Norges Handelshøyskole

FIN11 Trading and Market Microstructure

Term paper

Predefined Information

Start date:	2020-11-03 09:00 AM	**Term:**	2020 12
End date:	2020-12-14 02:15 PM	**Assessment type:**	Norwegian 6-point scale (A-F)
Examination type:	Term paper (70%)		
SIS Code:	191 FIN11 1 O3 2020 12		
Internal assessor:	(Anonymised)		

Participant

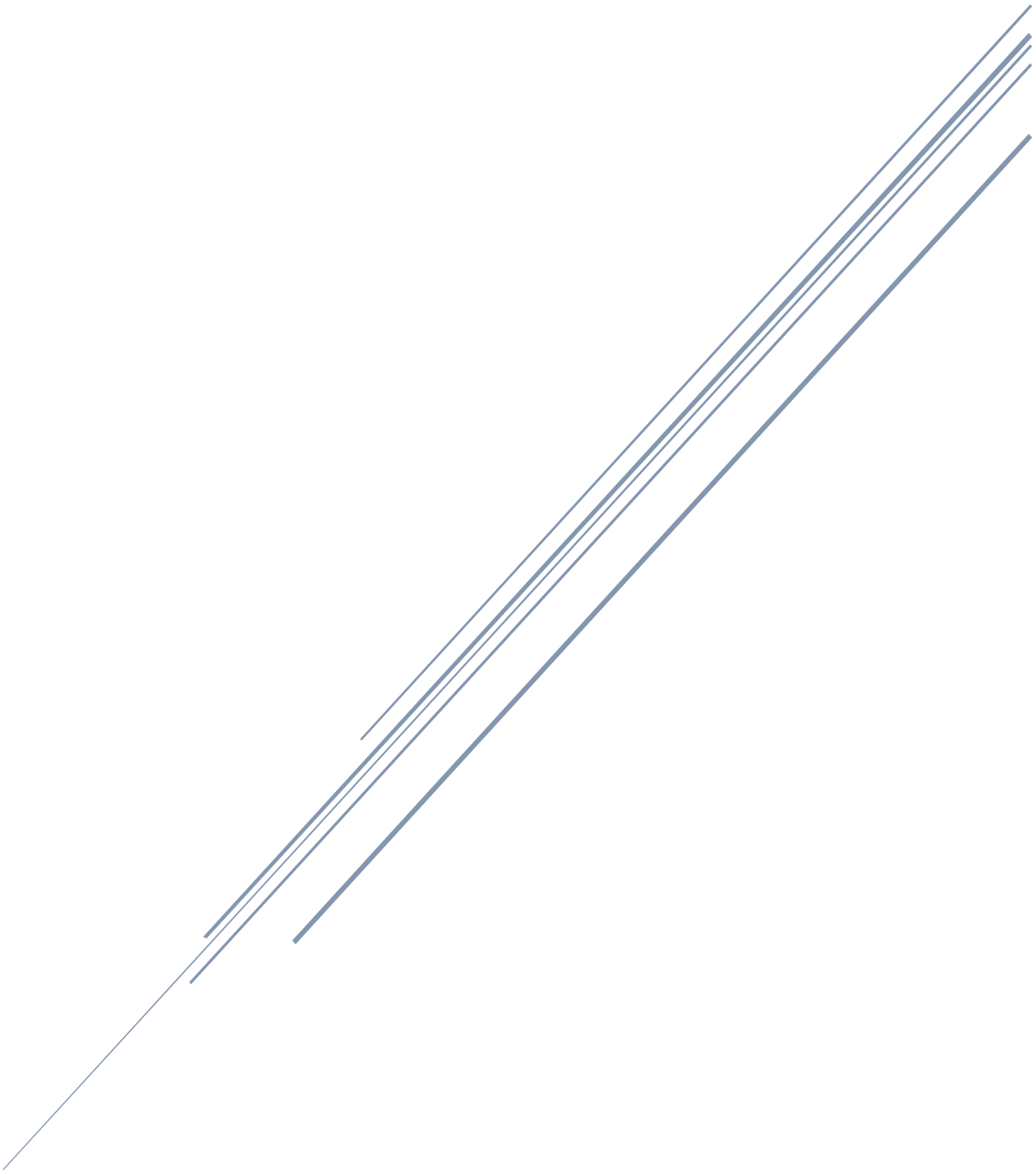
Candidate No.:	110003

Group

Group name:	(Anonymised)
Group number:	2
Other members:	110050, 110009, 110031

HEDGING WEATHER RISK WITH OPTIONS

FIN11 Exam Paper Fall 2020



Candidates: 110031, 110003, 110050, 110009

Words: 6406

Executive summary

Weather derivatives are used to hedge against weather-related financial losses in various industries worldwide, but this strategy is not employed in Norway to any significant extent (Benth, 2020). Therefore, we have investigated whether Scandinavia's largest waterpark, Bø Sommarland, could reduce its revenue volatility by hedging with precipitation call options. To investigate whether this option actually is of any relevance, we have (1) researched the weather derivatives market, and (2) created precipitation call options using the McIntyre pricing model. Furthermore, we have evaluated the potential of a Norwegian weather derivatives market.

We find that a hedging strategy based on a precipitation call option could benefit Bø Sommarland, but the positive effect on risk-adjusted returns is relatively small. Despite having a functioning weather derivatives market in the United States to imitate and potential benefits of hedging with weather derivatives, we conclude that it is difficult to get this market going in Norway. Significant obstacles include insufficiencies with the weather station network combined with Norway's varying topography, uncertainty regarding the pricing of weather options, and lack of incentives to use this market.

Table of Contents

Executive summary 1
Table of Contents 2
Introduction 3
Part 1: Weather Derivatives 4
The Emergence of the Weather Derivatives Market 4
Market Participants 4
Traditional Methods for Hedging Weather-Related Risks 6
Purchasing Process in the Primary Market 6
Considerations for Risk Managers 8
Weather Indices 8
Precipitation Options 10
Part 2: Creating a Precipitation Call Option for Bø Sommarland 11
Introduction 11
Choice of Case Subject 11
Methodology 11
Data 15
Findings 18
Pricing Using McIntyre 20
Limitations 24
Reflections 24
Weather Recording 24
Pricing 25
Incentives 25
Conclusion 26
References 28
Appendix 1 - Communication 31
Appendix 2 - All Hedging Results (1998-2019) 36

Introduction

«It has rained over 200% more than usual in June, hence the reduced profits" (Hanstad, 2012). This paraphrased quote was uttered by Bernt-Gunnar Berntsen, CEO of Bø Sommarland, after experiencing significantly reduced customer traffic compared to previous years. In 2005, the Chicago Mercantile Exchange (CME) estimated that nearly 70% of U.S. companies are affected by adverse weather conditions to different extents, and it is reasonable to assume that similar percentages could apply in other countries (Alexandridis & Zapranis, 2013). Weather derivatives are used to hedge against weather-related losses in various industries worldwide, but this strategy has not been employed in Norway to any significant extent (Benth, 2020). To investigate whether such a market could function in Norway, this thesis outlines the weather derivatives market's microstructure and investigates whether a Norwegian company could reduce its revenue volatility by hedging with precipitation call options. Scandinavia's largest waterpark, Bø Sommarland, will serve as our case company.

The paper is structured in two parts. Part 1 introduces the weather derivate market microstructure. This part aims to present the market participants and explain the essential characteristics specific to the weather derivatives market. Additionally, it outlines the purchasing process of a weather option. Part 2 investigates whether Bø Sommarland could reduce their revenue volatility with precipitation call options. We do this by creating a such an option and analyzing its effect on revenue volatility. We present our findings and disclose relevant limitations to the analysis. Lastly, we reflect upon the potential of a Norwegian weather derivatives market and provide a conclusion.

We have contacted various organizations and entities that have provided essential insights and data in our endeavor to acquire information. The CEO of Bø Sommarland's competitor Hunderfossen suggested using Bø Sommarland as a case subject, as he claimed the business is highly exposed to rainfall. CFO of Bø Sommarland, Iver Fyksen, then provided financial data for Bø Sommarland. We also corresponded with The Norwegian Meteorological Institute regarding weather station maintenance, data recording methods, and the topographical effects on precipitation. Additionally, we have consulted with Fred Espen Benth, a professor in financial mathematics from UiO. He specializes in mathematical finance in energy markets and is the author of *Modeling and Pricing in Financial Markets for Weather Derivatives.* Benth provided insight into the structure of the weather derivatives market on the CME. Transcripts are provided in the appendix.

Part 1: Weather Derivatives

The purpose of part 1 is to introduce the weather derivatives market. Part 1 has the following structure. Firstly, the emergence of the weather derivatives market will be presented. Secondly, the market participants and their motives will be explained. Thirdly, traditional methods used instead of weather derivatives will be examined. Afterward, the weather index concept will be explained, and examples of such indices will be presented. Lastly, important terminology and features of precipitation call options will be provided in preparation for the Bø Sommarland case.

The Emergence of the Weather Derivatives Market

The first weather derivative was constructed in 1996, and these financial instruments began modestly trading over the counter (OTC) in the following years (Weather Risk Management Association, 2020). The Chicago Mercantile Exchange introduced the first exchange-traded weather futures and options in 1999 (Akhilesh, 2019). Since its inception in the late 1990s, the weather derivatives market has grown substantially. The market's growth has mainly been in the United States, while Europe's development has been slower. Participants in this market represent various industries, and the CME is the world's largest weather derivative exchange. Today, the weather derivatives market predominantly consists of temperature-based contracts, which account for more than 80% of all weather trading (Alexandridis & Zapranis, 2013). However, there are products designed for other weather conditions such as wind, precipitation, and snow. Currently, the CME provides temperature indices for seven major U.S. cities, Amsterdam, London, and Tokyo. Indices for Oslo have been available in the past.

Market Participants

The primary market refers to the opening transaction of a weather derivative, while subsequent transactions are referred to as the secondary market. In the primary market, the buy-side is represented by a hedger, and the sell-side is represented by the party that writes the derivative. For the subsequent discussion, the option-writer will be referred to as an investor. In addition, a clearing broker and an exchange are usually included to facilitate the transaction (Jones, 2007). A description of the hedgers and investors and their motives for using weather derivatives will be conducted.

Hedgers

In the weather derivatives market, the hedger is the party whose revenue is affected by adverse weather conditions (Alexandridis & Zapranis, 2013). The hedger's income can be influenced because the weather affects the production process or because it changes consumer demand. According to the Weather Risk Management Association (2020), industries affected by weather include agriculture, construction, energy production, retail, and recreation. For example, farmers can purchase precipitation options to hedge against drought, and amusement parks could use them to hedge against low customer traffic in periods with high precipitation. Conditions favorable to one hedger could be detrimental to another, because of the weathers offsetting nature.

A weather option-based hedging strategy involves purchasing options that yield a profit if the weather conditions that reduce the revenues occur (Alexandridis & Zapranis, 2013). Effectively, the precipitation options can compensate the hedger for some of the losses incurred because of adverse weather conditions. With this strategy, the revenues are reduced slightly in periods of favorable precipitation levels because of the cost of acquiring the options. However, the losses can be reduced significantly in periods with unfavorable precipitation when the options can be exercised. A major benefit of this strategy is that it could result in a more stable and predictable income flow, potentially improving operational planning and making the business more efficient (Haugan & Rasmussen, 2019).

Investors

In the primary market, the hedger's counterparty in a weather derivative transaction is an investor. When a hedger and an investor decide to conduct a weather derivative transaction, the hedger's weather-related risk is transferred to the investor. Examples of investors include large banks, insurance companies, hedge funds, proprietary traders, and individual investors (Alexandridis & Zapranis, 2013).

There are two important reasons why certain investors are attracted to the weather derivatives market, specifically. Firstly, weather derivative payoffs are generally uncorrelated with other kinds of investments (Jewson & Brix, 2005). This may be favorable because investors can issue weather derivatives without increasing the overall company risk significantly. Additionally, the low correlation between the return on weather derivatives and other securities can make them useful for portfolio diversification (Edelweiss Group, 2020). Secondly, a portfolio of weather derivatives can be low-risk because of weather contracts'

potentially offsetting nature (Jewson & Brix, 2005). According to Jewson and Brix (2005), the weather derivatives market would ideally consist of hedgers collectively hedging against equal and opposite amounts of each weather-related risk. If this is the case, investors could effectively transfer risk between hedgers and have limited risk exposure.

Traditional Methods for Hedging Weather-Related Risks

Despite the potential benefits of a weather option-based hedging method, most businesses adopt other alternatives for decreasing revenue volatility. A more common choice for hedging weather-related risk is insurance, which serves some of the same purposes as an option (McDonald, 2013). The insured pays an insurance premium, and the insurer is obligated to pay compensation should the conditions covered in the insurance policy occur. Otherwise, insurance holds no value. An essential distinction between insurance and precipitation options is that insurance usually protects the ensured against less probable events, while options are better equipped to compensate for smaller and more frequent losses (Alexandridis & Zapranis, 2013). Also, precipitation options require less effort from the claimant when claiming the compensation itself because there is no possible claims dispute and no requirement for proving the loss (Coriolis Capital Limited, 2020). Furthermore, businesses who can diversify their product usually ensure that they have income sources that are not weather dependent. For instance, Hunderfossen Amusement park in Lillehammer circumvents the problems associated with periods of high precipitation by including indoor activities in their product. Lastly, surveys conducted by hospitality and tourism management professors SooCheong Jang and Chun-Hung Tang at Purdue University found a "lack of awareness and expertise" regarding weather derivatives in general (Haugan & Rasmussen, 2019).

Purchasing Process in the Primary Market

Weather derivative transactions are OTC transactions. This means that they are unlisted securities traded in a decentralized market, implying a more complex trading-process for the hedger. According to the Weather Risk Management Association (2020), a retail or recreation company that wants to hedge weather-induced revenue volatility with a weather option must go through the following process.

First, it must identify a correlation between low-revenue days and a specific weather condition measured at a particular weather station. Then it must quantify the weather risk by estimating the relationship between marginal financial losses and a numeric deviation from a weather index based on that station's measurements. This relationship determines the option's

tick-size, θ. Afterward, it must select the portion of the weather risk it wants to hedge and a maximum payout representing the worst-case scenario. Websites like WeatherXchange.com (2020) allow hedgers to send pricing requests to multiple option writers.

Although the hedger in principle can contact a risk-taker directly, it is more favorable to do so through a specialized broker. The broker then connects the hedger with an option writer. It is also common practice for specialized brokers to provide advice in the structuring of the contract. Like any other transaction, both parties in this type of OTC transaction assume counterparty risk (Mitchell, 2020). Therefore, both the hedger and risk-taker benefits from mitigating counterparty risk by clearing the transaction through a clearing agency established by an exchange. For weather derivatives, the CME provides this service through its clearinghouse, CME Clearing (CME Group, 2020). By acting as an intermediary through its clearinghouse, the CME becomes the buyer to the seller and the seller to the buyer, thereby guaranteeing settlement.

To trade through the CME, the hedger must conduct a block trade (CME Group, 2020). A block trade is a privately negotiated transaction executed via brokers (Corporate Finance Institute, 2020). When the parties agree to the transaction, the broker reports to CME Clearing, which then clears the transaction (CME Group, 2009). Eligible CME clearing brokers are licensed and specialized in the weather derivatives market. These weather derivative block trades usually have a minimum block threshold and a specified reporting window, which currently are twenty contracts and fifteen minutes, respectively (CME Group, 2020). The transaction process is shown in *figure 1*.

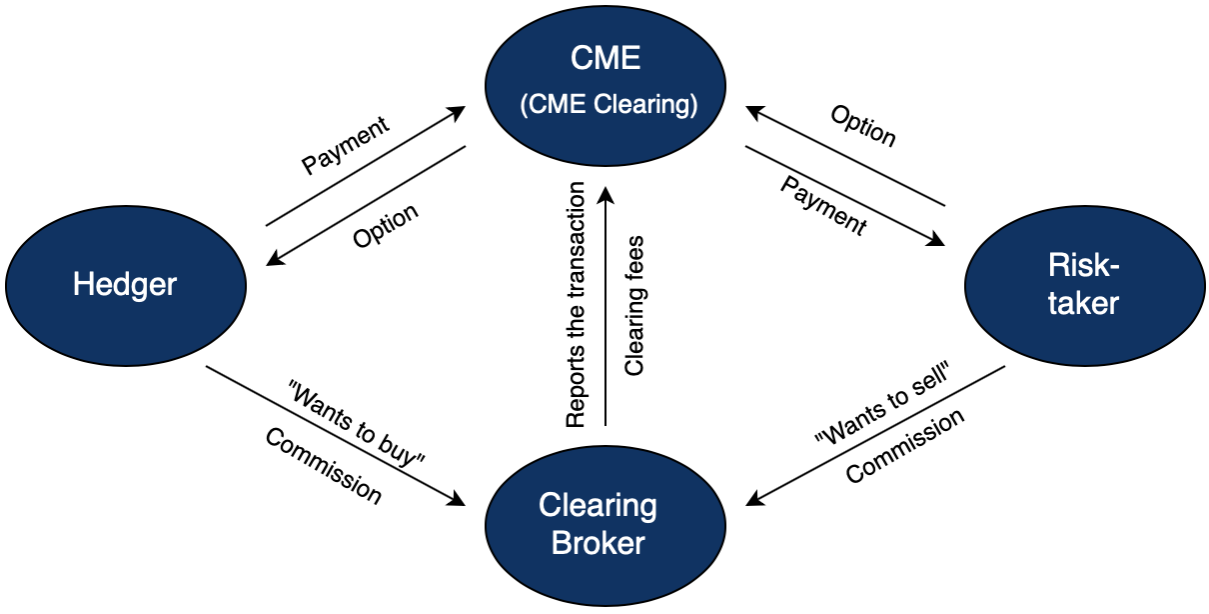


Figure 1: Purchasing process.

An important note is that purchasing weather options through the CME requires the option to be based on an underlying weather index currently listed on the exchange. Since the CME currently only lists temperature indices, other weather derivatives cannot be traded through the CME. This implies that traders who trade derivatives based on indices not listed on the CME cannot clear the transaction through the CME. This increases the counterparty risk, likely attaching a higher premium to the transaction (Murphy, 2019).

Considerations for Risk Managers

Weather risk is unique because it is highly localized, uncontrollable, and not precisely predictable despite advances in meteorological science. These limitations to weather contracts give risk managers implications on both sides of the transaction (Alexandridis & Zapranis, 2013). According to Manfredo and Richards (2009), risk managers face basis risk and geographical spatial risk.

Basis risk is the risk of a discrepancy between income-loss due to weather events and payoff. Since the payoff of a weather option depends on a weather index and not the money lost due to unfavorable weather, it is unlikely that the payoff will exactly compensate the loss (Jewson & Brix, 2005). With a high correlation between income-loss and unfavorable weather, basis risk decreases. Spatial risk is geographical and is the difference between the weather measured at the weather station for the underlying index and the actual weather at the hedger's location. In correspondence with Hildegunn Nygård (2020), from the Norwegian Meteorological Institute, we found that spatial risk is particularly relevant in countries with varying topography because this causes weather conditions to be more localized.

Weather Indices

Weather is an untradable asset. Therefore, weather derivatives use weather indices as the underlying. Weather indices function as a method for quantifying weather conditions, which enables ascribing monetary value. Because different types of hedgers are exposed to different weather-related risks, there is a need for different weather indices. Both weather indices covering different weather conditions and variations of indices within the same weather category are needed. Currently, only temperature-related indices are offered on the CME, but considering this paper focuses on hedging with precipitation options, both temperature and precipitation indices are presented below.

HDD/CDD: Heating and cooling degree day indices measure how much the daily average temperature (DAT) deviates from a base temperature. According to Alexandridis and

Zapranis (2013) the DAT is the average of the temperature high and low on a given day, usually 65F in the U.S. and Canada and 18C in Europe (Weather.gov, 2020). These indices are designed to quantify energy demand for buildings' heating and cooling. They are currently listed on CME's weather product slate for 7 U.S. cities, Amsterdam, and London (CME Group, 2020).

$$HDD = \int_{d_1}^{d_2} \max(18 - T(i), 0)\, di \qquad CDD = \int_{d_1}^{d_2} \max(T(i) - 18{,}0)\, di$$

ARD: An accumulated rainy days index measures the sum of rainy days, R.D., over a period. According to Coriolis Capital Limited (2020), the daily precipitation threshold for what is considered a rainy day is 3mm. Other sources accept user-specified thresholds (WeatherXChange, 2020).

$$ARD = \sum_{i=1}^{n} RD_i \ , \qquad where \begin{cases} RD_i = 0, & if\ daily\ precipitation\ is \geq 3mm \\ RD_i = 1, & if\ daily\ precipitation\ is < 3mm \end{cases}$$

C.R.: A cumulative rainfall index measures the accumulated daily precipitation, R_i, during a specified period (d_1, d_n). This index was previously offered on the CME, and the precipitation was measured in inches. The precipitation call option for Bø Sommarland will be based on this index.

$$CR = \sum_{i=d_1}^{d_n} R_i$$

Precipitation Options

In preparation for the Bø Sommarland case, it is necessary to explain the precipitation option's characteristics.

Table 1: Terminology.

Terminology	
Type	**Call options** provides the right to buy. Put options provide the right to sell.
Exercise	The hedger exercises its right to buy or sell the underlying asset.
Exercise style	American-, Bermuda-, **European-Style**. European options can only be exercised at expiration.
Expiration/ Maturity	Date and time when the option contract expires.
Strike Level, K	Predetermined level at which the option can be exercised.
Premium	Price of the option and compensation to the option writer.
Risk-Free Rate	Interest rate in a risk-free account, e.g. savings account or government bonds.
Underlying Asset	The asset upon which the option's price is based. Weather derivatives uses weather indices.
Index Value	Value of the index, e.g. **mm of precipitation**, average wind speed or average temperature.
Tick size, θ	Marginal monetary value of the difference between index value and strike level.
Payoff	Purchasers yield from the option should it be exercised.
Profit	**Purchaser/Hedger:** Payoff - Future Value of Premium, **Writer:** Future Value of Premium - Payoff.
Maximum Payout	Upper limit for option payoff, determined by the hedgers worst case scenario.
Weather Station	Provides weather data for creating the weather index.

An option contract provides the buyer with the right, but not the obligation, to buy or sell an underlying asset at a predetermined price in the future (McDonald, 2013) .The predetermined price is referred to as the strike price. The option buyer will exercise the option depending on how the underlying asset's value develops relative to the strike price. The option writer is obligated to accommodate the buyer's choice, and therefore requires compensation for being in a disadvantageous position. This compensation is called the option premium (McDonald, 2013). An important distinction between a precipitation option and conventional options is that the underlying asset, precipitation, cannot be traded. Followingly, the value of a precipitation option is derived from a precipitation index, and the strike price is substituted with a strike level, K. Aside from this, the options work the same.

The option created in part 2 is a European-style call option. Call options provide the purchaser with the right to buy the underlying precipitation index at the strike. European-style options only enable exercising the option at expiration (CME Group, 2020).

Part 2: Creating a Precipitation Call Option for Bø Sommarland

Introduction

The purpose of part 2 of the paper is to investigate whether a Norwegian weather-exposed company could employ a hedging strategy involving precipitation options to reduce revenue volatility. Part 2 has the following structure. Firstly, we will explain the reason for choosing Bø Sommarland as the case subject. Secondly, the selected methodology regarding the precipitation index and pricing model is presented. Thirdly, we will present precipitation data and operating income for Bø Sommarland. Afterward, findings will be presented. The findings include a regression analysis of the relationship between precipitation and revenues for Bø Sommarland, and how the McIntyre pricing method has been used to price the precipitation call option. Lastly, a disclosure of relevant limitations regarding the case is provided.

Choice of Case Subject

We contacted several companies, which we thought could be affected financially by adverse weather conditions, searching for a suitable subject company for our case. Various golf clubs, the Fløien Folkeresturant, and the Norwegian Ice Cream Truck were contacted with little success before we decided to direct our attention towards amusement parks. After communicating with the CFO of Tusenfryd and the CEO of Hunderfossen, two of Norway's most famous amusement parks, it became clear that Bø Sommarland would be a suitable choice. Hunderfossen's CEO stated during a phone conversation that "Bø Sommarland's revenues probably plummet like a rock by the first drop of rain" (Høstmælingen, 2020). Tusenfryd's CFO, who is also the CFO of Bø Sommarland, also admitted in an e-mail that Bø Sommarland's product is a lot more sensitive to adverse weather conditions than Tusenfryd's product (Fyksen, 2020).

Methodology

Precipitation Index

In the absence of Norwegian precipitation indices, we have created a cumulative rainfall (C.R.) index specifically for the Bø Sommarland area. This index will function as the base for the precipitation call option.

The $\overline{CR}_Y$ index is based on the C.R. index presented in part 1. However, we have added a component to the equation allowing us to calculate the average cumulative seasonal precipitation based on observations dating back to 1969. The precipitation indices previously listed on the CME were based on precipitation measured in inches, but we will use the metric system instead to accommodate the Norwegian market. The average cumulative rainfall will be measured as seasonal precipitation between June 7th (d_1) and August 15th (d_m) in each year since 1969. These dates are the opening and closing dates for Bø Sommarland.

$$\overline{CR}_Y = \frac{1}{n} * \sum_{t_1}^{t_n} \sum_{d_1}^{d_m} R_{td}$$

Table 2: Notation.

Notation	
$\overline{CR}_Y$	Average Seasonal Precipitation, Year Y
Y	Current Year
t_1	Year 1, (1969)
n	Number of Years, Y- t_1
d_1	Day 1, (7. June)
m	Number of Days, (7. June - 15. August = 70 days)
R_{td}	Precipitation on Day d in Year t (millimeters)

Weather stations may fail to record weather because of break downs, problems with the GSM network, station replacement or termination, maintenance, and during troubleshooting (Nygård, 2020). Having a complete dataset is integral for creating a functioning index. Alexandridis' and Zapranis' method (2013) for filling missing datapoints is illustrated below, and is used for this purpose in the analysis. The method assumes that replacing missing datapoints with the average value from the seven preceding and following days is sufficiently accurate. Basing an index on data from multiple weather stations within proximity to the hedger might limit the loss of datapoints, hence making the index's database more robust.

$$Precipitation_{d,avg} = \frac{\sum_{j=1}^{7} Precipitation_{d-j} + \sum_{j=1}^{7} Precipitation_{d+j}}{14}$$

To limit spatial risk, it is necessary to collect data from weather stations within a reasonable distance from Bø Sommarland. The Norwegian topography makes weather, and especially precipitation, highly localized. Even small geographical distances between the hedger and the weather station can cause the station to record different weather conditions than what the hedger is experiencing. Spatial risk must be accounted for to avoid errors in the hedging strategy and the derivative valuation process (Alexandridis & Zapranis, 2013).

McIntyre Pricing Model

In contrast to temperature, which is relatively predictable because of seasonal regularities, precipitation occurs more irregularly. Difficulties with developing a mathematical model that can estimate precipitation at a specific location accurately are the main reasons why it is complicated to price precipitation derivatives. Resultingly, there is no particular standard pricing model for precipitation derivatives. Pricing uncertainty introduces increased risk for both parties in the contract, resulting in higher premiums.

Although there is no standard pricing model for precipitation derivatives, a wide selection of methods exists. Methods for pricing precipitation options include the indifference pricing method by Xu, et al. (2008), Monte Carlo simulations, modified versions of the Black-Scholes method, and the McIntyre pricing method as used by Leggio (2007). The traditional Black-Scholes option pricing method is commonly used for pricing options based on a tradable underlying asset. However, it falls short when pricing weather derivatives because of the untradable underlying.

This research paper will use the McIntyre pricing method to exemplify whether a Norwegian business can use precipitation derivatives to their advantage. We chose this model because of its analytical simplicity and because it is mathematically intuitive. However, it might not be as accurate as other more complex pricing models because it accounts for less factors (Leggio, 2007). The McIntyre pricing model assumes that precipitation over time follows a normal distribution, and is based on a closed form solution derived to describe the fair value of a derivative (McIntyre, 1999). The model follows the equation illustrated below.

$$WC = \varphi(m - K)N\left(\frac{\varphi(m - K)}{\sigma}\right) + \sigma^2 P(K)$$

Table 3: Notation.

Notation	
WC	Option Premium
$\varphi = \pm 1$	1 = Call Option / -1 = Put Option
m	Mean Precipitation
K	Strike Level
$N()$	Cumulative Standard Normal Distribution
σ	Standard Deviation
P	Probability Density Function for a Standard Normal Random Variable

To illustrate the different risk-profiles Bø Sommarland might have, the strike level will be set at four different values. From the purchaser's perspective, the risk will be the lowest when the strike level is set close to the mean precipitation. When the deviation between the strike and the mean increases, so does the purchaser's risk. From the writer's perspective, the risk changes in the opposite direction. Hence, the premium increases when the strike level is set closer to the mean precipitation. Using different strike levels will also illustrate how the hedging strategy's costs and effect change relative to the strike level.

The payout from the precipitation option would add to Bø Sommarland's revenues as described in the following equation. We have not accounted for opportunity costs.

$$R = SR - WC + Y$$

Table 4: Notation.

Notation	
R	Total Revenues
SR	Sales Revenues
WC	Option Premium
Y	Option Payoff = θ * *MAX(0; Index Value - K)*

In *table 4*, Y is the product of the tick-size, θ, and the difference between the index value (actual precipitation in mm) and the strike level. The tick-size is the monetary value for each increment the index value exceeds the strike level. The option purchaser earns a profit if the payoff is larger than the future value of the premium. It is important to note that volatility in the McIntyre method is based on the price-maker's estimates of the option's real volatility.

Therefore, it might be a partially subjective input. Implied volatility thus corresponds to the premium.

Data

Precipitation

The precipitation data is collected from the Norwegian Meteorological Institute's website, seklima.no. We found three weather stations measuring daily precipitation within 8.2 kilometers from Bø Sommarland: Bø, Lifjell, and Gvarv. Despite all stations having missing data, we were able to create a complete precipitation dataset using Alexandridis' and Zapranis' ± seven days average formula and by collecting data from all three stations.

We will examine the precipitation during the following three intervals: 1969-2019, 1998-2019, and 2010-2019. The precipitation data from the first interval will be the basis of the cumulative rainfall index, and the data from the last two intervals will be used in the regression analysis. The precipitation data in the interval 2010-2019 is measured during the opening hours of Bø Sommarland, as recommended by the Weather Risk Management Association (2020). *Table 5* includes descriptive statistics of the precipitation data for each interval. The purpose of the table is to demonstrate how precipitation varies in each interval.

Table 5: Descriptive precipitation statistics.

Variable	Mean (mm)	Std.Dev. (mm)	Min. (mm)	Max. (mm)	Skewness	Kurtosis
Seasonal Precipitation (1969-2019)	261,1	81,5	100,7	435,4	0,0535	-0,4903
Seasonal Precipitation (1998-2019)	241,7	79,98	114,7	435,4	0,3395	-0,3067
Seasonal Precipitation During Opening Hours (2010-2019)	68,6	44,99	68,6	200,8	0,4179	-1,3036

From *table 5*, we observe that all intervals have skewness that is approximately symmetric. When looking at kurtosis, there is a bigger difference. The Kurtosis can be described as platykurtic, meaning that the excess kurtosis is lower than 0, as shown in the descriptive statistics. This means that the precipitation data have thinner tails than a normal distribution. Followingly, this means there are less extreme positive or negative events for lower values of excess kurtosis.

Figure 2 shows seasonal precipitation from 1969-2019 with the black line and precipitation during opening hours from 2010-2019 with the blue line. Because the McIntyre pricing model assumes that precipitation follows a normal distribution, we ran a Shapiro Wilk test on the precipitation data from the interval between 1969-2019 to confirm if this assumption holds. The Shapiro Wilk test for normality on the precipitation data was accepted at a 5% level, with test statistics of 0.98496 and a p-value of 0.7797. This indicates that the precipitation data follows a normal distribution, enabling us to use the McIntyre pricing model.

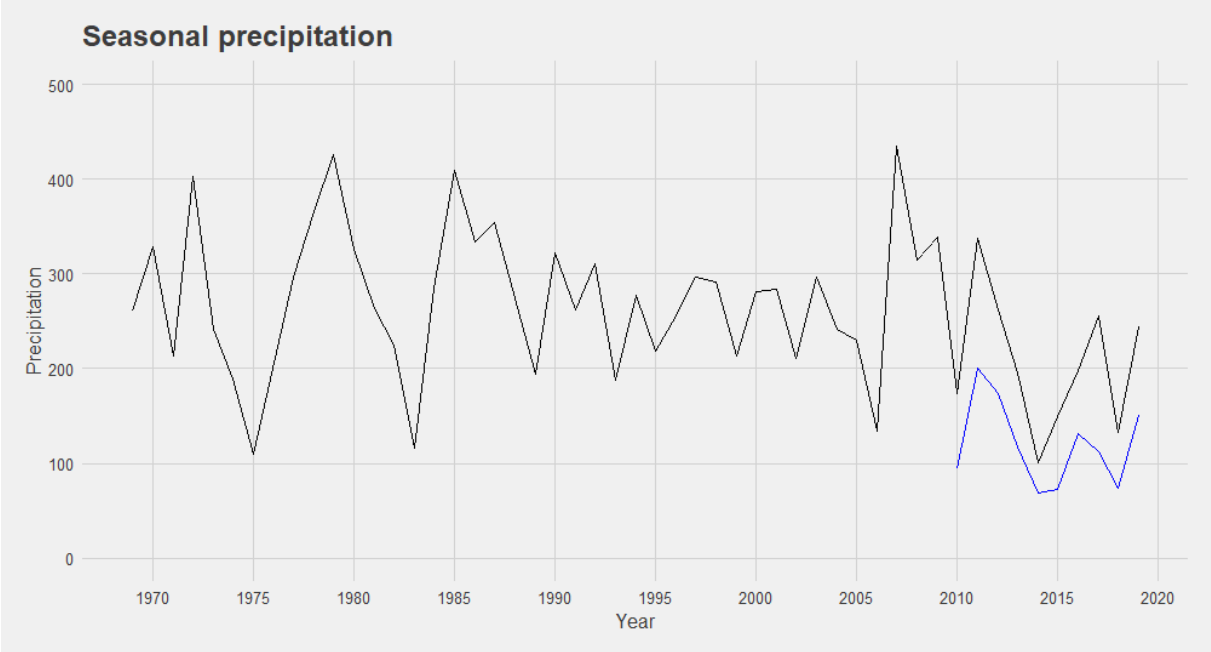


Figure 2: Seasonal Precipitation.

The Shapiro Wilk test has been run for the other intervals as well, yielding similar results. *Figure 3* shows the QQ-plot for the seasonal precipitation, further strengthening the case of a normal distribution.

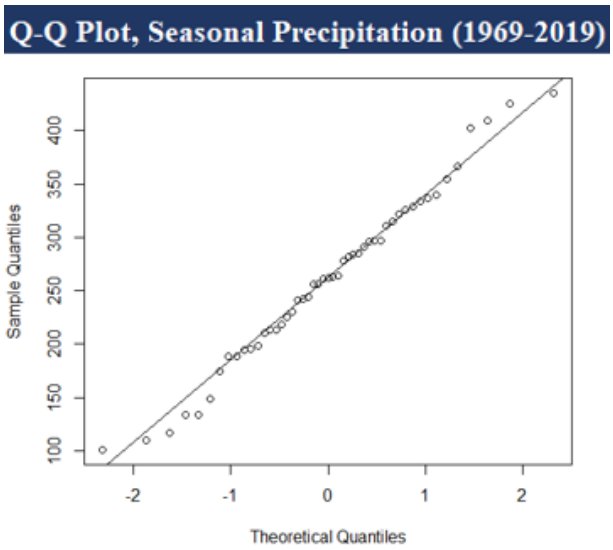
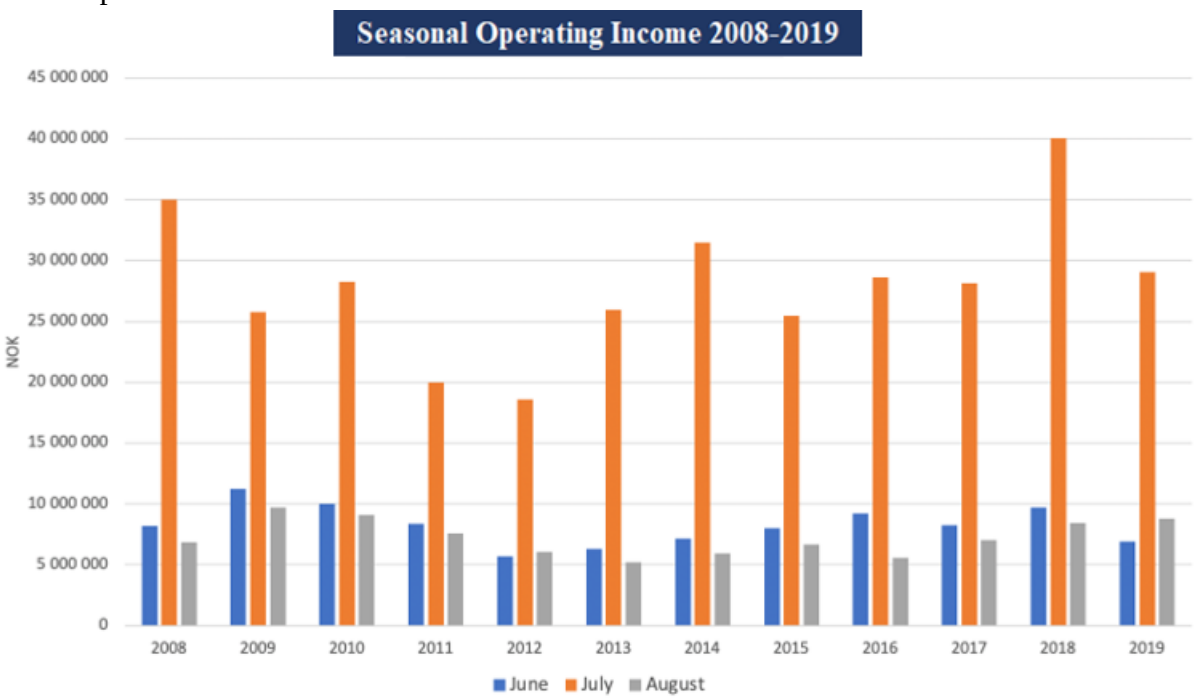


Figure 3: Q-Q Plot, Seasonal Precipitation.

Financial Data

We were provided with data on Bø Sommarland's monthly operating income from 2008-2019 from Iver Fyksen, CFO of Bø Sommarland, and collected annual data dating back to 1998 from proff.no.



Variable	Mean (kr)	Std.Dev. (kr)	Min. (kr)	Max. (kr)	Skewness	Kurtosis
Seasonal Operating Income	43 525 652,51	6 850 292,63	30 360 208,71	58 127 412,76	0,40	-0,28

Figure 4: Seasonal Operating Income 2008-2019.

Descriptive statistics for the operating income from 2008-2019 is shown in *figure 4*. The mean operating income is approximately 43.5 million NOK, with a corresponding standard

deviation of 6.9 Million NOK. The minimum operating income is 30.3 million NOK, and the maximum operating income is 58.1 Million NOK.



Variable	Mean (kr)	Std.Dev. (kr)	Min. (kr)	Max. (kr)	Skewness	Kurtosis
Annual Operating Income	42 661 590,91	6 459 850,81	30 360 208,71	58 127 412,76	0,64	0,39

Figure 5: Annual Operating Income 1998-2019.

The annual operating income for Bø Sommarland is equal to the seasonal numbers because the waterpark is only open during the summer season, from June 7th to August 15th. Therefore, the annual operating income from proff.no is used in the interval 1998-2007, and the data received from Bø Sommarland's CFO in the interval between 2008-2019. The descriptive statistics for the annual operating income are shown in *figure 5*. There is a large spread from maximum operating income of 58.1 million NOK and minimum operating income of 30.4 million NOK, with a corresponding standard deviation of 6.5 million NOK.

Findings

Regression

Using a precipitation option will only reduce revenue volatility if there is a correlation between precipitation and revenues. Therefore, it is necessary to confirm whether such a relationship exists or not. We found a linear regression model to be suitable and conducted a linear regression on the historical precipitation data in two different models. The purpose for testing two regression models is to determine which one is the most suitable.

1. Seasonal revenue and rain during the opening hours + 1 hour (before opening/after closing) for the season. (2010-2019)
2. Seasonal revenue and seasonal mean precipitation (1998-2019)

Table 6: Regression models.

Model	R-Squared	Adjusted R-Squared	P-Value
(1): 55 319 970 - 106 765 * Precipitation	0,415	0,342	0,0445
(2): 51 620 769 - 39 091 * Precipitation	0,224	0,183	0,0304

Table 6 shows that precipitation has significant effect on revenues at a 5% significance level. However, there is a clear difference in the variance explained by the different models. The R-Squared is 0,415 in model 1 and 0,224 in model 2.

The Weather Risk Management Association (2020) states that an hourly-based index fits businesses in the recreational sector, such as Bø Sommarland. Therefore, it could have been appropriate to use model 1. However, our dataset would not provide enough datapoints to base the pricing model on. For that reason, the second regression model is used in the pricing model because hourly precipitation data from 2010 and later are severely lacking. Model 2 shows a statistical significance and is based on more observations, making it more suitable despite the explained variance being lower than with model 1. From *figure 6* below, we can observe the how revenue and precipitation changes over the years from 1998 to 2019.

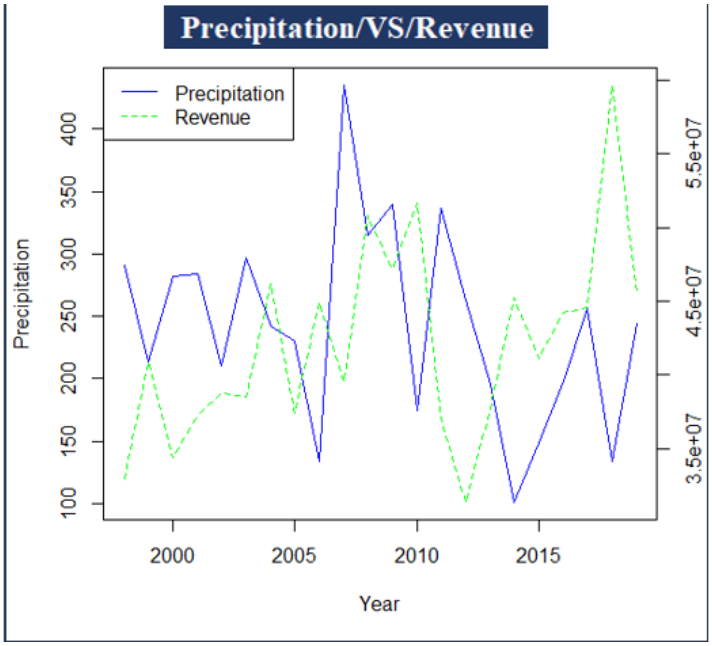


Figure 6: Precipitations and Revenue.

Pricing Using McIntyre

In our analysis, we have set the four strike levels at μ, μ+0.5, μ+σ, and μ+2σ. The purpose is to illustrate the trade-off between the level of risk a business owner wishes to hedge and the premium. The regression on seasonal revenue (1998-2019) shows that for each mm of precipitation, Bø Sommarland's revenues are reduced by NOK 39 091. Therefore, this number is used as the tick-size, θ. Furthermore, we assume that the option has to be bought between summer-seasons to adjust the index, and that the expiration date would be on August 15th. The purchaser's risk is limited to the premium payment, and the writer's risk is essentially limitless (McDonald, 2013). Thus, weather options usually include a maximum payout cap to protect the parties from extreme weather conditions, but this is not included in our example. Since the weather index changes over the years, so does the premium. This variation in mean precipitation, and how the premium changes accordingly, can be observed in the tables below and in appendix 2.

Table 7:Hedging with different strike levels, 2007-2009.

Results 2007		mm precipitation	435		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				39 484 000	39 484 000
μ	268	257 862	6 538 730	39 484 000	45 764 867
μ+0.5σ	306	144 869	5 077 566	39 484 000	44 416 697
μ+σ	343	83 002	3 616 403	39 484 000	43 017 401
μ+2σ	418	31 496	694 075	39 484 000	40 146 579
Results 2008		mm precipitation	315		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				50 804 000	50 804 000
μ	273	277 843	1 639 815	50 804 000	52 165 972
μ+0.5σ	312	156 399	104 115	50 804 000	50 751 716
μ+σ	351	89 747	0	50 804 000	50 714 253
μ+2σ	430	34 027	0	50 804 000	50 769 973
Results 2009		mm precipitation	339		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				47 154 000	47 154 000
μ	274	273 872	2 554 391	47 154 000	49 434 519
μ+0.5σ	313	154 106	1 033 360	47 154 000	48 033 253
μ+σ	352	88 405	0	47 154 000	47 065 595
μ+2σ	429	33 524	0	47 154 000	47 120 476

Table 7 illustrates how the portfolio value would differ from the no-hedge strategy if the four different call options would have been implemented in 2007-2009, where precipitation exceeded several of the strike levels. These years are good examples of how Bø Sommarland could be compensated for precipitation above strike levels. In 2007, the call option with a strike level of 268mm would give the option purchaser a payout of 6.5 million NOK. On the

other hand, our findings suggest that in most of the last 22 years, the seasonal precipitation-levels do not exceed the strike levels set in our model, and *table 8* of 2017-2019 illustrates this matter.

Table 8: Hedging with different strike levels, 2017-2019.

Results 2017		mm precipitation	256		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				44 565 000	44 565 000
μ	264	290 795	0	44 565 000	44 274 205
μ+0.5σ	305	163 881	0	44 565 000	44 401 119
μ+σ	345	94 127	0	44 565 000	44 470 873
μ+2σ	426	35 670	0	44 565 000	44 529 330
Results 2018		mm precipitation	133		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				59 696 000	59 696 000
μ	264	286 189	0	59 696 000	59 409 811
μ+0.5σ	304	161 220	0	59 696 000	59 534 780
μ+σ	344	92 569	0	59 696 000	59 603 431
μ+2σ	424	35 085	0	59 696 000	59 660 915
Results 2019		mm precipitation	244		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				45 464 000	45 464 000
μ	261	293 360	0	45 464 000	45 170 640
μ+0.5σ	302	165 364	0	45 464 000	45 298 636
μ+σ	343	94 996	0	45 464 000	45 369 004
μ+2σ	424	35 995	0	45 464 000	45 428 005

When seasonal precipitation is below the strike level, the precipitation option yields no payoff. This would have resulted in a lower portfolio-value at the end of the year than the historic operating income without purchasing any call options. *Figure 7* below illustrates specifically how the 2019 call- option with a strike set at 261mm would function in practice.

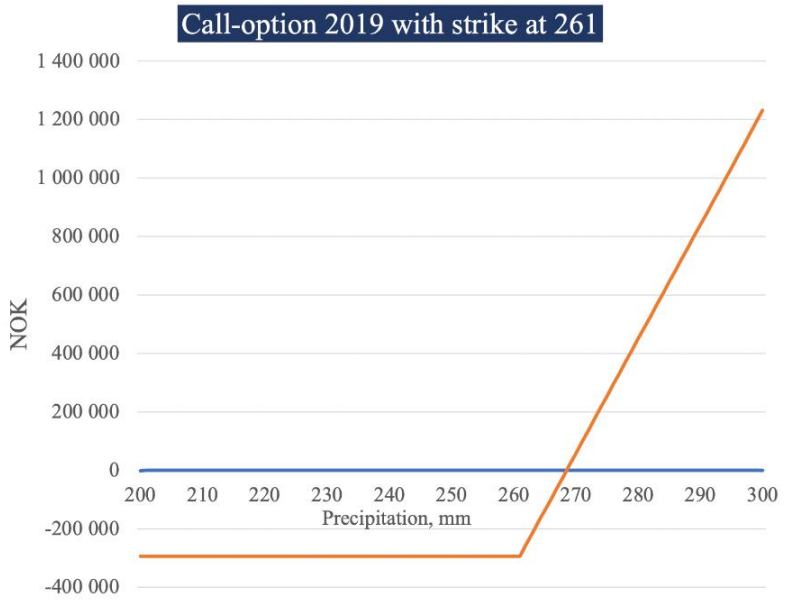


Figure 7: Call-Option 2019.

The K is 261mm, θ is NOK 39 091/mm, and the premium is NOK 293 360. The figure shows that the option payoff is 0 until the index value exceeds the strike level (K) and that the option buyer is in a profit once the payoff exceeds the premium (break-even at 268.5mm).

Figure 8 below illustrate all four hedging strategies compared to operating income with no hedging every year from 1998 to 2019 and actual precipitation for each year.

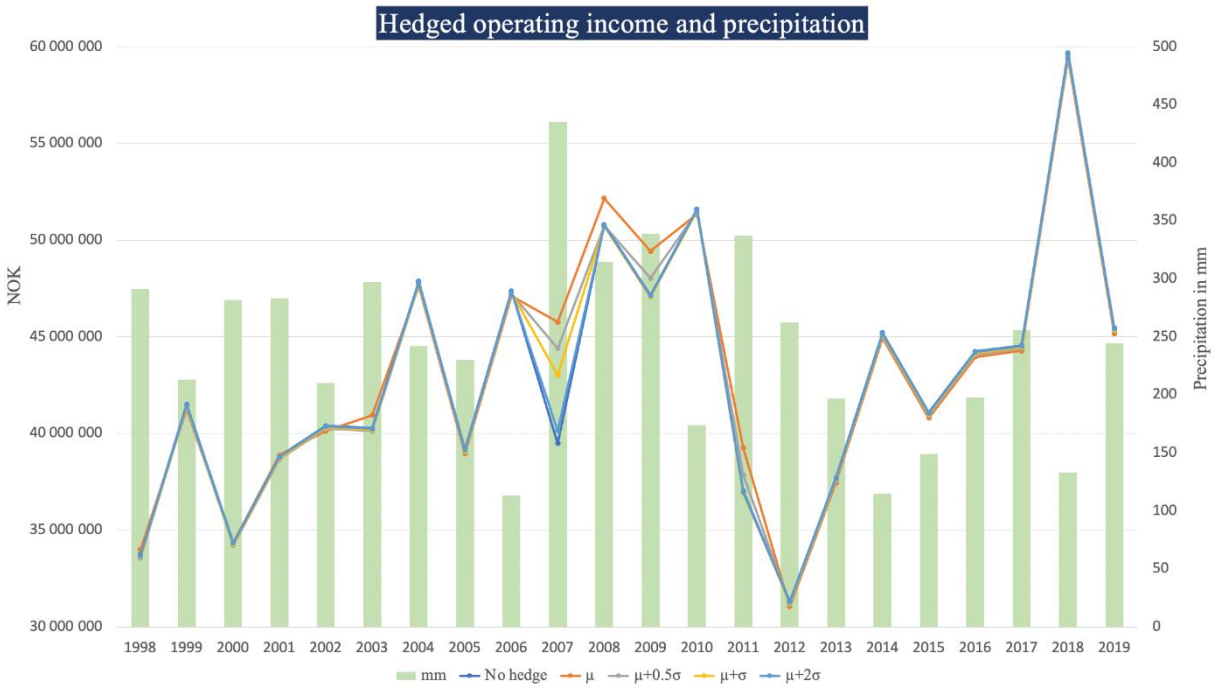


Figure 8: Hedged operating income and precipitation.

As *figure 8* illustrates, a hedging strategy using the precipitation call options has the desired effect on risk reduction in some years. In years such as 2007 and 2009, it is evident that payoff from several of these precipitation options would compensate for poor performance due to high precipitation levels. However, in years such as 2012, the options do not have the required effect. Previous studies on weather derivatives have generally studied a couple of years. In our analysis, we have investigated the possible effect of these options over a period of 22 years. Despite our findings regarding the correlation between revenue and seasonal precipitations, our findings suggest that Bø Sommarland implementing precipitation options will have little effect on their risk reduction. *Table 9* below illustrates the risk-adjusted return (RAR) for three different periods.

Table 9: Risk-adjusted return (RAR).

1998-2019	OI	OI/STD	Change in RAR %
No hedge	42 679 000	6,48	0,00%
μ	43 103 375	6,52	0,63%
μ+0.5σ	42 853 724	6,53	0,82%
μ+σ	42 755 646	6,53	0,78%
μ+2σ	42 677 276	6,49	0,22%
2010-2019	OI	OI/STD	Change in RAR %
No hedge	43 795 400	5,53	0,00%
μ	43 766 610	5,67	2,58%
μ+0.5σ	43 736 609	5,58	1,02%
μ+σ	43 704 602	5,52	-0,19%
μ+2σ	43 760 979	5,52	-0,07%
2017-2019	OI	OI/STD	Change in RAR %
No hedge	49 908 333	5,88	0,00%
μ	49 618 219	5,84	-0,62%
μ+0.5σ	49 744 845	5,86	-0,35%
μ+σ	49 814 436	5,87	-0,20%
μ+2σ	49 872 750	5,88	-0,08%

We do not have full insight into the financial data and investment opportunities for Bø Sommarland. Therefore, we have made this simple comparison measure, which can remind of the Sharpe-ratio without consideration of the risk-free rate. The purpose of this measure is to easily compare the different call options to the no-hedge strategy by dividing the total operating income by the standard deviation. A positive RAR would mean a smoother income. As we can see from *table 9*, the results are disappointing, with only a 0,82% change in adjusted risk for the whole period. When we look at the period from 2010-2019, we see that the effect would be better with 2,58%. However, when looking at the last three years, the precipitation option would actually have a negative effect at all four strike levels.

By paying a premium upfront, the precipitation option allows the outdoor waterpark to transfer some of the weather risks to an outside investor. In theory, this could reduce the financial pressure and result in less volatile revenues. This is supported by our analysis, where we found that the change in RAR for the whole period is positive. However, it is important to note that this positive effect is small.

Limitations

The limitations section will focus on how the precipitation data and the pricing model might have affected our results in the findings section.

Since there was no weather station at Bø Sommarland, the precipitation data were collected from weather stations approximately 8 kilometers away. This may have caused spatial risk, which could affect the relevance of our index. To avoid any spatial risk, the weather station would have had to be stationed at Bø Sommarland's property. There may also be a problem with basis risk. The variance explained by precipitation on operating income was only 0.204, indicating that precipitation affects their operating income less than we have calculated for.

Lastly, the McIntyre pricing model is less accurate than other models such as indifference pricing or Monte Carlo simulation. Therefore, the calculated premium may be less accurate than what is considered optimal. Thus, could it be beneficial to use another pricing model to achieve more accurate pricing.

Reflections

A weather derivatives market comparable to the one in the United States does not exist in Norway, and there are several reasons for why precipitation options is difficult to implement to a Norwegian market. Therefore, we will reflect upon three important reasons for why this might be, based on findings from parts 1 and 2.

Weather Recording

Reliable weather data is necessary in order to price weather derivatives properly. In our research, we found that the current Norwegian weather recording infrastructure had insufficiencies. When communicating with the Norwegian Meteorological Institute (2020) via e-mail, we were informed that the three weather stations used for developing our index all had different owners and that MET is only physically responsible for operating one of them. If an option is to be constructed on an underlying index based on data from a weather station, the weather station's measurements must be reliable. A solution to this issue could be to collect data from high-priority stations in the same manner as the CME (2020) has previously done in the U.S. These stations could be located at airports or in major Norwegian cities. However, having centralized weather stations might increase spatial risk. Norway’s varied topography can also contribute to increased spatial risk. For this reason, implementing high-priority stations seems insufficient for covering the need for reliable weather data.

Pricing

Assuming that weather data is reliable, uncertainty regarding pricing precipitation options still applies. One of the reasons being the non-existence of a standard pricing model for precipitation options. Since the underlying is untradable and does not have an inherent monetary value, current valuation frameworks are inconsistent and vary a lot. This makes it difficult for financial institutions to calculate a fair price, and for the hedgers to evaluate whether the price is reasonable. In part 2, we calculated a precipitation call option for Bø Sommarland, but it is uncertain if weather derivative providers would agree with this price.

Another problem that may prove detrimental in the viability of derivative pricing is basis risk. The seller and buyer of the derivative may disagree over the price as the effect precipitation has on the business may be unclear. If the participants are not certain of the effect precipitation has, it could be difficult to agree on the tick-size and premium. This could be connected to the findings in our example, where the tick-size is approximately 39 000. It is not certain that the seller or buyer would agree to this, as the variance explained by our regression model is only 0.2204.

Incentives

Although the notion of hedging frequent losses of probable weather events may sound appealing for a hedger, there are several reasons why weather derivatives have struggled to gain foothold in Norway. A lack of knowledge about weather derivatives' existence and their complex nature may discourage small to medium businesses from using them. Our interview with Hunderfossen Famliy Park's CEO (2020) confirmed this, stating that weather derivatives would, according to him, be beyond their level of knowledge, and that they would rather encurrage more traditional hedging strategies such as insurance or investing in indoor activities decreasing their weather exposure.

Drawing parallels from our findings from pricing a precipitation option for Bø Sommarland, it is likely that high premiums with disappointing results of only a 0,82% improvement in adjusted risk, will discourage the hedger from buying with an option. However, the conclusion could differ between other businesses. This might lead to the conclusion that the hedgers benefit more from using traditional hedging methods, resulting in low demand for advanced financial hedging products and low liquidity in a weather derivatives market.

Furthermore, several factors incentivizes the sell-side not to engage in weather derivative contracts in addition to the difficulties regarding precipitation pricing and Norwegian weather

stations. Since, according to Leggio (2007), the businesses most likely to benefit from precipitation options are relatively small businesses, option writers' profits might be limited. According to the Financial Times (2007) this may explain why leading investment banks, such as BNP Paribas and Société Général shut down their weather derivatives operations in 2007.

Additionally, lack of liquidity in Europe and especially Norway gives little incentive for the commodity exchanges to provide standardized contracts. The lack of an exchange clearing OTC transactions further increases risk and cost associated with the transactions, which in turn again reduces liquidity. According to Benth (2020), the only alternative financial contracts that may be used to hedge weather are energy contracts on OMX/Nordpool, because the producs are relatively weather sensitive.

Conclusion

We have examined the weather derivatives market and analyzed whether a Norwegian amusement park could hedge rainfall-induced revenue volatility with a precipitation call option. The aim was to understand whether such a market could function in Norway.

Part 1 outlined the microstructure for weather derivatives' primary market. It established the different market participants' roles on both the buy-and sell-side and particularly emphasized the CME's importance. All weather derivative transaction are traded OTC, and the CME functions as a clearinghouse for its standardized indices. A hedger or investor who wishes to trade a derivative through the CME must trade one of the standardized derivative contracts through a block trade which is then reported to the CME's clearinghouse by a clearing broker. Precipitation derivatives can currently not be traded through the CME, introducing counterparty risk and a less efficient market.

We were able to create a precipitation index and call option for Bø Sommarland. We found that for some years the hedging strategy helped stabilize their operating income and thereby reduce their risk-adjusted returns. Therefore, is it reasonable to conclude that implementing a hedging strategy based on weather derivatives could benefit a Norwegian company under certain circumstances. However, the disclosed limitations regarding our analysis require that the findings should be viewed with some reservations.

It is difficult to establish a functioning weather derivatives market in Norway, despite the potential benefits these products may offer. Important obstacles we identified include current

insufficiencies with the weather station network combined with Norway's varying topography, uncertainty regarding pricing weather options and indices, a lack of incentives for both buy- and sell-side, and the fact that there are more convenient and well-known alternatives for hedging weather-related risks.

References

Akhilesh, G. (2019, September 18). *What is a Weather Future?* Retrieved December 6, 2020, from Investopedia.com: https://www.investopedia.com/terms/w/weatherfuture.asp

Alexandridis, A., & Zapranis, A. (2013). *Weather Derivatives: Modeling and Pricing Weather Related Risk.* New York: Springer.

Benth, F. E. (2020, December 9). Personal Communication. (C. 110003, Interviewer)

CME Group. (2009). *cmegroup.com.* Retrieved November 25, 2020, from Weather Product Brochure: https://www.cmegroup.com/trading/weather/files/WT-124_WeatherBrochure_r11.pdf

CME Group. (2020). *Block Trades*. Retrieved November 28, 2020, from cmegroup.com: https://www.cmegroup.com/clearing/trading-practices/block-trades.html#cme

CME Group. (2020). *Weather Futures and Options Codes.* CME Group.

CME Group. (2020, December 10). *What is Clearing?* Retrieved from cmegroup.com: https://www.cmegroup.com/education/courses/clearing/what-is-clearing.html

CME Group. (2020). *www.cmegroup.com*. Retrieved from https://www.cmegroup.com/education/courses/introduction-to-options/introduction-to-options.html

Coriolis Capital Limited. (2020). *www.corioliscapital.com*. Retrieved from https://www.corioliscapital.com/hedging-weather-risk/what-are-they/difference-from-insurance/

Corporate Finance Institute. (2020). *Over-The-Counter (OTC)*. Retrieved November 29, 2020, from corporatefinanceinstitute.com: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/over-the-counter-otc/

Edelweiss Group. (2020). *www.edelweiss.in*. Retrieved from https://www.edelweiss.in/investology/introduction-to-investing-c6eaf4/what-is-portfolio-diversification-b13fdc

Fyksen, I. (2020, October 25). Personal Communication. (C. 110031, Interviewer)

Hanstad, I. (2012, 06 24). *e24.no*. Retrieved from https://e24.no/naeringsliv/i/1nroRK/lite-fornoeyelig-sommer-for-fornoeyelsesparkene

Haugan, A., & Rasmussen, J. (2019). *Pricing weather derivatives, and constructing portfolios that reduce the weather risk for ski resorts.* Trondheim: NTNU.

Historic daily weather USA. (2020, December 4). Retrieved from CME Group: ftp://ftp.cmegroup.com/weather/usa/temperature/historical/daily

Høstmælingen, H. (2020, October 27). Phone call. (C. 110050, Interviewer)

Ishmael, S. (2007, June 20). *Sun shines Again on Weather Derivatives*. Retrieved December 11, 2020, from ft.com: https://www.ft.com/content/61afe8b0-1f62-11dc-ac86-000b5df10621

Jewson, S., & Brix, A. (2005). *Weather Derivative Valuation: The Meteorological, Statistical, Financial, and Mathematical Foundations.* Cambridge University Press.

Jewson, S., & Brix, A. (2005). Weather derivatives and the weather. In S. Jewson, & A. Brix, *Weather Derivative Valuation: The Meteorological, Statistical, Financial and Mathematical.* Cambridge University Press.

Jones, T. L. (2007). Agricultural Applications Of Weather Derivatives. *International Business & Economics Research Journal, 6*, 53-59.

Leggio, K. B. (2007). Using weather derivatives to hedge precipitation exposure. *Managerial Finance, 33*(4), 246-252.

Manfredo, M., & Richards, T. (2009). Hedging with weather derivatives: a role for options in reducing basis risk. *Applied Financial Economics, 19*(2), 87-97.

McDonald, R. (2013). *Derivatives Markets.* Northwestern University.

McIntyre, R. (1999). Black-Scholes will do. *Energy Power and Risk Management*.

Mitchell, C. (2020, April 28). *Introduction to Counterparty Risk*. Retrieved December 11, 2020, from Investopedia.com: https://www.investopedia.com/articles/optioninvestor/11/understanding-counterparty-risk.asp

Murphy, C. (2019, May 14). *Counterpary Risk*. Retrieved December 11, 2020, from Investopedia.com: https://www.investopedia.com/terms/c/counterpartyrisk.asp

Nygård, H. (2020, 12 09). Exam Thesis NHH. (N. Foss, Interviewer)

Weather Risk Management Association. (2020, Decemer 8). *History of the Weather Derivatives Market*. Retrieved December 8, 2020, from wrma.org: https://wrma.org/resources/history-weather-market/

Weather Risk Managment Association. (2020). *Retail and Recriation*. Retrieved November 25, 2020, from wrma.org: https://wrma.org/risks/retail-recreation/

Weather.gov. (2020, December 25). *Weather.gov*. Retrieved November 25, 2020, from What are Heating and Cooling Degree Days: https://www.weather.gov/key/climate_heat_cool

WeatherXchange. (2020, December 10). *How WeatherXchange works*. Retrieved from weatherxchange.com: https://www.weatherxchange.com/en/HowItWorks

WeatherXChange. (2020). *www.weatherxchange.com*. Retrieved from https://www.weatherxchange.com/en/Industries?fbclid=IwAR3yLojmI8rlRxGqHeiji4Z4LvLmXD-ggk9ceB-PR91xuRH48rE3kUzfBOc#TourismLeisure

WRMA. (2020). *https://wrma.org/*. Retrieved from https://wrma.org/

Xu, W., Odening, M., & Musshoff, O. (2008). Indifference pricing of weather derivatives. *American Journal of Agricultural Economics*, 979-993.

Appendix 1 - Communication

Correspondence with Fred Espen Benth, professor at UiO.

From: [redacted]
Sent: 08 December 2020 13:48
To: Fred Espen Benth
Subject: Spørsmål om et norsk marked for værderivater (Eksamensoppgave NHH)

Hei.
Vi er en gruppe studenter på NHH som skriver en eksamensoppgave som undersøker om Bø Sommarland kan hedge seg mot vær-risiko ved å kjøpe en regnopsjon. En viktig del av oppgaven vår er også å undersøke hvorvidt et marked for værderivater kunne vært mulig i Norge. Vi prøver derfor å få innsikt i værmarkedet og handelsprosessen på CME, men sliter med å finne konkret info rundt dette siden produktene trades OTC.

Konkret lurer vi på:

1. Hvordan kjøpsprosessen på CME for disse produktene foregår – fra bedriften bestemmer seg for å hedge til de er hedget. Hvilke institusjoner går det igjennom?
2. Hvordan ser du for deg at et slikt marked kunne sett ut i Norge, og hvordan kjøpsprosessen ville sett ut her?

Vi ville satt veldig stor pris på en liten prat rundt temaet hvis du har tid. Eventuelt kan vi også ta det over mail.

Fra: Fred Espen Benth <fredb@math.uio.no>
Sendt: Friday, December 11, 2020 1:52:52 PM
[redacted]
Emne: Re: Spørsmål om et norsk marked for værderivater (Eksamensoppgave NHH)

Hei,

det høres ut som en veldig spennende oppgave. Jeg ble kontaktet av en organisator av uteservering for noen år tilbake, som ønsket slike derivater i forbindelse med fotball-vm/em. Så det er litt interesse i alle fall.

1. Jeg tror at temperaturderviativer/futurews på CME er relativt likvide, mens alt annet av værderivater ikke er det (før hadde de regnderivativer i noen amerikanske byer på CME). Jeg tror at de opererer som clearing-hus, altså clearing av handler der to parter inngår en slik kontrakt. Børshandlede futures handles som alle andre futures-kontrakter, der "settlement" er i form av en objektivt målt temperatur (omgjort til penger).

2. I Europa i hvert fall har xet vært Hadler der forsikringsselskaper har inngått som motpart i værderivater. Det er slik markedet fungerer, man må finne en motpart hvis man ønsker slike forsikringskontrakter. ENRON forsøkte seg på dette i Norge før de gikk konkurs. Interessant nok kan dere tenke på strøm-futures på OMX/NordPool som en delvis forsikring mot fremtidig vær, siden disse vil være sensitive både mot regn/snø (=mer vann som gir høyere reservoarfyllning) og temperatur (etterspørsel). De er skrevet på spotpris, men likevel sensitive mot temperatur og regn.

Mvh.

Fred

Correspondence with Iver Fyksen, the CFO of Tusenfryd and Bø Sommarland

Fra: [redacted]
Sendt: torsdag 12. november 2020 13.45
Til: Bjørn Håvard Solli <bhs@tusenfryd.no>
Emne: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei,

Vi er en gruppe fra Norges Handelshøyskole som ønsker å skrive en oppgave hvordan værutsatte bedrifter kan forsikre seg mot økonomiske tap som følge av regn.

For å undersøke om Tusenfryd kan forsikre seg mot regn i sommerferien trenger vi tall over månedsvise driftsinntekter for perioden juni-august de siste 10 årene. Vi ønsker å undersøke om dårlige sesonger med mye regn påvirker omsetningen deres, og utforme en prisingsmodell for et vær-derivat, som gjør at bedriften kan redusere risiko og oppnå en mer stabil inntekt.

Dataene som blir brukt i oppgaven kommer kun til å bli innlevert til en sensor ved NHH, og vil ikke bli publisert på noen som helst måte i ettertid.

Vi hadde satt stor pris på om dere kunne hjelpe oss med dette.

Vennlig hilsen,

Fra: Iver Fyksen
Sendt: søndag 15. november 2020 kl. 11:40
[redacted]
Kopi: Bjørn Håvard Solli
Emne: SV: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei Nicholas,

Det går fint, så vedlagt har inntektene for perioden juni – august tilbake til 2010 (2020 er ikke relevant da vi har hatt kapasitetsrestriksjoner pga. korona).

Hvis vi kunne fått en kopi av oppgaven når den er innlevert, hadde vi satt pris på det.

Lykke til!

Med frydefull hilsen

Iver Fyksen
Økonomidirektør

Tusenfryd AS | Fryds vei 25 | N-1407 Vinterbro | Norway
Tlf: +47 64 97 64 22 | Mobil: +47 95 91 83 10 | Skype: iver.fyksen
Epost: iver@tusenfryd.no | www.tusenfryd.no

Følg oss på Facebook! www.facebook.com/tusenfryd

Fra: Iver Fyksen
Sendt: mandag 16. november 2020 kl. 12:08
Til: [redacted]
Emne: SV: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei,

Jo – dere kan for så vidt kontakte meg hvis det skulle være behov for noe mer, men hvis det skal veldig mye mer enn 10 år tilbake i tid begynner det å bli litt mer krevende å finne frem data. På den annen side – hvis det ikke finnes noe interessant å ta tak i over de siste 10 årene er det kanskje heller ikke en veldig aktuell problemstilling.

Mvh Iver

[redacted]
Sendt: søndag 15. november 2020 14.30
Til: Iver Fyksen <iver@tusenfryd.no>
Emne: SV: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei igjen!

Takk for inntektsdataene, dette setter vi stor pris på. Dersom vi finner tilstrekkelig korrelasjon mellom nedbør og inntekter til å skrive oppgaven vår, vil vi selvfølgelig sende deg en kopi ved innlevering av eksamen, 14. desember.

Vi ønsker ikke å være til bry, men kunne vi tatt kontakt med deg dersom det viser seg at vi trenger tilsvarende inntektstall fra enda tidligere perioder? Hvis mulig, hvilken e-post er det best at vi henvender oss til?

Vennlig hilsen,
[redacted]

Fra: Iver Fyksen
Sendt: mandag 23. november 2020 kl. 17:33
[redacted]
Emne: SV: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei [redacted]

Jo, dere har rett i at Bø Sommaland sitt produkt er mye mer værsensitivt enn Tusenfryd sitt. Jeg er økonomisjef for Bø Sommarland også, så vedlagt har dere tilsvarende data derfra.

Mvh Iver

Fra: [redacted]
Sendt: søndag 22. november 2020 16.40
Til: Iver Fyksen <iver@tusenfryd.no>
Emne: SV: Forespørsel om regnskapstall i forbindelse med eksamensoppgave ved Norges Handelshøyskole (NHH)

Hei,

Etter mye prøving og feiling virker det dessverre ikke som værdata i Tusenfryd området er utfyllende nok til å utføre en hensiktsmessig analyse.

På den annen side, har vi funnet lovende korrelasjon mellom inntektstallene til Bø Sommarland og nedbøren i området. Jeg forstår det slik at du er styremedlem der, og lurer derfor om du kunne sette meg i kontakt med en som kunne skaffet oss tilsvarende inntektsdata fra Bø Sommarland. Hvis det ikke lar seg gjøre så takker vi for hjelpen uansett!

Correspondence with Tone Husebye, from the Norwegian Meteorological Institute

Fra: **Tone Braadland Husebye** <tonebh@met.no>
Date: tir. 8. des. 2020 kl. 14:37
Subject: Re: Eksamensoppgave ved NHH
To: Felleskonto Klimavakten <klimavakten@met.no>
Cc: Drift av observasjonssystemene <obsklim.od@met.no>

Hei! Her kommer resten!

0 er ikke nedbør
(det spørs litt hvor data hentes fra, men det skal stå hvis det er noe annet)
Alle tre stasjonen har komplett nedbør data per døgn siste år
Data kan hentes i seklima.met.no.

Jeg ser at nedbørdata for Lifjell-Øysteinnatten mangler for siste 30 døgn og siste 13 mnd på Yr (de er der siste 24 t)

Stasjonseier har service ansvar.

Gvarv eies og driftes av Meteorologisk institutt.
Værstasjonen i Bø eies av Nibio.
Lifjell - Øysteinnatten eies av Høgskolen i Telemark.

Ofte skyldes manglende data værforhold som fører til forsinkelser i gsm-nettet
Feil på selve værstasjonen som kan utbedres ved service, utbedres så fort vær og føre forholdene tillater det.
Større feil på selve værstasjonen kan være avhengig av bestilling av nytt utstyr og egnede forhold for remontering.
Det er svært sjeldent med feil på selve sensoren, det kan like gjerne være feil i nettet eller med strømtilgangen som er først må lokaliseres før den utbeders.

Vennlig hilsen
Tone Husebye
Meteorologisk institutt
Overingeniør, Observasjon&Klima-divisjonen
Mobil: 95779029, epost: tonebh@met.no

Correspondence with Hildegunn Nygård, from the Norwegian Meteorological Institute

Fra: Hildegunn V. Dyngeseth Nygård
Sendt: onsdag 9. desember 2020 kl. 12:40
Til: observasjon
Kopi: [redacted]
Emne: Re: Eksamensoppgave ved NHH

Hei!
Først litt om stasjonene dere henter data fra:
Gvarv (SN32060) eies og driftes av Meteorologisk institutt (MET).
Bø (SN32240) eies og driftes av NIBIO.
Lifjell (SN32200) eies og driftes av Høgskolen i Telemark. Siden denne stasjonen står på fjellet, så er det en del driftsproblemer med denne, feks av vindmåleren fryser fast og viser da 0 m/s selv om det kan blåse.
MET distribuerer og kvalitetskontrollerer data fra mange eksterne stasjoner, men har altså ingen ansvar for driften. Eksempel på eksterne er: Statens vegvesen, NIBIO, NVE, kommuner, Avinor m.fl.

Svar på spørsmålene:
1. Er litt usikker på hvor du ser nullverdier. Hvis det står 0 under nedbør, så har den målt 0 mm nedbør. Der det mangler data (feks feil på stasjonen eller at stasjonen er nede), vil det stå "-" i datatabellen i Seklima.

2. Ja, vi har faste vedlikeholdsrutiner på stasjoner som MET eier og drifter. Disse besøkes ca hvert 3. år. Man tar da feltkontroll av instrumentene. Vi har en egen avdeling som jobber med drift av observasjonssystemene våre (værstasjoner, værradar, radiosonde mm.). I tillegg har vi lokale tilsynspersoner som gjør noe vedlikehold som tømming av automatiske nedbørmålere og feilrettinger. Vi har som mål å ha høy oppetid på våre stasjoner, men det er jo ikke like lett på stasjoner som ligger på Svalbard eller ute på en øy uten fastboende. Eksterne stasjoner har ikke samme oppfølging som våre stasjoner, men det varierer fra eier til eier.

3. Vi er selv ansvarlig for driften av våre stasjoner og Bane Nor sine, men ikke for andre eksterne stasjoner.

4. Svært sjelden hærverk. Har nok mer problem med slitasje på utstyr pga værforholdene på stedet. Og på Svalbard har vi opplevd hærverk av isbjørn!! Men der har vi nå pakket stasjonene ekstra godt inn, så det problemet har vi ikke hatt i seinere år.

5. Svært mange deler sine data med oss, som vi distribuerer ut på Yr og Seklima. Det er ingen andre kilder med frie data enn Seklima, Yr eller vårt api (frost.met.no) som jeg vet om.

6. Ja, varierende topografi har veldig mye å si og gir store lokale variasjoner i været. Så det er nok vanskeligere å varsle vær i Norge enn i et flatt land som Danmark. Vi må jo ha et mye tettere nettverk av værstasjoner for å fange opp lokale variasjoner, og vi har problemer med at fjellene skygger for værradarene våre. Her står det litt om utfordringene med å lage gode værvarsel: https://www.met.no/nyhetsarkiv/derfor-blir-vaervarselet-aldri-perfekt

Håper dette var til hjelp. Lykke til med eksamensoppgavene.

Vennlig hilsen

Hildegunn D. Nygård
Forsker/meteorolog
Meteorologisk institutt
Observasjons- og klimadivisjonen

Appendix 2 - All Hedging Results (1998-2019)

The payoff for mm of rain in excess of the strike price	39 091

Results 1998		mm precipitation	291		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				33 734 000	33 734 000
μ	277	283 005	559 580	33 734 000	34 010 576
μ+0.5σ	316	159 380	0	33 734 000	33 574 620
μ+σ	356	91 492	0	33 734 000	33 642 508
μ+2σ	436	34 681	0	33 734 000	33 699 319

Results 1999		mm precipitation	213		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				41 509 000	41 509 000
μ	277	275 629	0	41 509 000	41 233 371
μ+0.5σ	316	155 121	0	41 509 000	41 353 879
μ+σ	355	88 999	0	41 509 000	41 420 001
μ+2σ	434	33 746	0	41 509 000	41 475 254

Results 2000		mm precipitation	282		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				34 365 000	34 365 000
μ	275	273 111	258 405	34 365 000	34 350 294
μ+0.5σ	314	153 668	0	34 365 000	34 211 332
μ+σ	353	88 148	0	34 365 000	34 276 852
μ+2σ	430	33 427	0	34 365 000	34 331 573

Results 2001		mm precipitation	283		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				38 823 000	38 823 000
μ	275	266 303	320 155	38 823 000	38 876 852
μ+0.5σ	313	149 738	0	38 823 000	38 673 262
μ+σ	352	85 849	0	38 823 000	38 737 151
μ+2σ	428	32 565	0	38 823 000	38 790 435

Results 2002		mm precipitation	210		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				40 397 000	40 397 000
μ	275	259 906	0	40 397 000	40 137 094
μ+0.5σ	313	146 048	0	40 397 000	40 250 952
μ+σ	351	83 691	0	40 397 000	40 313 309
μ+2σ	426	31 755	0	40 397 000	40 365 245

Results 2003		mm precipitation	297		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				40 280 000	40 280 000
μ	273	258 251	924 991	40 280 000	40 946 740
μ+0.5σ	311	145 093	0	40 280 000	40 134 907
μ+σ	348	83 133	0	40 280 000	40 196 867
μ+2σ	423	31 546	0	40 280 000	40 248 454

Results 2004		mm precipitation	242		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				47 866 000	47 866 000
μ	274	252 933	0	47 866 000	47 613 067
μ+0.5σ	311	142 026	0	47 866 000	47 723 974
μ+σ	348	81 340	0	47 866 000	47 784 660
μ+2σ	422	30 873	0	47 866 000	47 835 127

Results 2005		mm precipitation	230		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				39 196 000	39 196 000
μ	273	248 367	0	39 196 000	38 947 633
μ+0.5σ	310	139 395	0	39 196 000	39 056 605
μ+σ	346	79 802	0	39 196 000	39 116 198
μ+2σ	419	30 295	0	39 196 000	39 165 705

Results 2006		mm precipitation	114		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				47 372 000	47 372 000
μ	272	244 844	0	47 372 000	47 127 156
μ+0.5σ	308	137 364	0	47 372 000	47 234 636
μ+σ	344	78 615	0	47 372 000	47 293 385
μ+2σ	416	29 850	0	47 372 000	47 342 150

Results 2007		mm precipitation	435		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				39 484 000	39 484 000
μ	268	257 862	6 538 730	39 484 000	45 764 867
μ+0.5σ	306	144 869	5 077 566	39 484 000	44 416 697
μ+σ	343	83 002	3 616 403	39 484 000	43 017 401
μ+2σ	418	31 496	694 075	39 484 000	40 146 579

Results 2008		mm precipitation	315		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				50 804 000	50 804 000
μ	273	277 843	1 639 815	50 804 000	52 165 972
μ+0.5σ	312	156 399	104 115	50 804 000	50 751 716
μ+σ	351	89 747	0	50 804 000	50 714 253

μ+2σ	430	34 027	0	50 804 000	50 769 973

Results 2009		mm precipitation	339		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				47 154 000	47 154 000
μ	274	273 872	2 554 391	47 154 000	49 434 519
μ+0.5σ	313	154 106	1 033 360	47 154 000	48 033 253
μ+σ	352	88 405	0	47 154 000	47 065 595
μ+2σ	429	33 524	0	47 154 000	47 120 476

Results 2010		mm precipitation	174		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				51 617 000	51 617 000
μ	275	272 222	0	51 617 000	51 344 778
μ+0.5σ	314	153 154	0	51 617 000	51 463 846
μ+σ	353	87 848	0	51 617 000	51 529 152
μ+2σ	430	33 315	0	51 617 000	51 583 685

Results 2011		mm precipitation	337		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				37 026 000	37 026 000
μ	273	275 633	2 521 565	37 026 000	39 271 932
μ+0.5σ	312	155 123	994 019	37 026 000	37 864 895
μ+σ	351	89 000	0	37 026 000	36 937 000
μ+2σ	429	33 747	0	37 026 000	36 992 253

Results 2012		mm precipitation	263		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				31 322 000	31 322 000
μ	274	273 899	0	31 322 000	31 048 101
μ+0.5σ	313	154 122	0	31 322 000	31 167 878
μ+σ	352	88 414	0	31 322 000	31 233 586
μ+2σ	430	33 527	0	31 322 000	31 288 473

Results 2013		mm precipitation	197		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				37 719 000	37 719 000
μ	274	269 106	0	37 719 000	37 449 894
μ+0.5σ	313	151 356	0	37 719 000	37 567 644
μ+σ	351	86 796	0	37 719 000	37 632 204
μ+2σ	428	32 920	0	37 719 000	37 686 080

Results 2014		mm precipitation	115		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				45 211 000	45 211 000
μ	268	269 197	0	45 211 000	44 941 803

μ+0.5σ	309	151 408	0	45 211 000	45 059 592
μ+σ	349	86 826	0	45 211 000	45 124 174
μ+2σ	429	32 931	0	45 211 000	45 178 069

Results 2015		mm precipitation	149		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				41 086 000	41 086 000
μ	268	286 744	0	41 086 000	40 799 256
μ+0.5σ	309	161 540	0	41 086 000	40 924 460
μ+σ	349	92 757	0	41 086 000	40 993 243
μ+2σ	429	35 156	0	41 086 000	41 050 844

Results 2016		mm precipitation	198		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				44 248 000	44 248 000
μ	266	292 319	0	44 248 000	43 955 681
μ+0.5σ	306	164 762	0	44 248 000	44 083 238
μ+σ	347	94 643	0	44 248 000	44 153 357
μ+2σ	428	35 863	0	44 248 000	44 212 137

Results 2017		mm precipitation	256		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				44 565 000	44 565 000
μ	264	290 795	0	44 565 000	44 274 205
μ+0.5σ	305	163 881	0	44 565 000	44 401 119
μ+σ	345	94 127	0	44 565 000	44 470 873
μ+2σ	426	35 670	0	44 565 000	44 529 330

Results 2018		mm precipitation	133		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				59 696 000	59 696 000
μ	264	286 189	0	59 696 000	59 409 811
μ+0.5σ	304	161 220	0	59 696 000	59 534 780
μ+σ	344	92 569	0	59 696 000	59 603 431
μ+2σ	424	35 085	0	59 696 000	59 660 915

Results 2019		mm precipitation	244		
	Strike(mm)	Premium	Exersice value	Revenues	Portfolio Value
No hedge				45 464 000	45 464 000
μ	261	293 360	0	45 464 000	45 170 640
μ+0.5σ	302	165 364	0	45 464 000	45 298 636
μ+σ	343	94 996	0	45 464 000	45 369 004
μ+2σ	424	35 995	0	45 464 000	45 428 005