1: Overview, electricity production and hedging in Norway. Values are listed as **average TWh/a** *(number of companies)*. Figure (a) presents the annual production subject to hedging policies (107 TWh/a) of the total annual production, accounting for the companies producing more than 0.1 TWh/a. Figure (b) presents the annual production of the companies participating in this study (31 TWh/a) of the total annual production of all contacted companies.

Liberalization of electricity markets has transferred more risk onto the producers, e.g. from bad investments (before this risk was born by the customers due to a cost-based pricing model), and introduced market places for exchange of electricity. The Nordic Power Exchange, Nord Pool, is the world's oldest multinational electricity exchange[1]. Its financial market is the largest and most liquid in terms of power derivatives, with €74.8 billion turnover and 57% market share compared to the bilateral OTC market. Lucia and Schwartz (2002) gives a thorough introduction to the attributes of Nord Pool. They emphasize that electricity prices are highly volatile, ranging up to an annualized volatility of 189% at Nord Pool. The non-storability of electricity makes cash-and-carry-based relationships invalid and contribute to the high price volatility[2]. Scandinavian electricity companies can hedge this price uncertainty through trading of power derivatives at Nord Pool (a tutorial on features of these derivatives is presented in Appendix A).

We find a widespread risk management practice among Norwegian electricity companies. The average annual electricity production in Norway is 123 Terawatt-hours (TWh[3]), of which 99% is hydroelectricity[4]. Figure 1(a) shows that 90% of the annual production is subject to hedging policies[5] considering companies with production of at least 0.1 TWh/a (accounting for 97% of total annual production); in other words companies that perform hedging account for close to 90% of the total production volume.

The empirical literature includes numerous studies of hedging practices of non-financial companies. These studies can be divided into three distinct categories: (a) case studies of one particular company, (b) case studies of several companies in the same industry (our approach) and (c) studies of many (100+) companies. While the first two categories are based on data extracted from the firms, the last category of studies relies on data from companies' financial statements. The latter category has the advantage of a standardized data collection from a large pool of companies, but Judge (2007) highlight several drawbacks in their exactness. First, these studies examine derivative usage and not hedging

[1]The Norwegian electricity market was liberalized in 1991 while Nord Pool was founded in 1996. Subsidiaries of Nord Pool are owned by NASDAQ OMX Commodities after an acquisition in December 2007.

[2]This aspect and the risk premium in power derivative prices are described in Wallace and Fleten (2002), Longstaff and Wang (2004), Kolos and Ronn (2008) and Botterud et al. (2009)

[3]1 Terawatt-hour (TWh) = 10^9 kilowatt-hours (kWh).

[4]Statistics Norway (SSB), 2003-2007.

[5]A company is assumed a hedger when this is described in annual reports, on web-sites or through interviews.

specifically, ignoring other hedging methods than derivative trading. Second, some fails to identify that the companies might aim to increase their risk exposure through derivative trading rather than to hedge. Finally, some studies only use keyword search to identify hedgers in their sample.

Studies of many companies are performed with data either from financial statements (Allayannis and Weston, 2001; Graham and Rogers, 2002), surveys (Nance et al., 1993; Bodnar et al., 1998) or a combination (Haushalter, 2000). Reviews of other (c)-category studies is found in Triki (2005) and Judge (2007). The literature of one-company case studies (proxies for our approach) includes Petersen and Thiagarajan (2000)[6], Brown (2001)[7] and Lalancette et al. (2004)[8].

Despite the comprehensive literature on risk management practices we find no empirical studies of hedging in non-financial companies based on detailed data from several companies and no study of hedging practices specifically for the power industry. The purpose of this paper is to study hedging policies in electricity companies. We follow similar case studies on non-financial companies (Petersen and Thiagarajan, 2000; Brown, 2001; Adam and Fernando, 2006; Brown et al., 2006). Our approach is more of a positive than a normative character and we attempt to describe and analyze how hedging of commodity production is actually performed - the policies, financial transactions and the results of these. More specifically we investigate whether hedging policies can add value.

The data set is acquired through direct inquiries to 33 Scandinavian hydroelectricity companies (the 29 largest by annual electricity production in addition to four others). 12 Norwegian companies agreed to participate (see Figure 1(b)), accounting for 25% of the Norwegian annual production. We have collected data on production and financial transactions from these 12 companies for a three year period (2007-2009). The data include 8171 unique derivative transactions.

These constitute unique multi-company data not found in current risk management literature. We contribute to the literature mainly by an empirical analysis of the individual hedging transactions and policies in 12 commodity producers. Analyses of hedging transactions and statements in the written policies reveals that a selective hedging practice (incorporation of market view in hedging decisions) is widespread among the companies. The majority of the companies have substantial profit contributions from their hedging transactions. The companies are more successful in decreasing the Cashflow at Risk (C-FaR) compared to reducing the cashflow variance. This makes us believe that C-FaR is a more effective quantity when evaluating the added value from hedging. We find that there are seasonal variations in the fraction of hedged production depending on the delivery season. However there are no clear trend for which season is more hedged. These findings contradict the neoclassical economy's interpretation of hedging as a pure risk-reducing method with no expected profit.

The paper is organized as follows: The remainder of this section summarizes the literature on hedging and corporate risk management. Section 2 describes the data set. Section 3

[6]Petersen and Thiagarajan (2000) compare the risk management strategies of two gold miners. The first firm hedges with financial derivatives while the other performs operational hedging. Their approach is to study the underlying gold price risk exposure of the revenues, operational costs and investment opportunities. The findings reveal that the derivative hedger does not reduce its gold price risk significantly compared to the operational hedger.

[7]Brown (2001) studies the currency risk management program of a U.S.-based manufacturer, HDG Inc. (pseudonym). His study treats three key questions: How is the program structured, why does HDG hedge and how do they hedge? The statistical tests indicate that the underlying volatility and exposure volatility are important indicators of a successful hedging practice. However, the study finds no clear evidence that the hedging program has any (positive) impact on the firm value.

[8]Lalancette et al. (2004) study the short-term financial risk management of the Canadian electrical utility Hydro-Quebec which is exposed to risks from interest rates, currency rates and aluminum prices. They apply an optimization model to the firm data. The study reveals that Hydro-Quebec incorporates own market view in their hedging decisions.

presents the characteristics and trends of the hedging practice of the companies. Section 4 presents analyses on how hedging of commodity prices can add value to the companies and Section 5 concludes.

1.1 Literature review

Neoclassical economics postulate that hedging cannot add value because of perfect markets and because investors can hedge themselves (Modigliani and Miller, 1958). Nevertheless, literature provides both theoretical arguments and empirical evidence that hedging, to some extent, can be value-adding.

Smith and Stulz (1985) propose three sources of non-linear costs which give companies incentives to hedge: (1) tax purposes - a convex tax function will give incentives for firms to reduce the volatility of their pre-tax earnings, (2) bankruptcy costs - through less volatile income streams the probability of default is reduced and the costs of financial distress are lowered, and (3) stakeholders' risk aversion - as the risks are reduced the firm can lower the risk premium to management, employees, suppliers, customers and owners. Stulz (1996) names these the 'real costs' of being exposed to financial markets. However, argument (1) is disputed. Nance et al. (1993) study a sample of 104 Fortune 500 firms performing hedging and find that the hedge ratio is proportional with the convexity of the tax function. On the contrary both Fok et al. (1997) and Graham and Rogers (2002) find no support for this argument in their empirical analyses of respectively 396 and 855 U.S. corporations. Instead the tax benefits from hedging originate from the increased interest deductions because of increased debt capacity (Graham and Rogers, 2002). Fok et al. (1997) confirm argument (2) and (3).

Hedging can also add value through firms' capital structure. Hedging firms benefit from a more flexible capital structure (Stulz, 1996), increased debt capacity (Stulz, 1996; Leland, 1998), a lower cost of capital (Froot et al., 1993) or reduction in equity holders' incentives to under-invest (Bessembinder, 1991). All arguments descend from an assumption that hedging increases predictability and reduces probability of default.

Brown (2001) acknowledges these motives as valid for corporate risk management, but suggests that there are other motives far more practical for non-financial firms: "information asymmetries between investors and management", "competitive strategies involving pricing decisions" and "efficiency gains through improved internal decision making and evaluation" (Brown, 2001, p. 402). Brown finds that senior management in his case study believes that the market penalizes disappointing earnings more than it rewards better-than-expected earnings, supporting his first claim.

A common approach to measure added value is through increased firm value. Based on a sample of 720 large non-financial firms Allayannis and Weston (2001) find that currency hedging firms have 4.9% higher value than non-hedging firms. The tax benefits from hedging due to increased interest deductions are estimated to 1.1% of the firm value in Graham and Rogers (2002). Lin and Chang (2009) discover that U.S.-residing airlines which hedge their jet fuel costs increase firm value compared to non-hedgers. Their results indicate that fuel price hedging is more valuable during periods of high price volatility.

On the contrary Jin and Jorion (2006) find no evidence that hedging firms are more valuable than non-hedging firms among a sample of 119 U.S. oil and gas producers. Their explanation is that the commodity risk of oil and gas producers is so simple to identify that investors can hedge it on their own. Smithson and Simkins (2005) review the empirical literature of risk management. They find extensive evidence of increased firm value from hedging, but refuse to generalize this result. They argue that the value-adding ability of hedging is highly dependent on the type of risk exposure the firm faces, relating to market efficiency, visibility and access.

91% of 350 U.S. non-financial firms cite that the most important objective of their hedging policy is to "manage volatility in cashflow (49%) or earnings (42%)" (Bodnar et al., 1996, p. 115). There is little or none empirical evidence in literature on whether managing this volatility adds value. Brown (2001), based on field-study data, finds evidence of income smoothing and reduced cashflow volatility for his case study, but does not test for significant volatility reductions. Judge (2007) argues that such volatility analyses must be based on detailed transaction data, like Brown (2001), rather than data gathered from financial reports (which do not report detailed gains or losses from derivative transactions). An example of this approach is found in Hentschel and Kothari (2001) who investigate 425 large U.S. firms and arrive at the conclusion that derivate trading does not result in significant reduction of stock price volatility[9].

Ederington (1979) claims that companies must balance risk avoidance and maximization of benefits from information advantage in their hedging policies. However, belief in own advantages might result in hedging practices that entail speculative motives. Companies are found to apply an approach called 'selective hedging' as they allow own market view to influence their hedging practice (Stulz, 1996). This selective hedging concept is replenished by Adam and Fernando (2006) who separate hedging into two components: *predictive hedging* attributable to the fundamentals of the firm and its operations and *selective hedging* attributable to the firms' views on price and market movements, i.e. speculation within risk management boundaries. Studying hedging in the gold mining sector, Adam and Fernando (2006) find clear evidence of positive return from predictive hedging while selective hedging has an expected value near zero and large variance. This corresponds with the assumption in Stulz (1996) that hedging of 'real costs' is value-adding while speculative trading reduces value.

An unformulated policy can contribute to extensive selective hedging. Brown (2001, p. 413) states that "risk management can be a smoke screen for speculative trading". Selective hedging is extensively studied by Brown et al. (2006). They propose three explanations for the widespread extent of this practice: First, risk management staff use selective hedging to identify their value creation potential. Second, historic success from incorporation of own market view in hedging decisions can encourage managers to extend the practice. And third, the lack of a supreme theory on optimal hedge ratios allows any hedge ratio to be justified. A Wharton-CIBC study (Bodnar et al., 1998) of U.S. non-financial firms confirms a tendency among management to 'beat the market'. About 60% of the firms indicate that they alter either the timing and/or the size of the hedge based on market views, whereas 32% actively take derivative positions based on their market views.

Selective hedging can in the worst-case lead companies towards bankruptcy, demonstrated in Stulz (1996) by the examples of Metallgesellschaft and Daimler-Benz. He asserts that in many cases management - ignoring the efficient market doctrine - will base its trading strategies on a belief that they are able to predict market movements. He proposes that transformation of the risk management function into a trading operation is a value-destroying strategy since the firm undertakes large and unfamiliar risks. Management must first investigate and understand the source of their information advantage before trying to act on it. In retrospect of their $100 million derivatives loss in 1994, a representative of Procter and Gamble cited that "we don't do a lot of hedging because, if we were smart enough to hedge, there is actually more money to be made in that than there is in selling soap"[10].

Adam and Fernando (2006) attribute the value from predictive hedging to the risk premium. This quantity is thoroughly studied in commodity markets. Fama and French (1987) find a non-zero risk premium in five of 21 commodity markets. The risk premium in

[9]Our study applies detailed data from spot revenues and hedging transactions like in Brown (2001) and are therefore able to perform volatility analyses, avoiding the pitfall presented in Judge (2007).

[10]Scott Miller, Director of National Governmental relations in Procter and Gamble, quoted from the print version of Wall Street Journal April 14^{th} 2001.

the commodity markets is defined in previous literature (Longstaff and Wang, 2004; Adam and Fernando, 2006) as:

$$\mathrm{R}(t,T) = \mathrm{F}_t(T) - E_t[\mathrm{S}(T)] \quad (1)$$

where $\mathrm{R}(t,T)$ is the risk premium[11], $\mathrm{F}_t(T)$ is the forward price at time t with delivery at time T and $E_t[\mathrm{S}(T)]$ is the expected spot price at maturity T.

Adam and Fernando (2006) and Botterud et al. (2009) argue that a constant positive (negative) risk premium will result in a biased hedging behavior of producing firms as they can capture this risk premium by increasing (decreasing) their hedge ratio. The risk premium behaves differently for electricity than other commodities mainly because of its non-storable feature which makes cash-and-carry-based relationships invalid. These characteristics are further discussed by Botterud et al. (2009). Longstaff and Wang (2004) find that there are significant risk premia in the short-term forward prices in the Pennsylvania, New Jersey and Maryland electricity market. This result is confirmed by Kolos and Ronn (2008) who also prove this for long-term forward prices in the same market. Based on a sample of 11 years of Nord Pool futures prices Botterud et al. (2009) find significant positive risk premia, ranging from 1.3% - 4.4% with increasing risk premia for longer holder periods (up to 6 weeks).

To determine the appropriate size of hedging transactions risk managers must take account for future market exposures, which are the simulated future production levels. Rausser (1980) claims that production planning decisions and financial market positions are independent for risk averse firms. However, if basis risk is introduced this is no longer valid. The basis risk is related to the residual risk originating from imperfect correlation between the underlying instrument and the derivative.

Wallace and Fleten (2002) argue that the benefits of decoupling production planning and risk management outweigh the drawbacks from ignoring the basis risk. They also present another argument for separation: the firm's financial transactions in an efficient market will not affect the value of their power portfolio while changes in the production plan will. Thus the producer should first schedule its production levels to maximize the value of the portfolio. Then it should implement risk management decisions and perform transactions such that the risk of the portfolio is adjusted to desired levels. Nasakkala and Keppo (2005) emphasize that commodity producers with high load volatility should postpone the hedging decision and await more information from the production planning process.

2 Data

The data collected and analyzed in this study are from the Nordic Power Exchange, Nord Pool, and the participating companies. The Nord Pool data consist of hourly spot price data and daily closing prices for related power derivatives. Company data include data from 12 Norwegian electricity companies producing at least 0.1 TWh/a each with a total average production of 30.8 TWh/a. The period analyzed is January 2007 throughout December 2009[12]. The data collected include production and revenue data for this period and data on transactions expiring during this period (a total of 8171 transactions). The data set also consists of written hedging policies from ten of the companies.

21 of 33 contacted companies declined the invitation to the study. Their stated reasons for not participating were either lack of available resources or confidentiality issues. However, a company that has incurred large losses in derivative trading might want to keep this information away from outsiders to avoid negative attention. This could be a reason

[11]The sign of $\mathrm{R}(t,T)$ is opposite of the standard notation in finance. All references to risk premium in other papers are adjusted to the sign in expression (1).

[12]Due to data constraints the period analyzed for two companies is January 2007 throughout June 2009.

Table 1: Summary statistics of the data collected among the participating companies. The data span over 36 (30) months, from January 2007 to December 2009 (June 2009). The transaction data are quantified by the number of transactions (totally 8171 transactions). The policies are either a full document - including goals, motivation, procedures, restrictions and chain of command - hedge ratio boundaries or no explicitly written policy. The exposure forecast method relates to how the company predicts future exposures subject to hedging. If this is by a production plan the average planning iterations for each delivery period (month) is given in parentheses.

Company	Months of data	Number of transactions	Degree of policy details	Exposure forecasting method
Company 1	30	46	None written	Production plan (119)
Company 2	36	67	Hedge ratios boundaries	Historical average production
Company 3	36	1 328	Full document	Production plan (21)
Company 4	36	171	Full document	Historical average production
Company 5	36	1 074	Hedge ratios boundaries	Production plan (118)
Company 6	36	1 108	Full document	Production plan (103)
Company 7	36	1 051	Full document	Historical minimum production
Company 8	36	368	Hedge ratios boundaries	Historical average production
Company 9	36	1 163	Full document	Historical average production
Company 10	36	1 555	Full document	Historical average production
Company 11	30	58	None written	Production plan (119)
Company 12	36	182	Full document	Historical average production

for non-participating companies to decline the invitation and would lead to a bias in the sample as only companies that are successful in hedging would participate. However, after communicating with all the companies we feel confident that this does not apply for a majority of the non-participating companies.

Companies that engage in both hedging and speculative ('naked') trading have clearly labeled all transactions with the appropriate portfolio, enabling us to separate transactions for hedging purposes from speculative trades. Each transaction contains information on type of power derivative, transaction date, delivery period, price area, contract volume, contract price[13] and whether the volume is hedged in the market (Nord Pool) or through a bilateral agreement. Production data describe the production volume for each production period as well as the revenue from this[14]. Data on planned production are iterations of simulated production containing date of iteration with belonging planned production periods and planned production volumes. The companies not using production planning as exposure forecast used either historical average production or historical minimum production instead, as indicated in Table 1. The hedging policies are either a full document - including goals, motivation, procedures, restrictions and chain of command - hedge ratio boundaries or no explicitly written policy.

The analyses are performed on a monthly basis, for the 36 months starting in January 2007 and ending in December 2009. This is due to the architecture of Nord Pool derivatives (power derivatives represents delivery over a time period and can therefore be split and aggregated into month-long derivatives) and the resolution of the data from the companies. Some companies apply a rougher resolution - quarter, year or even several years - in their hedging policies, but a monthly perspective encapsulates all resolutions.

All data from the companies are treated confidentially. For this reason the companies are referred to by company numbers. All absolute values are normalized and presented such that the specific companies cannot be identified.

2.1 Abnormal values for Company 11

Some attention must be given to the data of Company 11. The analyses will show extraordinary values compared to other companies. This is due to three periods where a substantial part of the production capacity unexpectedly was shut down due to technical problems in their production plants. The company is committed to deliver license power, about 10% of the average production levels, to neighboring municipalities and counties (this is further described in Section 3.3). During these periods the license power commitments exceeded production levels, requiring the company to buy electricity to fulfill their obligations. This results in negative exposure which gives abnormal results, but the data set is kept this way to ensure that all analyses are consistent and present actual situations.

3 Description of hedging practices

3.1 Policies

All companies consider a hedging portfolio of long positions from expected physical production and short positions through derivatives. This portfolio is subject to hedging practices, for most companies described in explicitly written hedging policies. Some companies treat policies and restrictions for both hedging and speculative trading practices in the same document - though separated, but only hedging policies are within the scope of this paper.

[13]Transactions on Nord Pool are denominated in € while the analyses are in Norwegian kroner (NOK). For currency-hedging companies the hedged currency rate is used for currency conversions while the spot currency rate is used otherwise.

[14]Revenue data are either provided by the companies or calculated from production data using the appropriate area price and assuming zero variable cost (fair approximation for hydroelectricity production).

Table 2: Policy group characteristics. The groups are formed through a binary classification tree: Explicit written policy (YES/NO), hedge ratio approach (YES/NO), hedge ratio target is a range (YES/NO).

Group	Group characteristics	Number of companies
1	No written hedging policy	2
2	Does not use a hedge ratio approach, Cashflow at Risk requirement	2
3	Uses a hedge ratio approach, time-to-maturity dependent hedge ratio requirement†	1
4	Uses a hedge ratio approach, time-to-maturity dependent hedge ratio range‡	7

† a specific target without mandate to deviate.
‡ a range with lower and upper boundaries.

Based on characteristics of their policies the participating companies are divided into four groups (see Table 2).

Group 3 and 4 differs by the freedom within their hedging policy. Group 3's hedge ratio requirement is set by a combination of the price level of three-years-to-maturity swaps and time to maturity, and without mandate to apply own market view in hedging transactions. On the contrary Group 4 companies allow market view to influence hedging decisions, based on belief in own market competence. This is executed through a hedge ratio range between upper and lower boundaries (illustrated in Figure 4 in the Appendix) which risk managers are allowed to decide their preferred hedge ratio within based on own market view. The companies consider themselves capable to withstand higher volatility from fluctuating hedge ratios ("the corporation is robust enough to [...] exploit market opportunities down to zero hedging" states Company 9). This is similar to arguments in Stulz (1996): a company with high credit rating (AAA) can afford to incur large derivative losses without risking default. Hence they are more likely to engage in selective hedging given they have an informational advantage.

Seven companies state explicit goals of their hedging activity in their policies. The more general goals relates to reduction of risk associated with the physical production: Company 6 states that "[the goal is to] secure price levels for the physical production" and Company 4 wants to "reduce the risk of the physical production". Company 7 and Company 10 have an income smoothing approach, as they aim to respectively "[control the risks associated with] periods of lower income and large fluctuations in the result" and "[to] reduce the fluctuations in profit and cashflow on the long term". Stulz (1996) asserts that the fundamental goal of hedging should be to eradicate the extreme lower outcomes of a firm's earnings function while the upside is preserved. Company 3 (and Company 12) employs this argument in their policy when they state that "the goal [of the hedging practice] is to secure an acceptable income and hedge as little as possible to retain as much of the upside potential as possible". Four companies explicitly states that they aim to maximize the value of their hedging portfolio: "hedging [...] shall contribute to maximize the company's revenues within the risk boundaries" (Company 4), "the goal of the hedging activity is to secure a profit or margin" (Company 6), "[we shall] maximize the value of the production portfolio - through active trading management based on market view" (Company 9) and "[hedging shall contribute to] maximize the profit in the long term" (Company 12). The group 1 companies have - through interviews - communicated that their unwritten hedging policies are founded on "ambitions to provide stable cashflows" and "[desire to build a] slightly long portfolio consisting of physical production and financial transactions". They also express that hedging decisions have been dictated from the top management of their companies.

Bodnar et al. (1998) reveals that 32% of non-financial firms in their sample actively take positions based on market view. This practice is also found in our study. Company 6 have "a portfolio for extraordinary hedging transactions based on expectations for future electricity prices". Company 9 establish hedging boundaries such that "it is possible to exploit [their] market competence". This is based on analyses of the available risk capital. Company 1 and Company 11 communicate that "own market and exposure views" and "the gut feeling of the superior officers" are important in their hedging decisions. In contrast Company 2 emphasize that their hedging department "does not have authorization to engage in speculative trading" and Company 10 states that "[speculative] trading is beyond the authority of this [hedging policy]". The companies express that they now seek more risk in the financial market compared to previous periods[15].

Bilateral contracts carry increased counterparty risk, but since they are OTC derivatives they do not require a buffer margin which is mandatory at Nord Pool. Four of the companies studied evaluate the possibility of bilateral contracts in their policies, and two of them actively use bilateral contracts for hedging purposes. In addition three companies use bilateral contracts without treating it in their written policy (Table 3).

Revisions of the policies range from yearly to none during the period studied. Six of the companies had the same policy through the whole period, while two revised once, one company revised twice and one company made yearly revisions. The revisions were of minor scale and did not alter fundamentals of the hedging policies of the companies.

Company 5 is the only company employing a benchmark indicator for hedging performance. This is performed through a theoretical hedge ratio along the time series dimension. The benchmark is modeled by factors like spot price simulations, time to maturity and simulations of future physical production, and is optimized to minimize the company's risk position.

3.2 Transactions

Power derivatives at Nord Pool include futures, forwards, European-style options and Contracts for Difference (CfDs)[16], and they are denominated in € per Megawatt-hour (MWh[17]) - 1 MWh represent the electricity *volume* produced from a source with *power size* 1 Megawatt (MW) operating for 1 hour. The exchange of spot electricity production through Nord Pool serves as the underlying with average spot price over the delivery period as underlying price (the underlying price for month swaps are illustrated in Figure 3 in Appendix A). The bilateral OTC market offers equivalent instruments in addition to swing contracts[18]. The futures and forwards contracts at Nord Pool are not in accordance with standard financial notation. Forward contracts are offered with yearly, quarterly and monthly delivery while futures contracts are with weekly and daily delivery, representing delivery over a time period and not for an instant in time like the case would be for a storable commodity. Thus Nord Pool futures and forwards are equivalent to financial swaps (Benth and Koekebakker, 2008) and for the remainder of this paper the term swap will be used instead of Nord Pool forwards and futures. All power derivatives have a holding period - the time from the transaction to maturity - and a delivery period - swaps are differentiated by delivery period: year, quarter, month, week and day swaps.

The year swaps dominate the traded volume (Table 3). Six out of 12 companies trade more than 50% in year swaps while only two have less than 40% of their volume in year

[15] Revealed during conversations with the companies.

[16] The underlying price for power derivatives is the *system* price while the physical production is priced in *area* prices depending on which price area the production resides in. The price difference between system price and area prices can be hedged with CfDs.

[17] 1 Megawatt-hour (MWh) = 10^3 kilowatt-hours (kWh).

[18] The buyer of a swing contract can choose when to purchase the electricity within a set of restrictions, enabling a flexibility option. Swing contracts are further described by Keppo (2004).

Table 3: Descriptive statics of hedging transactions, based on 8171 unique transactions. The bilateral contracts are listed as % of the total traded volume [MWh] for each company (the residual volume is traded at Nord Pool). Swaps (differentiated by length of delivery period), CfDs (Contracts for Difference) and options are listed as % of the total traded volume, adding up to 100%. Company 5, Company 9 and Company 10 do not have any trade neither with bilateral partners nor in other instruments. Ex. = volume exercised.

		Counterparty	Allocation of derivatives as % of total derivative volume									
		Bilateral	Swaps (*length of delivery*) *						Call options		Put options	
Group	Company	contracts	*Year*	*Quarter*	*Month*	*Week*	Total**	CfDs	Not ex.	Ex.	Not ex.	Ex.
1	Company 1	26%	*58%*	*36%*	*5%*	*1%*	100%					
	Company 11	29%	*50%*	*38%*	*6%*	*1%*	94%	6%				
2	Company 3†	3%	*40%*	*7%*	*1%*	*1%*	49%		16%	4%	17%	12%
	Company 12		*70%*	*8%*	*1%*		79%	12%	4%		4%	
3	Company 4	36%	*34%*	*23%*	*4%*		61%	39%				
4	Company 2	33%	*76%*	*24%*			100%					
	Company 5		*59%*	*32%*	*9%*		100%					
	Company 6		*24%*	*54%*	*9%*	*1%*	87%				13%	
	Company 7	25%	*54%*	*21%*	*24%*	*1%*	99%	1%‡				
	Company 8	2%	*36%*	*23%*	*21%*	*2%*	81%	19%				
	Company 9		*57%*	*32%*	*9%*	*2%*	100%					
	Company 10		*41%*	*37%*	*21%*	*1%*	100%					

* None of the 12 companies in this study trade day swaps.
** ±1% deviation due to rounding error.
† Also have 2% of traded volume in swing contracts.
‡ Only one transaction.

Table 4: Cumulative volumes hedged with *swaps* in % of total *swap* volume. The volume is the sum of absolute transaction volumes.

		Holding period [months]				
Group	Company	60	36	24	12	6
1	Company 1	24 %	53 %	54 %	69 %	77 %
	Company 11	0 %	47 %	50 %	66 %	77 %
	Group mean	12 %	50 %	52 %	68 %	77 %
2	Company 3	8 %	11 %	25 %	44 %	67 %
	Company 12	0 %	25 %	60 %	81 %	92 %
	Group mean	4 %	18 %	43 %	63 %	80 %
3	Company 4	49 %	54 %	60 %	77 %	91 %
4	Company 2	0 %	20 %	36 %	72 %	93 %
	Company 5	0 %	6 %	16 %	42 %	61 %
	Company 6	0 %	1 %	11 %	36 %	63 %
	Company 7	3 %	14 %	29 %	54 %	70 %
	Company 8	0 %	8 %	19 %	33 %	52 %
	Company 9	0 %	0 %	3 %	27 %	52 %
	Company 10	0 %	0 %	1 %	31 %	66 %
	Group mean	0 %	7 %	16 %	42 %	65 %

swaps. Three companies trade more than 20% of their volume in month swaps while the corresponding value for the rest of the companies is 9% or less. The trade in week swaps is only minor. Five companies use the bilateral market in addition to Nord Pool while seven companies utilize other instruments than swaps. Options are suitable for companies with large uncertainties in expected production since they postpone the decision to trade swaps until date of option expiry. However, they are utilized by only three companies. Swing contracts enable a flexible load during the delivery period, but are limited to a handful trades only for Company 3, amounting to 2% of total swap volume. Only Company 3 trades all types of derivatives regularly over the analyzed period.

The mean percentage price deviation between the system price and area prices (Table 11 in Appendix A) shows two-digit percentage difference during Q3 2007, Q2 and Q3 2008, and September 2009. This price difference is caused by downtime in transmission capacity between price areas. The companies express that the CfD market suffers from low liquidity and is therefore not suitable to hedge the basis risk from this price difference. This is also found in the low utilization of CfD derivatives among the companies (Table 3). Hence the basis risk will influence the accuracy of the hedging policies during periods of high congestion in the transmission grid.

Swaps constitute the greater part of the traded volume and are regarded as the main hedging derivative among the companies. Figures for swap volume depending on holding periods as % of total swap volume are listed in Table 4. Two of the companies, Company 1 and Company 4, initiated more than 25% of the swaps five years or more before maturity. Group 4 stands out with a relatively lower hedging activity at far maturities. Two years before maturity the other groups had entered into 52% of their total hedge volume on average while the corresponding value for group 4 is 16%.

With the exception of Company 6, Company 7 and Company 10, all companies trade year swaps to build a hedging foundation at far maturities. As maturity approaches they use quarter, month and week swaps to fine-tune their hedging ratio. Company 1, Company 4 and Company 11 all hedge large parts of their production with year swaps until respectively 50, 55 and 35 months before maturity while they only trade shorter swaps for the remainder time.

These findings must be put in perspective of the Nord Pool market. Year swaps have a maximum holding period of five years, quarter swaps two and a half years, month swaps a half year and week swaps six weeks. The availability of far maturity swaps is therefore restricted to year and partly quarter swaps. Bilateral contracts can be traded with further maturities.

3.3 Exposure

There are two types of hydroelectric production: run-of-the-river and reservoir. While the production from a run-of-the-river plant depends on the current stream of the river a reservoir plant is regulated and enables the producer to control the outflow. Reservoir plants have the advantage of scaling down during periods of low prices and up when the price is high (the participating companies' aggregated production consist of 21% run-of-the-river and 79% reservoir production). This has significant consequences for risk management. With this high degree of flexibility the exposure remains uncertain until actual production starts, mainly because of two phenomena in reservoir electricity production. First, the ability to store water grants an option to not produce now and wait for periods of higher prices, a practice known as 'transferring water'. Second, several of the companies in the study have indicated a practice where - for fiscal periods with lower-than-expected earnings - the production has been scaled up in the end of the period to meet profit targets. In other industries this is known as 'channel stuffing'. These two practices will interfere with the long-term production plan and make it challenging to plan the appropriate size of hedging transactions to comply with restrictions in the hedging policy.

The exposure is subject to attributes of governmental regulations. First hydroelectricity producers have to deliver up to 10% of physical production at low or no fee to the public authorities where their production plants reside (license power[19]). Second, the Norwegian tax code enforces a natural resource tax for hydroelectricity production in addition to the standard corporate tax. The tax is a result of Norwegian regulation policies to apply additional taxes on extraction of natural resources. Revenues from physical production are taxed with both the natural resource tax and the corporate tax, while revenues from financial contracts are only subject to corporate tax. The following calculation of the change in after-tax profit from an increase in spot price of 1 unit illustrates how the natural resource tax affects hedging decisions:

$$\textit{increase} \text{ after-tax profit physical production} = \textit{decrease} \text{ after-tax profit financial contracts}$$

$$\underset{\text{Spot revenue}}{1} - \underset{\text{Natural resource tax}}{0.30} - \underset{\text{Corporate tax}}{0.28} = -(\underset{\text{Derivative cashflow}}{x} - \underset{\text{Corporate tax}}{0.28 \cdot x}) \tag{2}$$

$$x = -0.583$$

Assume that x is the net *long* position on the financial market as fraction of expected production that ensures a full hedge; a position where the after-tax profit is not affected by changes in the spot price. Then the increase (decrease) in after-tax profit from physical production following a spot price increase (decrease) *must* equal the decrease (increase) in after-tax derivative profit. We also assume that the correlation between the price and

[19]Electricity companies residing in Norway are obliged to compensate the counties and municipalities which are affected by regulated electricity production, due to permanent damages in the nature because of the production plant and its operation . This compensation consists of a fee and a share (up to 10%) of the average physical electricity production, called license power, which is delivered at low or no fee. These volumes are not exposed to market uncertainties and therefore not subject to hedging considerations. For this reason the license power must be subtracted from the physical production when risk exposure is calculated. All production values in the further analyses are exclusive license power.

Table 5: Forecast error (the mean absolute percentage error) for each exposure forecast method. The values are averaged over the companies using each method (Table 1).

Method of exposure forecast	Forecast horizon [months]				
(number of companies)	24	12	9	6	3
Production plan (5)	43%	52%	50%	38%	33%
Historical average production (6)	17%	17%	17%	17%	17%
Historical minimum production (1)	14%	14%	14%	14%	14%

production volume is zero[20] (the production level is unaffected by a price change). If the price per unit increase by 1 the revenues per unit from the physical production increase by 1 (variable cost is negligible in hydroelectricity production while all fixed costs is unaffected by a price increase) while the cashflow from a *long* position increases by x. Both sides of the equation are reduced by the corporate tax, but the after-tax profit from the physical production is further reduced by the natural resource tax. Hence a full hedge for electricity companies is different from the full hedge for other industries - a unitary hedge ratio (hedge ratio of 1).

The natural resource tax is 30% and the corporate tax 28%[21]. Thus a full hedged position implies that the net long position is -58.3% of the expected production; 58.3% of expected production is must be sold through power derivatives to reach a full hedged position. Only Company 9 explicitly refers to the natural resource tax and its consequences for the hedge ratio in their policies. Interviews with some of the companies reveal that they also are familiar with consequences of this tax.

The practice among the studied companies is that the production planning and hedging operation is performed separately, in accordance with Wallace and Fleten (2002). Three different methods to forecast the exposure from physical production are utilized in the studied companies: historical average production , historical minimum production and production plan (based on a dynamic production planning tool). Each company's method is presented in Table 1. There is a one to three years horizon on the production planning. Company 7 uses historical minimum production to be able to avoid situations where unexpected downtime in production results in net short position in the hedging portfolio (volumes sold through power derivatives exceed production volumes).

The companies' success in predicting their exposure is measured by the forecast error (the mean absolute percentage error). For the companies utilizing a method based on historic production the forecast error remains the same independent of time to maturity. The minimum production level method has lowest forecast error while the companies using production plans have the largest average forecast error (Table 5). To test for a difference in predictability of forecasting methods - between the production plan and the historical average production - the Kruskal-Wallis test for equality of variances (see Appendix B.3)

[20]The zero correlation between price and production volume is disputable. A negative correlation between loads and swap prices lower the incentives for hedging since this is relationship acts as a natural hedge while the converse is true for a positive correlation (Nasakkala and Keppo, 2005). We find that both relationships are plausible on Nord Pool. Since Nord Pool is an established and liquid market we assume that all market participants are price takers. Then short-term price increases give producers the incentive to increase the electricity production for the purpose of exploiting high price levels. However, the daily production levels of all participants are fixed by a daily auction, such that producers are not able to hike production levels in response to an unexpected daily price increases. The short-term relationship is therefore only slightly positive. On the other hand long-term price increases are a result of reduced supply (in hydroelectricity this is caused by reduced inflow of water) which results in reduced production levels. Thus a long-term relationship between price and production levels is negative.

For the purpose of (2) the horizon of profits is ambiguous and it is therefore challenging to interpret the correct sign of the correlation. Therefore we believe that a zero correlation gives a reasonable benchmark for a full hedged position.

[21]http://www.regjeringen.no/nb/dep/fin/dok/nouer/2000/nou-2000-18/3/8.html?id=359771.

Table 6: Test for difference in mean absolute percentage error between the methods production plan and historical average production. The test is performed for several different forecast horizons

Forecast horizon [months]	Kruskal-Wallis test statistic	p-value
36	0.83	0.361
24	1.63	0.201
12	3.33	0.068*
9	2.70	0.100
6	1.20	0.273
3	0.83	0.361
1	0.83	0.361

* significant at 10% level in a one-tail test.

is applied to the data[22] - 11 observations - for several times to maturity (36, 24, 12, 9, 6, 3 and 1 month). The p-values are presented in Table 6.

There is a significant difference between the forecasting methods on a 10% significance level 12 months before maturity. Thus a forecasting method based on historic production levels is better to predict the exposure level subject to hedging compared to an approach with a dynamic production planning tool. This is mainly due to the mean absolute percentage error of Company 11, caused by the extraordinary months described in Section 2.1 and resulting in extreme forecast errors. Nevertheless, this reveals the pitfalls of using a production plan as exposure forecast for hedging decisions. The historical minimum production method is designed to minimize the effects of such extraordinary periods and avoid net short positions.

This result indicates that companies should use different methods for estimation of risk exposure subject to hedging (we find a method based on historic production to be most accurate) and for maximization of the value of the water in the reservoirs (a dynamic model is more appropriate since the hydroelectricity production is quite flexible (Wallace and Fleten, 2002)). A historical forecasting method gives higher predictability for the hedging operation and less forecasting error compared to a dynamic approach.

3.4 Hedge ratio characteristics

Detailed production and transaction data allow for calculation of hedge ratios - the fraction of production hedged. The following section describes the hedge ratio both before maturity (applied by Brown (2001), Adam and Fernando (2006)) as well as at maturity (following Brown et al. (2006) and Lin and Chang (2009)). The companies in group 3 and 4 apply hedge ratio targets in their hedging policies and it is possible to measure their hedging performance by constructing the hedge ratio h:

$$\mathrm{h}_{t,d,i} = \frac{1}{\mathrm{E}(t,d,i)} \sum_{\tau<t} -\mathrm{C}(\tau,d,i) \tag{3}$$

where

$\mathrm{C}(t,d,i)$	Short position[23]initiated at date t with delivery period d for Company i
$\mathrm{E}(t,d,i)$	Exposure forecast for delivery period d updated at date t for Company i
t	Observation date
d	Delivery period for swap: {January 2007, ..., December 2009}
i	Company: {Company 1, Company 2,..., Company 12}

[22] Assumed non-normal due to low sample size.

[23] C is a short transaction since all hedgers will have a net short financial position. As C is preceded by a negative sign the hedge ration h will get a positive sign.

The hedge ratio comprises three dimensions: the time series dimension t (relative to the time to maturity and not the absolute timeline), cross-section dimension d and the companies i.

The hedge ratio reflects the NOK increase (decrease) in the hedging portfolio for each NOK decrease (increase) in underlying price while the standard deviation of (3) measures the consistency in a company's hedging practice. Hedge ratios and standard deviations at different times to maturity are presented in Table 7.

The hedge ratio along the time series dimension portray the development of hedging activity as transactions are performed and exposure forecasts are revised. Figure 4 in Appendix C plots the hedge ratios as a function of time to maturity for each company and detailed values are presented in Table 7. All the hedge ratios build up gradually as maturity approaches, consistent with the policies described in Section 3.1. This 'staircase formation' is formed as the companies increase their hedge ratio gradually. The plots fluctuate rapidly because the companies perform hedging transactions as often as several times a month and even several times within a week. For companies with production plans as forecast method the fluctuations are also caused by changes in these.

The standard deviation for Company 12 merely exceeds 0.1 (Figure 4(d) in Appendix C). The range between lower and upper quartiles remains with the shape of the median which indicates that Company 12 practices a consistent hedging policy. On the contrary Company 11's standard deviation exceeds 1.4 and remains above 1.0 for the greater part of the time before maturity (Figure 4(b) in Appendix C). This is reflected in the wide range between lower and upper quartiles. In contrast to Company 12 Company 11 has large variability in their monthly hedging practice, but they succeed in reducing the variability six months prior to maturity. Their large variability between the months is attributable to the months of production outage, as described in Section 2.1. Six out of the seven companies in group 4 have maximum standard deviations of less than 0.4.

The lower quartile of Company 3 has negative values (Figure 4(c) in Appendix C). I.e. in more than 25% of the months they had negative hedge ratios at this time before maturity, resulting in a long financial position in addition to their long position from expected spot production. In 2005, early 2006 and parts of 2008 Company 3 took substantial long positions for all delivery periods, resulting in these negative hedge ratios. There are several possible reasons for this. First, Company 3 has a C-FaR approach to hedging and no specific hedge ratio target. This allows for selective hedging. Second, during 2005 and 2006 the company revised their policy to scale down the hedging activity. In this perspective the long positions are transactions aimed at increasing market exposure according to new policies. However, during Q1 and Q2 of 2006 all the hedge ratios in the time period analyzed were negative, as low as -2.24 for July 2007 per March 2006. This could be an overreaction into the new policies, but is most likely a result of selective hedging.

The companies in group 3 and 4 have upper and lower hedge ratio boundaries at specific times to maturity. As an example Company 2 states that their hedge ratio two years before maturity should lie between 0.1 and 0.3 while one year before maturity the corresponding values are 0.2 and 0.4. Figure 4 reveals that the median hedge ratio of Company 5, Company 6, Company 8 and Company 9 lie within their hedge ratio boundaries while the median hedge ratio of Company 2, Company 4[24], Company 7 and Company 10 do not. Thus four out of eight companies manage to stay inside their allowed hedge ratio boundaries. However, the other four companies have thinner ranges compared to the companies that are in accordance with policy boundaries. Hence it proves challenging to accommodate to policy targets if the boundaries are too restrictive.

Average hedge ratios at maturity for group 2, 3 and 4 are in the same proximity. Group 1 is clearly over-hedging their exposure while the rest of the groups are close to a full hedge

[24] Even though Company 4 does not have a hedge ratio range, they change hedge ratio target subject to market price. Their range is constructed from the targets of different price scenarios.

Table 7: Descriptive statistics for the hedge ratio of each company. The hedge ratio is the fraction of (forecasted) production hedged. The table includes median values for hedge ratios based on the 36 monthly values as well as standard deviations over this period. The values are plotted in Figure 4 in Appendix C.

			Median				Standard deviation			
Group	Company	Time to maturity	2 years	1 year	6 months	Maturity	2 years	1 year	6 months	Maturity
1	Company 1		0.48	0.73	0.76	0.91	0.35	0.25	0.23	0.21
	Company 11		0.57	0.69	0.76	1.06	1.19	1.16	0.73	1.90
	Group mean		0.53	0.71	0.76	0.99				
2	Company 3		0.07	0.05	0.20	0.53	0.15	0.60	0.59	0.26
	Company 12		0.36	0.48	0.48	0.52	0.08	0.07	0.06	0.08
	Group mean		0.22	0.26	0.34	0.53				
3	Company 4		0.38	0.51	0.51	0.48	0.28	0.27	0.27	0.28
4	Company 2		0.14	0.27	0.34	0.38	0.07	0.09	0.09	0.10
	Company 5		0.18	0.28	0.34	0.36	0.08	0.29	0.24	0.19
	Company 6		0.03	0.29	0.42	0.35	0.07	0.12	0.18	0.21
	Company 7		0.16	0.23	0.24	0.34	0.06	0.09	0.08	0.11
	Company 8		0.08	0.15	0.23	0.49	0.05	0.06	0.12	0.18
	Company 9		0.00	0.18	0.34	0.61	0.06	0.14	0.23	0.23
	Company 10		0.00	0.45	0.52	1.15	0.05	0.39	0.60	0.80
	Group mean		0.09	0.26	0.35	0.53				

(0.583 as calculated in Section 3.3) on average. At maturity four out of eight companies of group 3 and 4 achieved their hedge ratio targets, three companies are marginally off their boundaries and Company 10 is wide above. In total seven out of eight companies reach or almost reach their hedge ratio targets. Hence the companies are more successful in conforming to policy restrictions at maturity than before.

In terms of standard deviation, Company 11 stands out with a relative standard deviation[25] of 179%, mainly due to two large spikes where the hedge ratio at maturity reached -6.40 and 7.29. Again the abnormal results for Company 11 are due to the circumstances described in Section 2.1.

The result for Company 3 is surprising. They lie close to a full hedge on average, and higher than most of the other companies. However, in their policies they describe their motivation for hedging to "secure an acceptable income and hedge as little as possible to retain as much of the upside potential as possible". Possible explanations for their high hedge ratios either are a belief of positive risk premiums in the Nord Pool market (as found for week swaps by Botterud et al. (2009)) or a very long transition period towards the revised policies of 2006 (less likely).

Due to the natural resource tax the hedge ratios for electricity companies are not comparable with findings in other studies of non-financial companies. However, analogous values can be calculated by normalizing the hedge ratios[26]: 1.69 (Group 1), 0.90 (Group 2), 0.82 (Group 3) and 0.91 (Group 4), while the mean for all groups except Group 1 is 0.88. This is considerably higher than found in previous literature on non-financial companies. Brown (2001) finds an average hedge ratio of 0.74 for the currency-exposure of HDG Inc. (pseudonym) 3 months before maturity. Brown et al. (2006) reveal an average hedge ratio of 0.34 among active hedging firms while Adam and Fernando (2006) find hedge ratios of 0.36 two years before maturity and 0.54 one year before maturity among North American gold miners which employs positive hedge ratios. For non-U.S. airlines, the average hedge ratio for jet fuel hedges is in the interval 0.73 - 0.83 (Lin and Chang, 2009).

Hedge ratios at maturity seem to follow a seasonal pattern over the cross-section dimension of delivery periods in Figure 2 - Company 10's hedge ratios at maturity are higher during winter than during summer. Adam and Fernando (2006) identify an equivalent seasonality when analyzing the hedge ratios of gold mining companies. Varying market conditions between seasons is a possible rationale for such behavior. To investigate this the one-way ANOVA test for equal means (see Appendix B.2) is applied to normally distributed data and the Kruskal-Wallis test for equal means (see Appendix B.5) is applied to non-normally distributed data[27] - 9 observations for each company. The p-values are presented in Table 8.

On a 5% significance level four out of the 12 companies have seasonal variations in hedge ratio at maturity while a 10% significance level includes eight companies. The pattern of the seasonality is ambiguous; on a 10% significance level five companies have higher hedge ratio at maturity during winter season (Q1 and Q4) while three companies have higher hedge ratios during summer (Q2 and Q3). Only Company 8 authorizes that their hedge ratio should be higher during winter, which they achieve.

Lucia and Schwartz (2002) find significant higher spot price volatility at Nord Pool during summer compared to winter. They attribute this to lower prices and more supply shocks during summer. Higher volatilities require higher hedge ratios to achieve same level of predictability and can explain higher hedge ratios during summer. Another explanation is that companies mainly trade with yearly swaps which have a fixed power size for all months. Since electricity production in Norway is considerable lower during summer,

[25] Relative standard deviation= $^{\text{Standard deviation}}/_{\text{Median}}$.

[26] Hedge ratios are normalized by dividing by the hedge ratio for a full hedged position (0.583). This gives a hedge ratio where the value 1 is equivalent with the unitary hedge ratio for other commodities.

[27] The data are tested for normality by applying Bera-Jarque tests (see Appendix B.1).

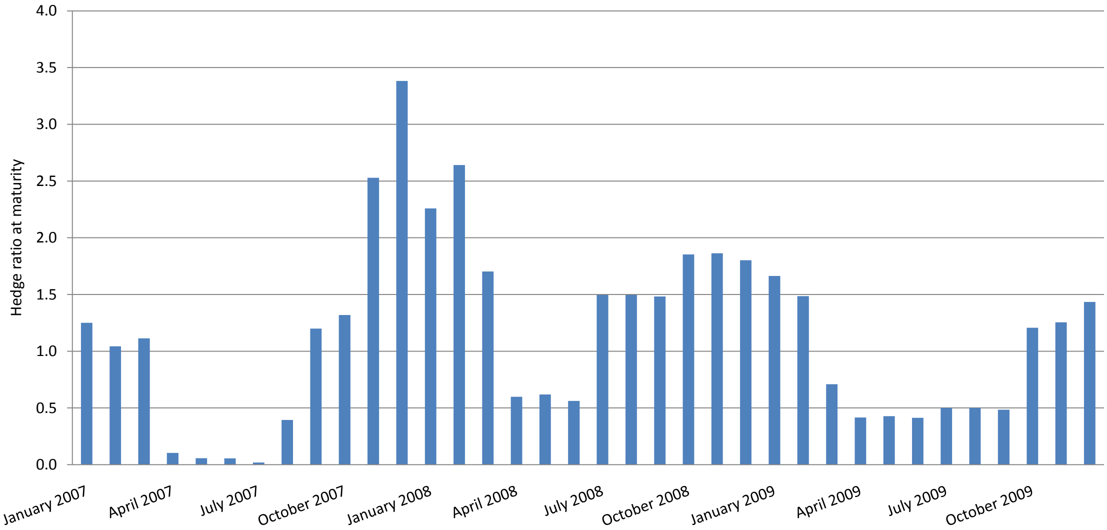


Figure 2: Hedge ratio at maturity plotted over the cross-section dimension d for Company 10. We can observe seasonality effects as the hedge ratio crests each winter season.

Table 8: Test of seasonality in achieved hedge ratio. ND = normally distributed. Test statistics are either from the one-way ANOVA test (normally distributed data) or the Kruskal-Wallis test (non-normally distributed data). High season is the season where the hedge ratios are significantly higher, either winter (Q1 and Q4) or summer season (Q2 and Q3).

Group	Company	ND	Test statistic	p-value	High Season
1	Company 1	Yes	1.76	0.174	
	Company 11	No	6.34	0.096*	Winter
2	Company 3	No	7.71	0.052*	Summer
	Company 12	Yes	1.82	0.164	
3	Company 4	Yes	1.72	0.182	
4	Company 2	No	7.33	0.062*	Summer
	Company 5	Yes	3.71	0.021**	Winter
	Company 6	Yes	1.37	0.271	
	Company 7	Yes	7.02	0.001***	Winter
	Company 8	No	7.49	0.058*	Winter
	Company 9	No	15.71	0.001**	Summer
	Company 10	Yes	12.97	0.000***	Winter

* significant at 10% level in a two-tail test.
** significant at 5% level in a two-tail test.
*** significant at 1% level in a two-tail test.

yearly swaps generate higher hedge ratio during this season compared to winter.

However, higher hedge ratios during winter can be explained by the high uncertainty of production levels during summer[28]. Nasakkala and Keppo (2005, p. 131) find that producers with "high load uncertainty postpone their hedging decision in order to get better load estimates". Hence producers with flexible production will be averse to hedge summer production at far maturities. Considering the low flexibility of run-of-the-river plants we would expect that producers with more (less) of this type of production show less (more) significance in seasonal variation. This is plausible considering that two of the four companies without significant seasonal variation have 50% or more of their production from run-of-the-river plants while the corresponding value for seven of the eight companies with seasonal variation is less than 20% - without any indication for which season is most hedged. Despite the ambiguity between seasons in both rationale and result, the findings are surprising and interesting. The seasonal behavior is extensive among the companies while only one company comments the issue in their policy. Selective hedging is a plausible explanation since the pattern is ambiguous on which season the hedge ratio is higher.

4 Analyses of added value from hedging

Smith and Stulz (1985) present three non-linear costs that explain hedging motives: tax convexity, reduced default risk and stakeholder risk aversion. There are several papers aiming to quantify value addition from hedging these costs (Nance et al., 1993; Fok et al., 1997; Graham and Rogers, 2002). However, for Norwegian electricity companies these costs are less relevant. First, their corporate tax function is linear, due to a uniform tax rate and allowance to carry forward losses to next years' budgets. Second, because of governmental regulations virtually all hydroelectricity companies in Norway are under public ownership by municipalities, counties and the state. This, along with low variable costs result in a negligible default risk for hydroelectricity producers. Thus the only argument left to motivate hedging is stakeholder risk aversion. The publicly owned electricity companies pay out large parts of their profit as dividend, making them important sources of financing for public authorities. Large reductions in the dividend - even on the short term - have large negative effects for owners, translating into high risk aversion. The risk aversion also affects the behavior of both management and employees. For this reason the hedging motive because of stakeholder risk aversion is considerably larger compared to that of a convex tax function or the default risk, but cannot explain the full rationale for the hedging practices.

Added value from hedging is usually measured as increased firm value (Allayannis and Weston (2001), Jin and Jorion (2006), Lin and Chang (2009)). However, none of the 12 companies in this study are publicly traded, making it unfeasible to perform reliable calculations on whether market values of the companies are correlated with hedging activities. This paper takes a different approach, inspired by Brown (2001), with focus on quantities treated in the companies' written policies. Main attention will be given derivative cashflows[29] (Adam and Fernando (2006) and Brown et al. (2006) analyses this), price and cashflow volatility (Ederington (1979) and Brown (2001) advice this approach) and Cashflow at Risk (recommended by Stein et al. (2001)).

[28]The inflow to hydro reservoirs is fairly stable every year and crests during the spring season when the snow melts. The companies must optimize their production such that they do not risk to have their reservoirs over-filled (the reservoir is not adequate to contain all the water). On the other hand they do not want to risk having to little water available during the high winter prices. Since the production capacity during winter is dependent on water used for summer production the projections for the summer production remains highly uncertain in wait for projections for winter demand (in close relationship with projected temperature levels).

[29]Termed 'hedging gains' by Brown et al. (2006).

4.1 Derivative cashflows

Company 4, Company 6, Company 9 and Company 10 explicitly state that a goal of their hedging policy is to maximize the value of the hedging portfolio (portfolio of expected production and derivatives). This is not in accordance with theoretical motivations for hedging, but can be explained by selective hedging since the companies motivate this by referring to their own market competence. The derivative cashflows are calculated as follows for short positions in (4a) swaps, (4b) Contracts for Difference, (4c) option calls and (4d) option puts (cashflows from swing contracts are calculated as if the contracts were swaps[30]):

$$\pi_s = Q \cdot (f_s(t_1, d) - \bar{p}_{system}) \tag{4a}$$

$$\pi_{CfD} = Q \cdot [f_{CfD}(t_1, d) - (\bar{p}_{system} - \bar{p}_{area})] \tag{4b}$$

$$\pi_c = Q \cdot max\{0, f_s(t_2, d) - k\} \tag{4c}$$

$$\pi_p = Q \cdot max\{0, k - f_s(t_2, d)\} \tag{4d}$$

where

$\bar{p}_{system}$	Monthly average system price [NOK/MWh]
$\bar{p}_{area}$	Monthly average area price [NOK/MWh]
$f_s(t_i, d)$	Swap price traded at date t_i with delivery period d [NOK/MWh]
$f_{CfD}(t_i, d)$	CfD price traded at date t_i with delivery period d [NOK/MWh]
Q	Contract volume [MWh], $Q<0$: short position, $Q>0$: long position
k	Strike price of the option [NOK/MWh]
t_1	Date of entering the financial contract
t_2	Date of option expiry
d	Delivery period for swap: {January 2007, ..., December 2009}

In addition, the option contracts entail a (5) premium P due at the time the option is entered:

$$P = p \cdot Q \tag{5}$$

where

p Option premium per unit [NOK/MWh]

For options the derivative cashflows is calculated in two parts. The option premium (5) reduces the cashflow of the month the option contract is entered, while the derivative cashflows ((4c) and (4d)) affect the month where the option is exercised. If exercised the option transforms into a swap, subject to (4a) at maturity of the swap.

Two of the companies had net negative derivative cashflows from the hedging transactions. Of the remaining ten companies five had positive derivative cashflows of less than 10% of spot revenue, while the corresponding values for the rest are 10-20%. However, Table 9 reveals large fluctuations in the payoff from one year to another. Company 7 has the smallest gap, ranging between 0.1% (2008) to 11.3% (2009) of spot revenue, while the corresponding figures for company with the largest gap (Company 11) are -14.8% (2008) and 30.7% (2009). Group 1 companies experience higher variation in yearly average derivative cashflows (a mean difference between maximum and minimum of 39.8% of spot revenue) than companies having written policies (24.6%). On average none of the four companies

[30] This is because we do not have access to information on how the contracts were exercised. We assume a constant load for the whole period of the swing contract, making them equivalent to swaps.

Table 9: Total derivative cashflows; values of monthly derivative cashflows as % of average monthly spot revenue, averaged over the period analyzed. Cashflows originate from swaps and, for some companies other derivatives (Table 3). Maximum and minimum values for the yearly average derivative cashflows are provided for robustness evaluations.

		Swaps	Other Derivatives	Total		
Group	Company	Mean	Mean	Mean	*Min*	*Max*
1	Company 1	1.4%		1.4%	*-9.1%*	*25.0%*
	Company 11	-4.9%	1.9%	-3.0%	*-14.8%*	*30.7%*
2	Company 3	4.6%	1.9%	6.5%	*-3.3%*	*27.9%*
	Company 12	2.9%	-0.3%	2.6%	*-10.0%*	*16.4%*
3	Company 4	-8.5%	-0.1%	-8.6%	*-22.1%*	*11.4%*
4	Company 2	3.4%		3.4%	*-3.2%*	*9.3%*
	Company 5	15.2%		15.2%	*2.3%*	*31.2%*
	Company 6	18.7%	-0.7%	18.1%	*1.3%*	*41.2%*
	Company 7	4.0%	0.1%	4.1%	*0.1%*	*11.3%*
	Company 8	12.9%	0.8%	13.7%	*4.5%*	*22.2%*
	Company 9	14.0%		14.0%	*6.3%*	*19.4%*
	Company 10	17.8%		17.8%	*7.3%*	*34.8%*

with explicit motivation for higher derivative payoffs achieved a higher cashflow (6.7% of spot revenue) than the eight other companies (7.4% of spot revenue).

Due to their short derivative positions the companies' derivative cashflows from hedging transactions are lower in periods of high spot prices. In 2008 the average system price at Nord Pool was 65% higher than in 2007 and 21% higher than in 2009. Six out of the 12 companies had negative derivative cashflows from hedging transactions in 2008. Three out of the four companies with the highest losses in 2008 had either no hedging strategy (group 1) or a hedging strategy based on a fixed hedge ratio requirement (group 3). Thus periods of extraordinary high spot prices call for a more dynamic strategy that allows for incorporating of market view in hedging decisions.

The analysis show that the derivative cashflows from the hedging transactions are mainly from swaps. The extent of other derivatives (CfDs, options and swing contracts), described in Table 3, is limited to six companies[31]. Of these Company 3 and Company 11 had respectively 30% and 64% of the total derivative cashflows from other derivatives than swaps, while the other companies had negligible or none profits compared to cashflows from swaps.

There are considerable profit contributions from hedging transactions, ranging above 10% of spot revenue for 5 companies, all from group 4. This is a substantial source of profit for the companies, but indicates extensive selective hedging. Stulz (1996) warns that this is a value-destroying strategy if the companies do not understand the source of their information advantage and the associated risks. Adam and Fernando (2006) also find large profits from hedging among 92 gold miners, with a mean derivative cashflow of 10% of spot revenue. However, Adam and Fernando analyze a ten year period, including two sub periods of falling prices and one sub period of rising prices. This paper analyzes data over a three year period with slightly rising (linear trend) prices (see Figure 3 in Appendix A). The positive profits are robust for group 4, where only Company 2 has one year of negative derivative cashflows.

[31]In addition Company 7 has one CfD transaction, but this is negligible compared with the other companies.

The mean total derivative cashflows show some correlation[32] with the annual production levels of the companies (correlation coefficient 0.33) and with the number of transactions (correlation coefficient 0.72). The relationship between derivative cashflows and number of transactions indicates that larger resources allocated to hedging activities (more transactions require more resources) give a combination of larger capacity to monitor market changes, and more market competence and access to market information. The latter is strongly connected to selective hedging behavior.

The large positive derivative cashflows can be related to the possible sample bias as discussed in Section 2. The size of the cashflows does not reject a hypothesis of a biased sample. We find it hard to believe that more than a handful of the rejecting companies declined because of large losses. Nevertheless, this concern cannot be neglected.

4.2 Price and cashflow volatility

Company 1, Company 7, Company 10 and Company 11 use reduction of cashflow fluctuations as motivation for their hedging practice. Reduced volatility of the hedging portfolio increases the predictability of the companies' cashflows and adds value by relaxing stakeholder risk aversion. The volatility in monthly hedging portfolio cashflows has two components: volatility in physical production volume and in prices. Cashflow constitutes the essential parameter for the companies[33], but derivatives can only hedge prices. Hence both the volatility that is expected to be reduced by hedging (price volatility) and the one that is essential to the companies (cashflow volatility) are analyzed.

The variance of the cashflows and prices with and without hedging[34] are used as measures of volatility. The data - 72 observations for each company - are tested for equality of variances by applying the two-sample variance test (see Appendix B.4) to normally distributed data and the Brown-Forsythe test (see Appendix B.5) to non-normally distributed data[35]. The p-values of the tests are presented in Table 10.

Only Company 1 and Company 12 achieve significant reduction in monthly cashflow variance on a 10% significance level. On a 5% level Company 1, Company 2 and Company 3 reduce the variance of monthly average prices while a 10% level includes another two companies. Both group 2 companies are among these five companies.

These results are surprising for several reasons. First, Company 1 stand out as the only company with significant variance reduction in both tests at low p-values although they have relatively few hedging transactions (similar to Company 2 and Company 12) compared with other companies (Table 1). It is notable that Company 1 achieves this without a written policy, even though they describe cashflow stability as an important motivation for hedging. Second, surprisingly few companies manage to reduce the cashflow volatility significantly. Most papers in Section 1.1 suggested that hedging should increase predictability and smooth earnings. However, based on our data material there is little evidence of reduction of cashflow variance among electricity companies from hedging while reductions in price variance is more extensive, though not across the whole sample. Power derivatives only hedge price risk, not volume risk, and should therefore - and they do - have a larger effect on price variance than cashflow variance. This is emphasized by Company 3, stating that their "policy is designed to secure price levels, not necessarily the total profit from production. There is still substantial residual risk associated with uncertainties in production levels".

[32]The correlation is calculated as the correlation coefficient between the sample of companies' total derivative payoff and the sample of companies' number of transactions.

[33]For many companies the yearly dividend is as important and cashflow is used as a proxy for this.

[34]The unhedged cashflow and price are respectively revenue from spot production and monthly average spot prices.

[35]The data are tested for normality by applying Bera-Jarque tests (Appendix B.1).

Table 10: Test of monthly cashflow and monthly average price variances, as well as C-FaR. ND = normally distributed. Test statistics are either from the two-sample variance test (normally distributed data) or the Brown-Forsythe test (non-normally distributed data). The C-FaR is the % negative deviation from the average monthly unhedged cashflow (spot revenue).

		Monthly cashflows					Monthly average prices		
		Volatility test			C-FaR test		Volatility test		
Group	Company	ND	Test statistic	p-value	Spot C-FaR	Net C-FaR	ND	Test statistic	p-value
1	Company 1	Yes	2.36	0.012**	79%	42%†	Yes	2.12	0.024**
	Company 11	Yes	1.39	0.191	84%†	91%	Yes	0.62	0.899
2	Company 3	No	0.18	0.674	92%	71%†	Yes	2.14	0.014**
	Company 12	Yes	1.74	0.052*	60%	50%†	Yes	1.71	0.059*
3	Company 4	No	0.07	0.799	73%†	75%	Yes	1.64	0.075*
4	Company 2	Yes	1.18	0.312	58%	48%†	Yes	1.84	0.037**
	Company 5	Yes	1.15	0.337	77%	65%†	Yes	1.07	0.423
	Company 6	Yes	0.97	0.531	65%	53%†	Yes	0.91	0.607
	Company 7	No	0.04	0.848	59%	59%†	Yes	1.22	0.281
	Company 8	Yes	1.11	0.377	65%	51%†	Yes	1.16	0.332
	Company 9	Yes	1.30	0.221	62%	50%†	Yes	1.26	0.245
	Company 10	Yes	1.15	0.343	76%	70%†	Yes	0.61	0.924

* significant at 10% level.
** significant at 5% level.
† Lowest C-FaR-value.

The result can also be explained by the perspective of the companies. The owners require stable yearly dividends, such that monthly fluctuations matter less as the dividend is based on yearly results. Several companies also have a quarterly perspective on the hedging portfolio in their policies. Both hedging behavior (Section 3.4), the Nord Pool spot price (Lucia and Schwartz, 2002) and the production levels entail seasonal patterns. This will contribute to monthly fluctuations in hedged cash flows and presumably the variations will smooth out in a yearly perspective. The basis risk from the difference between system price and area price (Section 3.2) will also affect the ability of hedging policies to smooth out cashflows. We identify substantial basis risk during Q3 2007, Q2 and Q3 2008, and September 2009 (Table 11 in Appendix A).

The analysis reveals that only one, Company 1, of the companies that focus on reduction in volatility achieves this. This result is surprising and brings attention to whether volatility reduction is possible to accomplish along with the other goals of the companies' hedging policies.

4.3 Cashflow at Risk

Cashflow at Risk (C-FaR) was introduced by Stein et al. (2001) and suggested as an alternative to the Value at Risk approach on the risks of periodic cashflows for non-financial companies. Group 2 companies use C-FaR approach and one of them states explicitly that securing an acceptable income while preserving the upside potential is the main purpose of their hedging practice. Company 7 and Company 10 also use this as motivation for the hedging activity. As discussed in Section 3.1 this corresponds to the proposition of Stulz (1996): that the fundamental goal of hedging is elimination of the lowest earnings outcomes.

C-FaR is applied through an empirical quantity: for each company we measure the deviation of each monthly cashflow from the average monthly cashflow. The second most negative deviation can be regarded as empirical estimates of the 5.6% ($^2/_{36}$) C-FaR (6.7% ($^2/_{30}$) for Company 1 and Company 11.). Table 10 presents the results. All but Company 4 (group 3) and Company 11 (group 1) achieve a lower empirical C-FaR with hedging than without. The two companies using the C-FaR approach both manage to achieve a lower empirical C-FaR with hedging.

The companies achieve reduced C-FaR on a much larger extent than volatility reduction. However, these two quantities overlap. While volatility reduction measures the income smoothing effect overall, C-FaR measures the smoothing of lower income levels. C-FaR is expected to decrease with hedging because the payoff of the short financial positions and income from physical production is negatively correlated. However, for a majority of the companies reduced C-FaR is accompanied with reduction of the highest income levels, without necessarily reducing the cashflow volatility significantly. Company 3, aiming to limit the earnings downside while remaining with the upside, manage to reduce the C-FaR, but also reduce the highest income levels. Nevertheless, high stakeholder risk aversion should imply that the companies value reduction of extreme low outcomes higher than the possibility for positive extremes.

In total the effects of different strategies on achieved reduction in cashflow and price volatility are ambiguous. The companies using a C-FaR approach both achieve significant reduction in price volatility and reduced C-FaR, but for the other policy characteristics groups there are no clear trend. For example, one of the two companies that do not have a written hedging strategy (Company 1) achieves significant reduction in cashflow and price volatility, and empirical C-FaR while the other no-policy company (Company 11) achieves neither.

5 Conclusion

This paper takes a different approach than the majority of empirical risk management literature. We gather unique transaction data from 12 Norwegian electricity companies. The benefits are precise data on the companies' performance which give basis for a fundamental understanding of the characteristics of risk management practices.

We identify four specific groups characterized by attributes of their written policies. The largest group, group 4, applies hedge ratio boundaries defined in their policies and authorize use of own market view in hedging decisions (selective hedging) inside these boundaries. This approach shows strong results for derivative cashflows, especially during periods of higher prices, compared with more static approaches.

We find extensive evidence of selective hedging practices across the sample. This practice is embedded in many of the companies' written policies, and justified by market competence and available risk capital. The majority of companies earn a substantial part of their total profit from hedging transactions while they do not manage to reduce cashflow volatility. In theory hedging is expected to give the opposite result with zero expected value and income smoothing. Enhanced appetite for risk among the companies and periods of high basis risk are possible explanations for the poor results for reduced volatility. The results indicate that the companies utilize hedging to maximize profit rather than to increase predictability in cashflows. Companies with written hedging policies - ten out of 12 - make clear distinction between hedging and speculation. Nevertheless, hedging in electricity companies seems to embody speculative motives.

Both theoretical literature and the companies agree that a desired result from hedging is elimination of the extreme lower outcomes of the earnings function. We find support for this practice both in the written hedging policies and by analyzing C-FaR. Close to all the companies manage to decrease their empirical C-FaR through hedging transactions. Compared with volatility reduction decreased C-FaR is widespread among the companies. The two quantities overlap, but due to risk aversion among the companies' stakeholders we believe that the C-FaR is a more appropriate quantity since it measures reduction of downside risk.

Eight out of 12 companies are found to have different hedge ratios depending on whether they are hedging summer or winter production. The pattern is ambiguous - five hedge more for winter and three more for summer - and not sanctioned in the written policies with the exemption of one company. We find the practice a result of the companies' own market expectations and attribute it to selective hedging.

Altogether the hedging policies in the Norwegian electricity industry are extensive. A high degree of flexibility in production and periods of extensive basis risk makes it challenging to practice consistent hedging policies. The companies are also found to employ selective hedging practices with freedom to use own market view within policy boundaries. We find that a majority of the companies comply with their hedging policies (seven out of eight companies with specific targets/ranges for hedge ratios at maturity meet these).

Further research should explore the risks associated with selective hedging practices. The companies in this study have a very low default risk and benefit from available risk capital, but clearly extend the hedging concept to include risks from selective hedging. A question that remains to be answered is whether the increased profit from hedging is a result of a positive risk premium and/or undertaking of systematic risk, and whether increased appetite for risk is healthy for the companies. Hopefully this paper will inspire further empirical studies in electricity or other commodity markets.

References

Adam, T. R., Fernando, C. S., 2006. Hedging, speculation, and shareholder value. Journal of Financial Economics 81 (2), 283 – 309.

Allayannis, G., Weston, J., 2001. The use of foreign currency derivatives and firm market value. Review of Financial Studies 14 (1), 243–276.

Benth, F. E., Koekebakker, S., 2008. Stochastic modeling of financial electricity contracts. Energy Economics 30 (3), 1116–1157.

Bessembinder, H., 1991. Forward contracts and firm value: Investment incentive and contracting effects. Journal of Financial and Quantitative Analysis 26 (4), 519–532.

Bodnar, G. M., Hayt, G. S., Marston, R. C., 1996. 1995 Wharton survey of financial risk management by U.S. non-financial firms. Financial Management 25 (4), 113–133.

Bodnar, G. M., Hayt, G. S., Marston, R. C., 1998. 1998 Wharton survey of financial risk management by U.S. non-financial firms. Financial Management 27 (4), 70–91.

Botterud, A., Kristiansen, T., Ilic, M. D., 2009. The relationship between spot and futures prices in the Nord Pool electricity market. Energy Economics.

Brown, G. W., 2001. Managing foreign exchange risk with derivatives. Journal of Financial Economics 60 (2-3), 401–448.

Brown, G. W., Crabb, P. R., Haushalter, D., 2006. Are firms successful at selective hedging? Journal of Business 79 (6), 2925–2950.

Ederington, L. H., 1979. The hedging performance of the new futures markets. Journal of Finance 34 (1), 157–170.

Fama, E. F., French, K. R., 1987. Commodity futures prices: Some evidence on forecast power, premiums, and the theory of storage. The Journal of Business 60 (1), 55–73.

Fok, R. C. W., Carroll, C., Chiou, M. C., 1997. Determinants of corporate hedging and derivatives: A revisit. Journal of Economics and Business 49 (6), 569–585.

Froot, K. A., Scharfstein, D. S., Stein, J. C., 1993. Risk management: Coordinating corporate investment and financing policies. Journal of Finance 48 (5), 1629–1658.

Graham, J. R., Rogers, D. A., 2002. Do firms hedge in response to tax incentives? Journal of Finance 57 (2), 815–839.

Haushalter, G. D., 2000. Financing policy, basis risk, and corporate hedging: Evidence from oil and gas producers. Journal of Finance 55 (1), 107–152.

Hentschel, L., Kothari, S. P., 2001. Are corporations reducing or taking risks with derivatives? Journal of Financial and Quantitative Analysis 36 (01), 93–118.

Jin, Y., Jorion, P., 2006. Firm value and hedging: Evidence from U.S. oil and gas producers. Journal of Finance 61 (2), 893–919.

Judge, A., 2007. Why do firms hedge? A review of the evidence. In: McCombie, J., González, C. R. (Eds.), Issues in Finance and Monetary Policy. Palgrave Macmillan.

Keppo, J., 2004. Pricing of electricity swing options. Journal of Derivatives 11 (3), 26–43.

Kolos, S. P., Ronn, E. I., 2008. Estimating the commodity market price of risk for energy prices. Energy Economics 30 (2), 621 – 641.

Lalancette, S., Leclerc, F., Turcotte, D., 2004. Selective hedging with market views and risk limits: The case of Hydro-Quebec. Quarterly Review of Economics and Finance 44 (5), 710–726.

Leland, H. E., 1998. Agency costs, risk management, and capital structure. Journal of Finance 53 (4), 1213–1243.

Lin, R., Chang, Y., 2009. Does Hedging Add Value? Evidence from the Global Airline Industry, Working Paper Series, National Chengchi University.

Longstaff, F. A., Wang, A. W., 2004. Electricity forward prices: A high-frequency empirical analysis. Journal of Finance 59 (4), 1877–1900.

Lucia, J. J., Schwartz, E. S., 2002. Electricity prices and power derivatives: Evidence from the Nordic Power Exchange. Review of Derivatives Research 5, 5–50.

Modigliani, F., Miller, M. H., 1958. The cost of capital, corporation finance and the theory of investment. The American Economic Review 48 (3), 261–297.

Nance, D. R., Smith, Clifford W., J., Smithson, C. W., 1993. On the determinants of corporate hedging. Journal of Finance 48 (1), 267–284.

Nasakkala, E., Keppo, J., 2005. Electricity load pattern hedging with static forward strategies. Managerial Finance 31 (6), 116 – 137.

Petersen, M. A., Thiagarajan, S. R., 2000. Risk measurement and hedging: With and without derivatives. Financial Management 29 (4), 5–29.

Rausser, G. C., 1980. Discussion [Hedging and joint production: Theory and illustrations]. Journal of Finance 35 (2), 498–501.

Smith, C. W., Stulz, R. M., 1985. The determinants of firms' hedging policies. Journal of Financial and Quantitative Analysis 20 (4), 391–405.

Smithson, C., Simkins, B. J., 2005. Does risk management add value? A survey of the evidence. Journal of Applied Corporate Finance 17 (3), 8–17.

Stein, J. C., Usher, S. E., LaGattuta, D., Youngen, J., 2001. A comparables approach to measuring Cashflow-at-Risk for non-financial firms. Journal of Applied Corporate Finance 13 (4), 100–109.

Stulz, R. M., 1996. Rethinking risk management. Journal of Applied Corporate Finance 9 (3), 8–25.

Triki, T., 2005. Research on corporate hedging theories: A critical review of the evidence to date, HEC Montreal Working Paper No. 05-04.

Wallace, S. W., Fleten, S.-E., 2002. Stochastic programming models in energy. In: Ruszczynski, A., Shapiro, A. (Eds.), Handbooks in Operations Research and Management Science. Vol. 10. North-Holland, Elsevier, Amsterdam, pp. 637–677.

Appendix A Nord Pool characteristics relevant to the financial electricity market

For the purpose of this paper there are two markets of interest on Nord Pool: the physical spot market and the financial market. The physical spot market offers trade for day-ahead physical delivery and prices are determined by daily implicit auctions. The financial market requires no physical delivery and all the derivatives traded are cash settled. Nord Pool offers four derivatives which use the system price of electricity as underlying price: Futures and Forwards (Swaps), Options and Contracts for Difference.

The Nordic electricity market is divided into several price areas. Within a price area the spot price is uniform, but it differs between areas. This difference is due to congestions and different production capacity between the areas. During the auction at Nord Pool both a system spot price and spot prices for each price area is decided. Producers and consumers must relate to the price of the area they reside in while the system price serves as their underlying price for the financial market. Table 11 reveals that there are periods where the system price deviate substantially from the area prices. This translates into increased basis risk in the financial market at Nord Pool. The system spot price, as well as its linear trend line and the average monthly spot price (underlying for month swaps) during the analyzed period are plotted in Figure 3.

The derivatives traded on the financial market are either base or peak load contracts. Base load contracts use the system price for all hours Monday through Sunday, while peak load contracts use the system price for Monday through Friday (including national holidays) covering the period 08.00 to 20.00.

A.1 Swaps (Futures and Forwards)

Futures on Nord Pool's financial market are traded as day and week contracts. Day futures can be traded up to one week prior to maturity, and week futures are listed with six consecutive contracts. These are all base load contracts. In addition futures for peak load are offered. The peak load futures are listed with 5 consecutive week contracts. The settlement of futures consists of both marked-to-market settlement prior to maturity and the final spot reference cash settlement after maturity. The marked-to-market settlement prior to maturity is the change in the market value of the contract (trading profit). Then the final settlement covers the difference between the final closing price of the future and the system price in the delivery period (settlement profit).

Forwards on Nord Pool's financial market are traded as month, quarter and year contracts. For base load forwards there are six consecutive month contracts, nine consecutive quarter contracts and five consecutive year contracts. For peak load contracts there are month contracts two months ahead, quarter contracts three quarters ahead and year contracts one year ahead. In contrast to futures, the marked-to-market is only accumulated prior to maturity, but not realized until maturity. The settlement after maturity is, as for futures, covering the difference between the forward contract price at time of deal and the system price in the delivery period.

The futures and forwards contracts at Nord Pool are not in accordance with standard financial notation. Forward contracts are offered with yearly, quarterly and monthly delivery while futures contracts are with weekly and daily delivery, representing delivery over a time period and not for an instant in time like the case would be for a storable commodity. Thus Nord Pool futures and forwards are equivalent to financial swaps (Benth and Koekebakker, 2008).

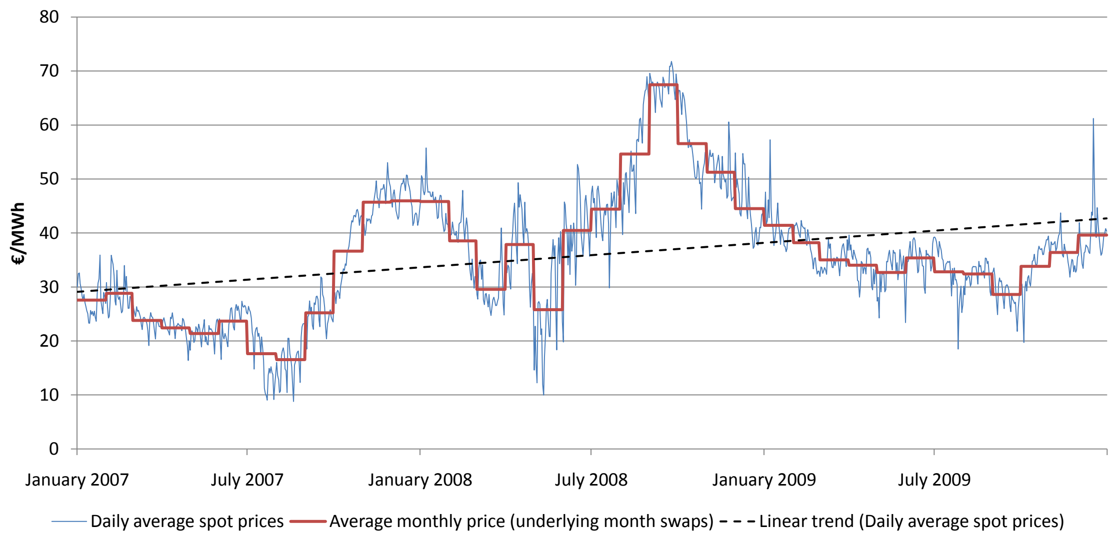


Figure 3: Plot of daily average spot prices, the linear spot price trend and the average monthly spot price over the period analyzed. The latter is the underlying price for month swaps. Year and quarter swaps are cascaded into month swaps and can therefore have the same underlying price. Week and day swaps have average weekly and daily spot price as underlying price. The plot shows a slight positive spot price trend during the analyzing period.

A.2 Contracts for Difference

Due to constraints on transmission capacity within the Nordic grid the price in a specific area can deviate from the system price. This difference in price is a basis risk for market participants and can be hedged by Contracts for Difference (CfD). By combining futures or forwards with CfDs, perfect hedging is possible independent of where the market participant is connected to the grid. The settlement of the CfD is based on the difference between the specific area price and the system price. The market price of a CfD reflects the market's prediction of the price difference during the delivery period.

A.3 Option Contracts

All option contracts traded on Nord Pool are European options. The underlying asset of the options is not the spot price, but the quarter and year forward contracts. The date of exercise for an option is the third Thursday in the month before delivery of the underlying contract.

Table 11: Mean percentage deviation between the Nord Pool system price and the respective area prices. The values reveal that there were two-digit percentage difference between the system price and area prices during Q3 2007, Q2 and Q3 2008, and September 2009. This price difference is caused by downtime in transmission capacity between price areas.

	Mean percentage deviation system price and area price		
	Area 1	Area 2	Area 3
January 2007	0%	-1%	-1%
February 2007	3%	-4%	-4%
March 2007	0%	0%	0%
April 2007	0%	0%	0%
May 2007	2%	-2%	-2%
June 2007	7%	-8%	-8%
July 2007	34%	-35%	-35%
August 2007	68%	-56%	-55%
September 2007	27%	-8%	-9%
October 2007	4%	-4%	-2%
November 2007	-1%	0%	0%
December 2007	-2%	0%	2%
January 2008	1%	-1%	0%
February 2008	4%	-6%	-1%
March 2008	9%	-10%	-6%
April 2008	27%	-19%	-19%
May 2008	48%	-52%	-86%
June 2008	38%	-42%	-38%
July 2008	15%	-29%	-23%
August 2008	11%	-18%	-6%
September 2008	5%	-10%	-2%
October 2008	5%	-8%	-4%
November 2008	4%	-4%	-3%
December 2008	4%	-1%	-1%
January 2009	1%	0%	0%
February 2009	0%	-1%	-1%
March 2009	1%	-1%	-1%
April 2009	2%	-4%	-4%
May 2009	2%	-4%	-4%
June 2009	0%	-2%	-1%
July 2009	1%	0%	-3%
August 2009	8%	2%	2%
September 2009	20%	14%	14%
October 2009	5%	5%	6%
November 2009	2%	-1%	-1%
December 2009	4%	-16%	-16%

Appendix B Statistical tests

B.1 Bera-Jarque test of normality

Data samples are tested for normality using the Bera-Jarque test:

$$H_0\text{: } \textit{Normality} \quad \text{vs.} \quad H_1\text{: } \textit{Non-normality}$$

The test statistic for the parametric Bera-Jarque test is is calulated as:

$$W = N\left[\frac{\mathrm{S}^2}{6} + \frac{(EK)^2}{24}\right] \tag{6}$$

where

N	Number of observations
S	Skewness of observations
EK	Excess Kurtosos = Kurtosis of observations - Kurtosis of normal distribution

The test statistic W is tested against the χ^2-distribution with 2 degrees of freedom. In all analyses the null hypotesis of normality is rejected at a 5% confindece level.

B.2 One-Way ANOVA test for equal means

This tests the null hypotesis of equal means for k independent groups, each consisting of n observations. The test statistic is calulated as:

$$F = \frac{k(n-1)}{k-1} \frac{n\sum_{i=1}^{k}(\bar{Y}_{i\cdot} - \bar{Y}_{\cdot\cdot})^2}{\sum_{i=1}^{k}\sum_{j=1}^{n}(Y_{ij} - \bar{Y}_{i\cdot})^2} \tag{7}$$

where

Y_{ij}	The value of the jth observation from the ith group
$\bar{Y}_{i\cdot}$	The mean of the observations from ith group
$\bar{Y}_{\cdot\cdot}$	The mean of all observations
n	Number of observations in each group
k	Number of groups

The test statistic F is tested against the F-distribution with $(k-1)$ and $(k(n-1))$ degrees of freedom.

B.3 Kruskal-Wallis test for equal means

This tests the null hypotesis of equal means for k independent groups, each consisting of n_k observations. The test is a non-parametric rank-sum test. The test statistic is calulated as:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{N_i} - 3(N+1) \tag{8}$$

where

R_i	Sum of ranks for the ith sample
N_i	Number of observations in the ith sample
N	Total number of observations $\sum -i = 1^k N_i$
k	Number of samples

The test statistic H is tested against the χ^2-distribution with $(k-1)$ degrees of freedom.

B.4 Two-sample variance test for equality of variances

This tests the null hypotesis of equality of variances for two normally distributed and independent samples. The test statistic is calulated as:

$$F = \frac{s_1^2}{s_2^2} \tag{9}$$

where

s_i^2 Sample variance of the ith sample

The test statistic F is tested against the F-distribution with $(n_1 - 1)$ and $(n_2 - 1)$ degrees of freedom, where (n_i) is the number of observations in the ith sample.

B.5 Brown-Forsythe test for equality of variances

This tests the null hypotesis of equal variances for k independent groups, each consisting of n_k observations.The test statistic is calulated as:

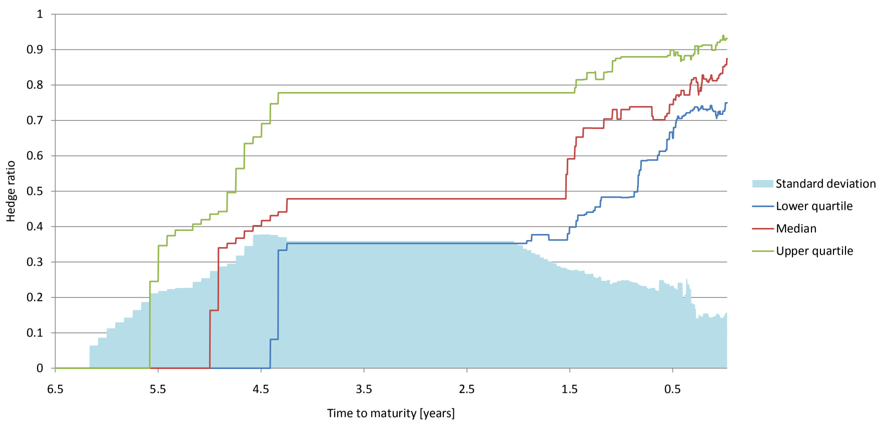
$$W = \frac{N-k}{k-1} \frac{\sum_{i=1}^{k} (Z_{i\cdot} - Z_{\cdot\cdot})^2}{\sum_{i=1}^{k} \sum_{j=1}^{N_i} (Z_{ij} - Z_{i\cdot})^2} \tag{10}$$

where

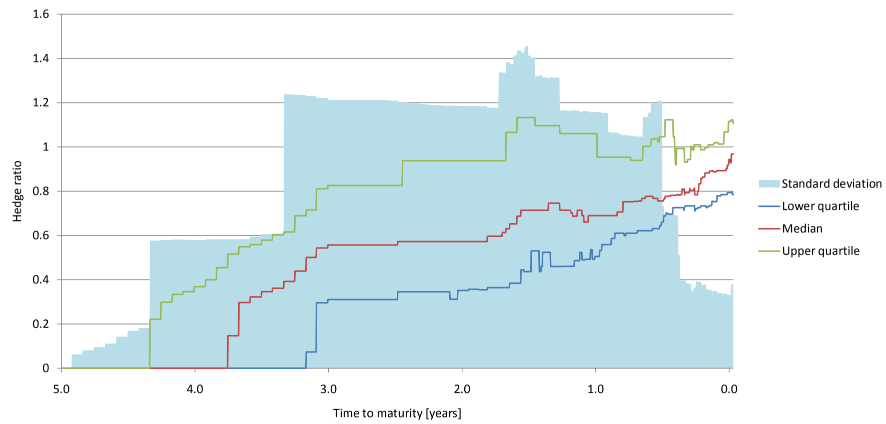
Y_{ij}	The value of the jth sample from the ith sample
$\tilde{Y}_{i\cdot}$	The mean of the ith sample
Z_{ij}	$\lvert Y_{ij} - \tilde{Y}_{i\cdot} \rvert$
$Z_{i\cdot}$	mean Z_{ij} for sample i, $\frac{1}{N_i} \sum_{j=1} N_i Z_{ij}$
$Z_{\cdot\cdot}$	mean of all Z_{ij}, $\frac{1}{N} \sum_{i=1}^{k} \sum_{j=1} N_i Z_{ij}$
N_i	Number of observations in the ith sample
N	Total number of observations $\sum -i = 1^k N_i$
k	Number of samples

The test statistic F is tested against the F-distribution with $(k-1)$ and $(N-k)$ degrees of freedom.

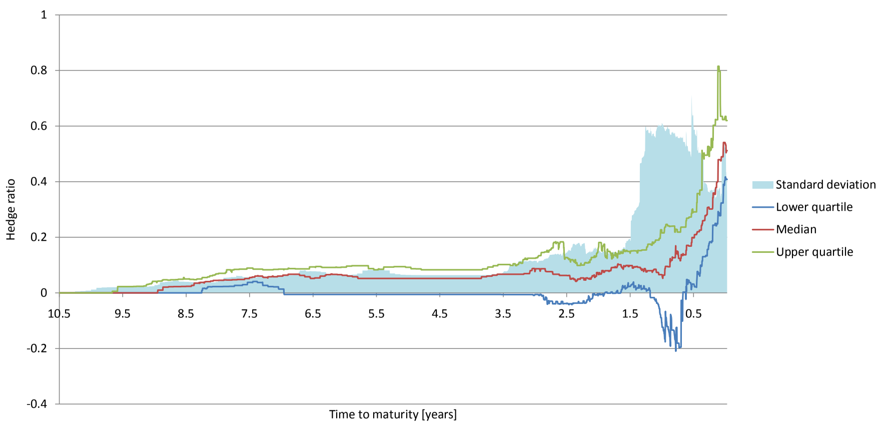
Appendix C Hedge ratio plots



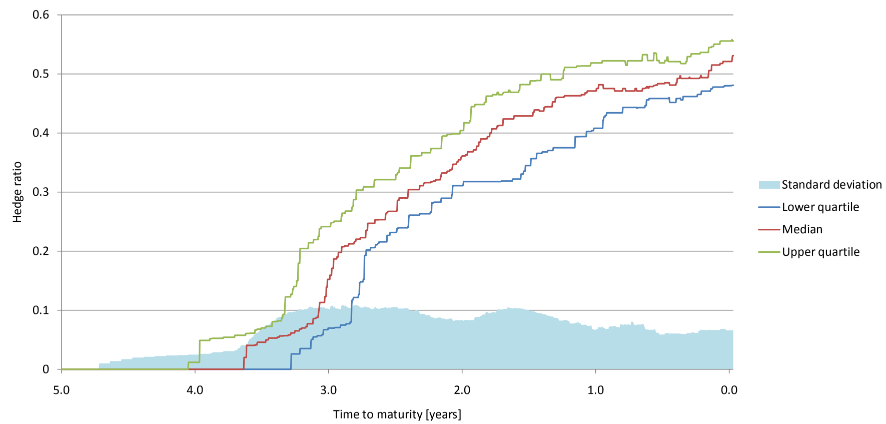
(a) Company 1 (group 1)



(b) Company 11 (group 1)

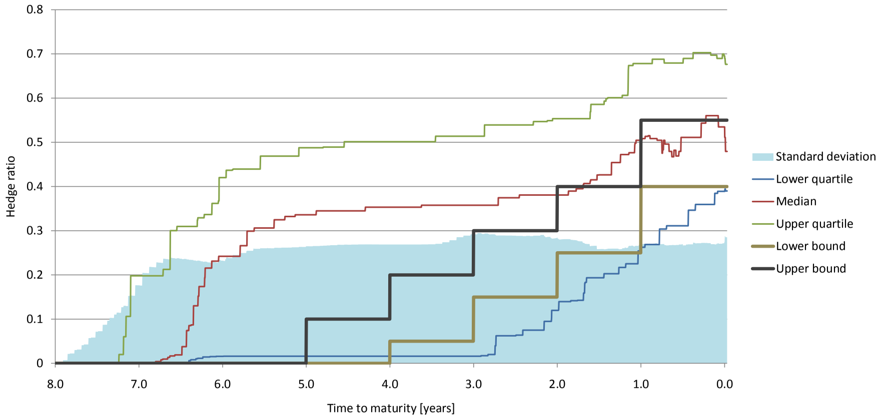


(c) Company 3 (group 2)

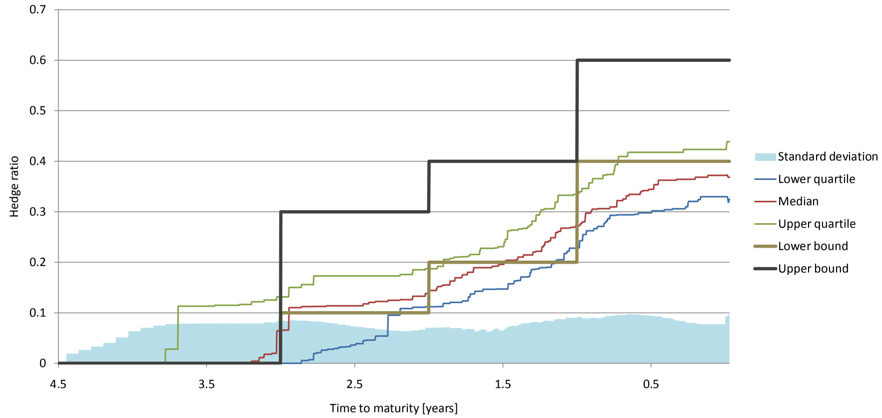


(d) Company 12 (group 2)

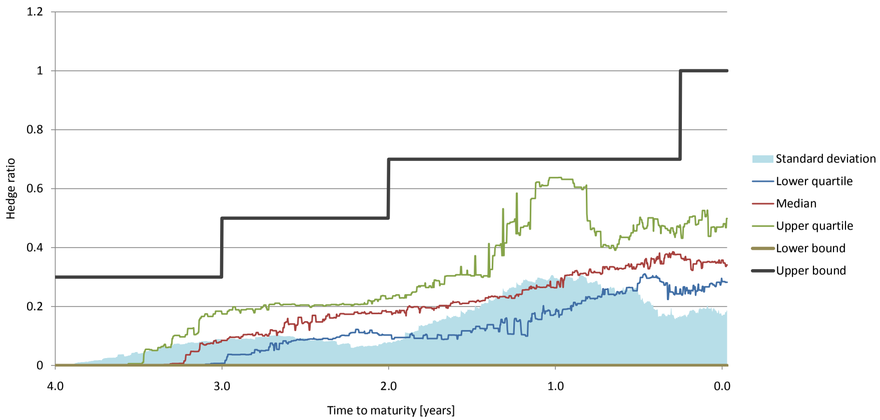
Figure 4: These figures plots expression (3) aggregated along the time series dimension. The vertical axis - hedge ratio - is the fraction of (forecasted) production that is hedged. The horizontal axis - time to maturity - is the residual time [years] before the delivery period starts. Since the plot is aggregated - 36 (30 for Company 1 and Company 11) monthly plots - the horizontal axis is relative to the maturity, not the absolute timeline. The three lines are respectively the lower quartile (25% quantile), median (50% quantile) and upper quartile (75% quantile) of the monthly plots while the area is the standard deviation between the monthly plots. The purpose of the quantiles is to give a general illustration of the hedging positions of each company during the period analyzed while the standard deviation illustrates the consistency of the hedging practice. The rapid fluctuations in the plots are due to the frequency of initiated transactions and - for some companies - updates of the simulated future production. Upper and lower bounds for the hedge ratio range are also provided for companies in group 3 and 4. These boundaries are given in the companies' hedging policies.



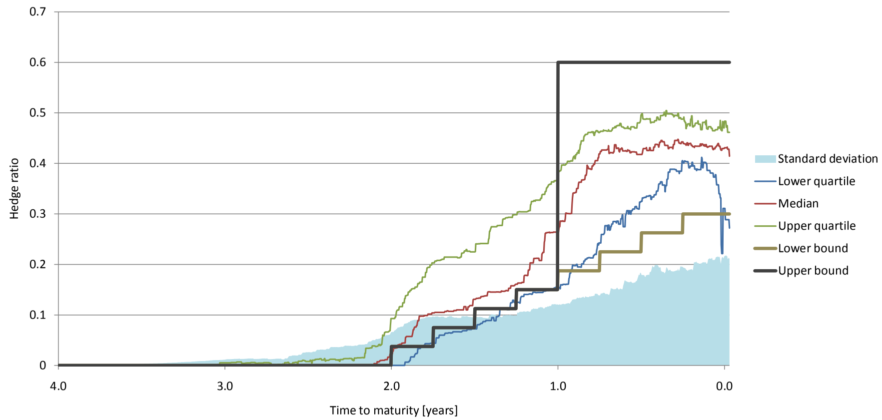
(e) Company 4 (group 3)



(f) Company 2 (group 4)

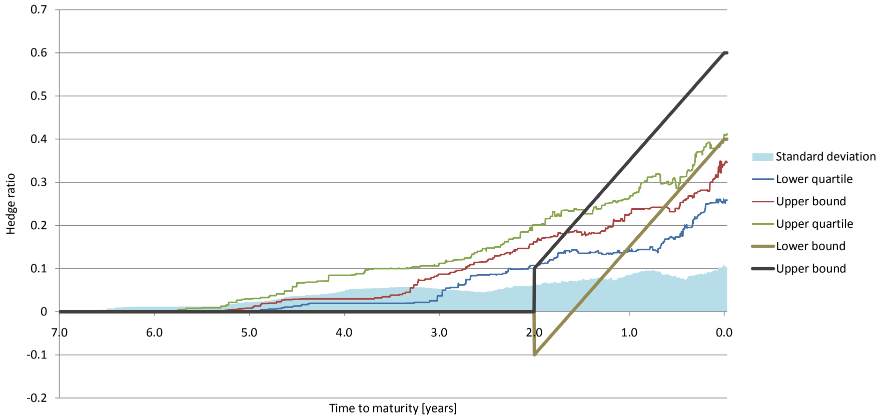


(g) Company 5 (group 4)

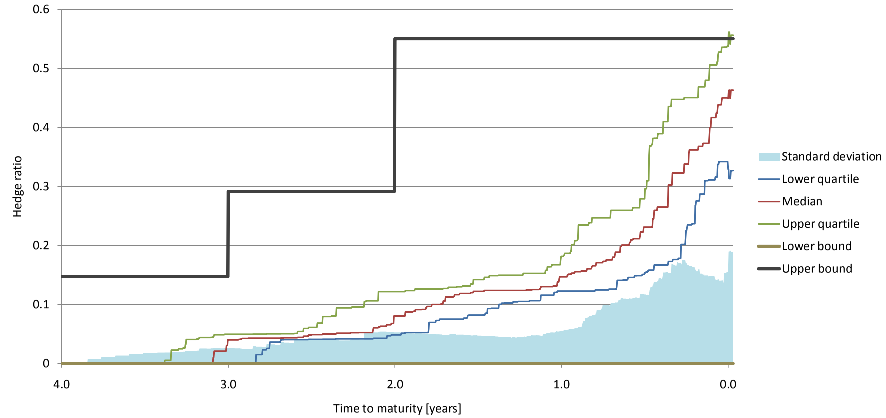


(h) Company 6 (group 4)

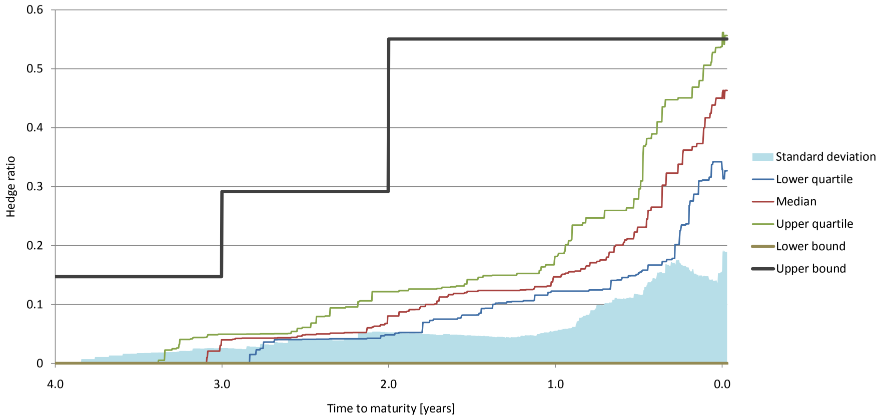
Figure 4: These figures plots expression (3) aggregated along the time series dimension. The vertical axis - hedge ratio - is the fraction of (forecasted) production that is hedged. The horizontal axis - time to maturity - is the residual time [years] before the delivery period starts. Since the plot is aggregated - 36 (30 for Company 1 and Company 11) monthly plots - the horizontal axis is relative to the maturity, not the absolute timeline. The three lines are respectively the lower quartile (25% quantile), median (50% quantile) and upper quartile (75% quantile) of the monthly plots while the area is the standard deviation between the monthly plots. The purpose of the quantiles is to give a general illustration of the hedging positions of each company during the period analyzed while the standard deviation illustrates the consistency of the hedging practice. The rapid fluctuations in the plots are due to the frequency of initiated transactions and - for some companies - updates of the simulated future production. Upper and lower bounds for the hedge ratio range are also provided for companies in group 3 and 4. These boundaries are given in the companies' hedging policies.



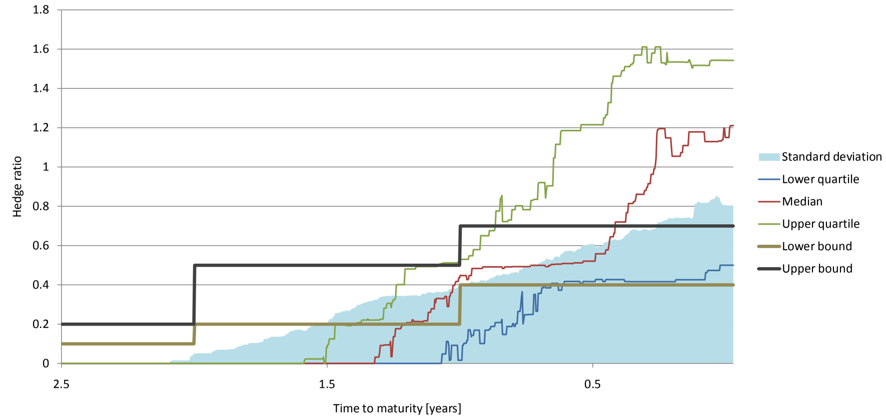
(i) Company 7 (group 4)



(j) Company 8 (group 4)



(k) Company 9 (group 4)



(l) Company 10 (group 4)

Figure 4: These figures plots expression (3) aggregated along the time series dimension. The vertical axis - hedge ratio - is the fraction of (forecasted) production that is hedged. The horizontal axis - time to maturity - is the residual time [years] before the delivery period starts. Since the plot is aggregated - 36 (30 for Company 1 and Company 11) monthly plots - the horizontal axis is relative to the maturity, not the absolute timeline. The three lines are respectively the lower quartile (25% quantile), median (50% quantile) and upper quartile (75% quantile) of the monthly plots while the area is the standard deviation between the monthly plots. The purpose of the quantiles is to give a general illustration of the hedging positions of each company during the period analyzed while the standard deviation illustrates the consistency of the hedging practice. The rapid fluctuations in the plots are due to the frequency of initiated transactions and - for some companies - updates of the simulated future production. Upper and lower bounds for the hedge ratio range are also provided for companies in group 3 and 4. These boundaries are given in the companies' hedging policies.