Weather derivatives as a hedging tool for construction firms

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Bachelor thesis

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Abstract

In this paper, the application of weather derivatives for construction companies is introduced. I start with the basic concept of risk management and the most commonly applied risk monitoring technique. Based on an analysis of the concept of weather derivatives, the different applicable weather derivatives are discussed. Furthermore, a set of valuation techniques is discussed, followed by an analysis of the use of weather derivatives in other industries. Next is the comparison between weather derivatives and regular insurance policies offered by insurance firms. Final part focuses on the business application for construction firms and an analysis of the results and implications.

1. Introduction

‘Weather risks are the uncertainty in cash flows and earnings caused by noncatastrophic weather events such as temperature, humidity, rainfall, snowfall, stream flow, and wind’. (Brocket et al. 2005) This risk affects almost all businesses. As estimated by the Chicago Mercantile Exchange (CME 2009), one-third of businesses worldwide are directly affected by weather conditions. Therefore, weather derivatives are appealing to many companies, because of the negative correlation of costs and revenue different companies can have for the same weather condition. For example, a ski-resort operator might profit from heavy snowfall during the winter season. While for an airline operator in the same region, snowfall will incur in many additional costs. The same is true for a winter season that has less or no snow at all, in that case the losses shift from one company to the other. Because of this negative correlation there exists an opportunity to offset the risk, by negotiating a contract that pays both parties based on a certain weather index (Golden, Wang, Yang 2007).

Like a future’s option on the S&P 500 index, the weather derivative pays off based on the index that is pre-specified in the contract. These contracts can be interesting for construction companies to integrate in their Risk Management programs. For obvious reasons construction companies bear the risk of severe weather conditions that enable projects to continue. The added value of risk management is researched extensively by Smithson and Simkins (2005). By examining all relevant published academic work, they found that using risk management tools (derivatives) was indeed associated with a reduced risk for both financial and non-financial companies.
This thesis aims at exploring the possibilities of incorporating weather derivatives in a construction company’s risk management policy. By highlighting the main risk factors for construction companies, I can determine how weather derivatives can add value for the stakeholders. There has been no earlier research in the field of financial risk management that researches the use of weather derivatives for Dutch construction firms. Therefore, this literature based research paper can add value to managers that wish to offset weather risk using derivatives. This thesis does not analyze the implementation of weather derivatives in some sort of administrative system. I describe the implication of the different weather derivatives that could be applicable, and explain how they should be used. Furthermore I explain under what conditions weather derivatives are preferable over insurance.

It shows that the use of weather derivatives can surely provide a good alternative for regular insurance policies, if, and only if a company possesses the required resources and capabilities. Crucial for successful weather risk management turns out to be quantifying exposure to different variables that affect a company. In addition, it is important that a company possesses a well functioning system that enables monitoring of current exposure, so that the necessary precautionary measures can be made in time. As the mentioned resources and capabilities might be hard to acquire, derivatives are most likely not to be used by small firms. In that case, other risk management practices are more effective.

Starting with an introduction to the concept of risk management, I will explain what factors determine a firm’s systematic risk, how they are measured, and how they can be linked to weather derivatives. Further on, market variables and contracts that can be used to hedge weather related risks, together with an overview of their pricing techniques are introduced. Next I will outline the key success factors for successful weather risk management. I will obtain this information from studies that are aimed at the agriculture, tourism or other industries. The third chapter will cover the main differences between weather derivatives and regular insurance against unwanted weather derivatives. Finally, I will by mean of examples show how weather derivatives can be incorporated in a firm’s corporate risk strategy.

2. Literature review and background

Like the weather, there are many more factors that influence a firm’s risk exposure. These insecurities all differ in size and likelihood. All factors together determine the riskiness of a project or company. For a firm, it is important that the total risk exposure is monitored
constantly (Stulz 2003). Because taking risk is inevitable if an organization is to achieve its goals, risk management is inseparably with doing business. Also, effective risk management is likely to improve a company’s performance, and contribute to the following objectives (Sadgrove 2005):

- Maintain market share
- Avoid worker litigation
- Avoid loss of production
- Reduce insurance premium
- Prevent loss of money
- Avoid obsolete construction methods
- Etcetera

It is a risk manager’s task to look at all those risks, and examine what their impact can be on the organization. In some cases, a company can use (financial) instruments in order to reduce mitigate the risk it is exposed to. The risk management process can best be described by the following flowchart:

The Risk Management Process. Taken from Crouhy et al. (2006)
The firm specific risks for construction firms can fluctuate heavily. Because of the many different contract parties and construction sites, a construction firm has a constantly changing risk profile. With increased time and cost pressure, risks are only likely to increase in the future. Therefore, it is very important that every construction company has an active risk management policy. Especially when it uses financial derivatives to hedge against risks, it needs some tools to monitor risk, and to monitor its exposure on the derivatives portfolio it manages.

The following formula is commonly used in order to express the amount of risk (Louwman en Steens 1994):

\[Risk = \sum_{i} P_i \times K_i\]

Where \(P_i\) is the probability of an event, multiplied by \(K_i\), which denotes the impact of that particular event. However, this formula provides you with a very static number that is hard to interpret by managers. In order to quantify the risk in terms of actual value, the RiskMetrics\textsuperscript{TM} method is developed by J.P. Morgan and Reuters to enable users to estimate their exposure under what has been called the ‘Value-at-Risk framework’, shortly denoted as VaR.

The VaR is the loss that will be exceeded with a given probability over some measured period. It uses the \(z\)\textsuperscript{th} quantile of a distribution as a number such that there is a probability of \(z\) percent that the random variable is below that number and \((100 - z)\) percent that it is above (Stulz 2003).

When returns on the derivatives portfolio are standard normally distributed, the expected value of their pay off is zero, and the volatility is equal to one. Any normally distributed variable can be standardized into a variable that does follow the standard normal distribution by subtracting the mean from the random variable and dividing the resulting variable by the volatility of the random variable:

\[\mu = \frac{z - E(z)}{Vol(z)}\]

The volatility is the square root of the sum of the expected value of the square of the difference between the realizations of a random variable and its expected value, divided by the number of observations minus one. That is, to correct for the number of degrees of freedom (Stulz 2003):
Adding this information all up, a risk manager can determine the Value at Risk of any portfolio, given a certain confidence level. With a confidence level of 97.5 percent, the Value at Risk of a portfolio would be:

\[ \text{VaR} = 1.96 \times \sigma \times \text{Portfolio value} \]

In the graph below, the VaR is indicated by the shaded area of the Bell curve.

If construction companies use weather derivatives, monitoring systems like RiskMetrics are essential. The concept of VaR is the most widely used for both financial and non-financial institutions. It also enables the calculation of the VaR for a portfolio containing options (JP-Morgan/Reuters 1996). However, as I will explain in a later stadium, the use of weather options is not recommendable for construction companies.
Weather derivatives

The history of weather derivatives starts in the United States, where the first publicized weather contract between two parties, Koch Energy and Enron, took place in 1997. That contract was based on a temperature index for Milwaukee, Wisconsin for the winter 1997-1998. After several years of Over The Counter (OTC) trading in weather derivatives, the Chicago Mercantile Exchange (CME) took trading in weather derivatives a step further by introducing publicly traded futures and options on futures in 1999 (CME Group 2011). By now, these relatively new financial instruments consist of combinations of instruments such as swaps, options and option collars. The payoffs of these instruments may be linked to a variety of “underlying” weather-related variables, including heating degree days, cooling degree days, growing degree days, average temperature, maximum temperature, minimum temperature, precipitation (rainfall, snowfall), humidity and sunshine (Campbell, Diebold 2004). This wide range of products offers businesses many opportunities to hedge all sorts of weather related risks.

The expansion of the market was driven by a number of important events that happened in the late nineties. One of which is the liberalization of the energy market in the United States. Prior to that, electricity companies could hedge themselves against drops in prices by buying ordinary energy derivatives. But with the liberalization they not only needed protection against drops in prices but there was also the risk of a volumetric drop. That fueled the demand for a derivative that was based on an underlying variable that is directly linked to the weather. Ever since the market for weather derivatives grew fast. A weather risk derivative survey commissioned by the Weather Risk Management Association (WRMA) and executed by PriceWaterhouseCoopers in May 2011 estimates that the total notional value of CME contracts was $9,379 million USD for the period 2010/11. Indicating an increase of 16 percent compared to the period 2009/10. With a changing climate and with further expansion of cities or regions that could be used to ‘write’ a futures contract on, it is likely that the market for weather derivatives will continue its growth over the next couple of years. Even though the market for weather derivatives seems large, as a fraction of the total derivatives market, weather derivatives present less than 0.005 percent (Huault, Rainelli-Weiss 2011) of the total notional value. Nevertheless, weather derivatives have been of great interest to various parties. In the period 1997-2007 weather derivatives were according to Husault and Rainelli-Weiss (2011) mentioned in 34 percent of all articles devoted to financial derivatives. This interest in weather derivatives is partly caused by the fact that weather derivatives are
different from any other financial derivative (Campbell, Diebold 2000). Most important
difference is that the payoff of a weather derivative cannot be replicated by an offsetting
portfolio. Hence, the underlying, the weather itself is not traded on an exchange. Second
distinction that should be made is that ‘normal’ financial derivatives are used for price
hedging, while weather derivatives are used for volumetric hedges. The last difference that
Campbel and Diebold mention is that the market for weather derivatives is not as liquid as it
is for other commodity derivatives. This is due to the location specific character of the
contract.

2.1 Background
The CME is the second largest of all exchanges worldwide in terms of contracts traded and/or
cleared. For weather derivatives the CME is the largest trading place. The contracts that are
traded on the trading floor find their origin at large corporations that wish to offset revenue
risk due to a fall in demand caused by undesirable weather conditions. The hedger will
negotiate a contract with another party, usually with the external help of a settlement agency.
The negotiated contract specifies exactly what the dependent weather variable will be. Of
course the contract also specifies which institute will be entrusted with the data collection.
This usually depends on the exact location of the weather station that is mentioned in the
contract. If the party that buys the contract is a speculator (e.g. bank or a hedge fund) it may
sell the contract to other speculators through the CME. Below there is a visual outline of the
main parties and processes involved in trading financial weather derivatives (Pryke 2007).
For a contract to be traded publicly, it needs to be standardized. This means that all the underlying variables are standardized to terms that are the same for all contracts. Standardization starts with specifying where the underlying weather variable is measured. The CME started with a list of 10 U.S. cities (Atlanta, Chicago, Cincinnati, New York, Dallas, Philadelphia, Portland, Tucson, Des Moines and Las Vegas) by now, this list has expanded to a total number of 38 cities in the U.S., Canada, Europe, Japan, and Australia (CME-Group, not dated). Standardization of a contract also involves the maturity and pay-out structure. The pay-out structure of a temperature related weather derivative is in 90 percent of the cases (Cao, Wei, Li 2003) based on the following two constructs:

- Heating Degree Days (HDD)
- Cooling Degree Days (CDD)
- Cumulative Average Temperature (CAT)

Contracts that are based on HDD’s are futures that are potentially useful for construction companies that wish to offset weather related risks. Another contract, which is in fact
specifically designed for the Dutch market are Frost contracts. In order for construction companies to understand weather derivatives and successfully hedge themselves against any weather exposed risk, it is important to fully understand the contracts. Therefore I will devote the next chapter of this thesis explaining the contracts.

A widely used alternative used to hedge risk is by mean of insurance. Unlike regular insurance, where there is a need to fail a claim in case of any damage, derivatives give a payout regardless of any damage that might have occurred to the holder of the derivative. Therefore, insurance is used for events that have a very low probability of occurrence but can cause a lot of damage, while derivatives are used for events that have a very high probability of occurrence and lead to relatively little damage (Golden, Wang, Yang 2007). However, some insurance firms in the Netherlands offer a specific polis that compensates for the loss, in case a construction company has to give its workers a day of due to bad weather conditions. If the coverage of the insurance matches the risk exposure the construction company is facing, it might provide a good alternative. A risk manager should therefore be aware of the pros and cons of both insurance as a risk hedger as well as weather derivatives.

3. Technical background
This first section will cover the most important derivatives that are used to hedge temperature related risk. Based on their characteristics I will determine whether they are suitable for a construction company to use during the winter period. The first section aims at describing each contract individually and explaining their pay out structure. Followed is the more general application and contractual content. The last part of this chapter aims at describing the most suitable valuation technique. This structure enables me to answer my first research question:

What type of temperature related weather derivatives, that are relevant for construction companies, exist and what are their implications?

Each contract that is based on an underlying weather variable gives a payoff that is linked to a certain index. For every weather type there exists an index or measurable standard that can be used for evaluating and pricing weather derivatives.

3.1 HDD and CDD contracts
HDD and CDD futures are contracts that measure how much days per contract period, which is either a month or a season, a day’s average temperature deviates from 65°F (or 18.33°C). The HDD season is from November until May. This period is called the Heating Degree Day
season because historically, the utility industry used 65°F as the base-line temperature at which the furnace would be switched on (Cao et al. 2003). A CDD contract is the measure for the number of Cooling Degree Days, which indicates the number of days per contract period on which electricity consumption is likely to increase due to the warm weather. A CDD season is from May until September. The remaining months April and October are often referred to as shoulder months. A HDD and CDD contract can also be denoted as (Zeng, 2000):

\[
HDD = \sum_{i=1}^{N} \max(0, 65^\circ F - T_i)
\]

\[
CDD = \sum_{i=1}^{N} \max(0, T_i - 65^\circ F)
\]

Where \( N \) is the number of days of the contract period, \( T_i \) is the arithmetic average of the observed daily minimum and maximum temperature on the \( i \)th day of the contract. \( T_i \) can be denoted as follows (Alaton et el. Date unknown):

\[
T_i = \frac{T_i^{max} + T_i^{min}}{2}
\]

A combination of a HDD and CDD contracts is called an Energy Degree Day (EDD), which can be used to hedge against weather risks throughout the whole year. For construction companies only the contracts based on a number of heating degree days is of interest, because it is during winter time that companies face the highest weather related risks. As seen in the pie chart below, almost 50 percent of the delay hours due to the weather occur in the first quarter of the year.
Contracts based on the Cumulative Average Temperature index are used for the summer season. Unlike the CDD or HDD index, there is no baseline of 65 degree Fahrenheit. It is simply the average daily temperature over a calendar month. That average is used to calculate the contract value.

### 3.2 Frost contracts

Another more specific contract that is available to hedge weather-related risk for construction companies that are situated in, or exposed to weather in the Netherlands is a Frost contract. A Frost contract is specifically designed for the Dutch market and introduced to the CME in 2005 (CME Group 2012). This type of contract was specifically designed after a large OTC contract was agreed upon in the previous year. A frost contract can be settled for the same period for which a HDD contract can be negotiated, which is November until May. As this contract is specifically designed for Dutch construction companies, it is no surprise that all frost contracts are based on the temperature measured in Amsterdam. A frost contract’s value is determined based on the number of frost days during the contract period. According to the CME rulebook, a frost day is defined as a day in which one or more of the following conditions is true:

- The temperature at 0700 local time (0600 UTC, except 0500 UTC beginning the last Sunday in March) is less than or equal to -3.2 degree Celsius;
- The temperature at 1000 local time (0900 UTC, except 0800 UTC beginning the last Sunday in March) is less than or equal to -1.5 degree Celsius;

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**Frost and weather delay hours per quarter for construction companies (1990-2011)**

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Frost Delay Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>48%</td>
</tr>
<tr>
<td>Q2</td>
<td>27%</td>
</tr>
<tr>
<td>Q3</td>
<td>14%</td>
</tr>
<tr>
<td>Q4</td>
<td>11%</td>
</tr>
</tbody>
</table>

Source: CBS Statline
- The temperature at 0700 local time (0600 UTC, except 0500 UTC beginning the last Sunday in March) is less than or equal to -0.5 degree Celsius, and the temperature at 1000 local time (0900 UTC, except 0800 UTC beginning the last Sunday in March) is less than or equal to -0.5 degree Celsius.

An interesting feature of a frost contract is that in contrast with HDD and CDD contracts, the Frost Days index excludes the Saturdays and Sundays of the contract period. It also excludes December 25, December 26 and January 1.

Each contract contains four basic elements (Cao et al. 2004). (i) The underlying variable: HDD, CDD or the number of Frost days. (ii) The accumulation period, which is the contract period for which the HDD or CDD account for. (iii) Specific information on which weather station will collect the meteorological data. (iv) The tick size: the amount that is attached to each HDD, CDD of frost day. Some contracts are sold with a maximum payoff. Usually this applies to option contracts (Cao et al. 2003).

### 3.3 Valuation

Determining the true value of a weather derivative is not as easy as it is for other derivatives. Even though it is a pretty straight forward contract, since the underlying of the contract is not traded, valuation leads to several possible valuation techniques that do not cause any arbitrage opportunities (Dorfleitner and Wimmer 2009).

According to Cao, Wei and Li (2003) the pricing and valuation of weather derivatives brings about two key issues: Assessment of the market price risk and accurate modeling of the underlying weather variable. These two elements bring together the economist and the meteorologist. This blend of financial mathematics and the weather is not straightforward (Pryke 1999). As the mathematician and the meteorologist both have their own way of forecasting the weather, it is the meteorologist that hold sway. This contributes to the fact that there is no general consensus regarding the question how to price weather derivatives (Dorfleitner et al. 2009). However, the existing valuation models can be grouped in three different categories. (i) Insurance or actuarial valuation models, (ii) historical burn analysis, and (iii) valuation based or dynamic models (Cao et al 2003).
3.3.1 Insurance or actuarial valuation models

Based on statistical analysis of historical data, this model tries to predict weather events. According to Cao et al this method is mainly used by insurance companies. By calculating the probability that a weather event will occur, the company values the contract by adding a premium. However, as the insured weather variables follow a certain trend, this method is not very useful (Cao 2009). To solve this problem, Dorfleitner and Wimmer (2009) oppose a linear model that is useful after detrending. As this model is useful for non-probabilistic events such as hurricanes, earth quakes and other catastrophic event, after removing a trend line, the model enables you to see the cyclical pattern of certain data. This is especially useful when the warming climate is taken into consideration. In meteorological studies this detrending technique is used a lot to distinguish between intrinsic and trend-induced variability changes (Scherrer et al. 2005).

3.3.2 Historical burn analysis

The least accurate and most simple method is the historical burn analysis. The historical burn analysis values the contract based on historical data of other contracts that were prices in the same contract period (i.e. identical contracts that were written on the same period, with the same number of HDD, CDD or Frost days). The average pay off of each contract is taken as an estimate for the contract value (Campbell et al 2000). The pricing errors that exist when using this valuation method are caused by a lack of data. Weather derivatives exist since the late nineties, and therefore do not provide enough data to fully capture the true distribution of the pay off. This is especially the case for Frost contracts, as they only exist since 2005. Even after 20 years of data, this methods still gives large pricing errors. This analysis is done by Cao, Wei and Li in their paper on weather derivatives. Analyzing the pay offs of the past 20 years, versus the difference of a 19 year analysis they found differences of almost 12 percent. When calculating the average payoff going back 10 years, differences increase to over 300 percent. They found these results from studying multiple HDD and CDD contracts for several cities in the U.S.

One could argue that using more historical data will increase the accuracy of the historical burn analysis, but that would imply that historical temperature movements perfectly predict future temperature movements. This assumption neglects the possibility of a cyclical trend, such as global warming (Scherrer et al. 2005).
3.3.3 Valuation based or dynamic models
A disadvantage of the historical or actuarial or the historical burn analysis is that they both do not account for the market price of risk. Dynamic models can account for that market risk. Cao and Wei base their dynamic model on the assumption that the daily temperature consists of two components. (i) The seasonal pattern plus a global warming trend and (ii) a random innovation. Based on the preferences (i.e. risk-averseness) of the trader, temperature derivatives can be valued, keeping into account that the standard deviation of temperature is larger during winter periods than it is in the summer. Cao, Wei and Li (2003) add an import note to the above mentioned technique of temperature modeling. They argue that one should always model the daily temperature and not the derived HDDs or CDDs per accumulation period. Modeling for example the number of HDDs or CDDs per period, ’will likely miss the finer features of these quantities’ (Cao, Wei and Li 2003).

They further add that derived variables are by definition period-dependent and path-dependent. They are difficult to track because they have a fixed ending point, meaning the 65°F threshold level.

4 Key Success Factors for weather risk management
To my knowledge there are no other studies that describe the critical success factors for construction companies that wish to offset their risk exposure by using weather derivatives. By researching relevant literature in the field of agriculture, tourism and utility services I will be able to discriminate the most important factors necessary for successful weather risk management. These findings will be elaborated in the following chapter and will enable me the answer my second research question:

Where should construction companies pay attention to when considering use of weather derivatives for hedging purposes?

Usage of weather derivatives
In the field of agriculture many studies examine the efficiency of weather derivatives (Chen et al. 2006 and Vedenov et al. 2004). They both conclude that using weather derivatives can shift the efficient frontier if the combination of weather variables is defined right. This is due to the nature of the agricultural business. Unlike construction companies, farmers are exposed to much more weather variables that can negatively affect yields. Chen et al. do argue that using weather derivatives solely is not sufficient. This also seems to apply to managers of a
construction company. Preventive measures can significantly reduce the exposure, and hence
the need for hedging. As indicated in the introduction, the main risk of construction
companies is the obligatory day of for their laborers on days that the average temperature
drops to chill temperatures of -6 Celsius. This might result in a time-lag resulting in high fines
due to contractual agreements. In order to prevent such problems, there are two main
precautionary measures a construction company can make. First, they should actively
consider whether to employ their own laborers or hire contractors. As contractors are not
subjected to the Collective Bargaining Agreement (CBA) they are more likely to continue the
work during the cold periods. This effect directly decreases a company’s weather exposure.
Other precautionary measures start in the planning phase. When contract negotiations take
place, managers could anticipate on the progress of the construction site and consider whether
laborers are possibly exposed to cold weather given the period of the year.

In the academic literature, ski-resorts have also been subject of research. Chun-Hung Tang
and Soo Cheong Jang research weather risk management based on two hedging strategies
(Tang et al. 2011): Geographical diversification and Financial hedging using weather
derivatives. For construction companies geographical diversification will not help. Unlike
snow fall, (i.e. the critical weather variable for ski-resort operators) temperature is more likely
to be the same for large geographical areas. International expansion as a diversification
strategy will be costly and for smaller companies a non-option.

The success of financial hedging weather risk lies in the correlation between cash flows and
snowfalls (Tang and Jang 2011). Resorts with a higher correlation ‘would enjoy better
hedging effectiveness’ (Tang, Jang 2011). Assuming that this is also the case for construction
companies, it is very important to measure a companies’ exposure prior to buying weather
derivatives. This is also supported by the research of Chen at al. (2006) who argue that there
are three types of data necessary for successful weather risk management. (i) Weather data (ii)
profit data, and (iii) abatement data. These datasets are also subject of research in the field of
energy providers.

Energy providers are exposed to a simple set of meteorological conditions, which also seem to
apply to construction companies. This results in a very high $R^2$ of 0.9416 when regressing the
monthly delivery of natural gas against the monthly average temperature. (Cao et al. 2003) It is important for construction companies to do similar analysis. By analyzing their exposure, in combination with their risk strategy will help to determine the optimal hedge ratio. This analysis also implies the active monitoring of a company’s exposure on the risk market. Actively tailing the hedge is necessary to prevent over or under hedging (Stulz 2003).

5 Financial derivatives or insurance
A widely used alternative used to hedge risk is by mean of insurance. Unlike regular insurance, where there is a need to fail a claim in case of any damage, derivatives give a payout regardless of any damage that might have occurred to the holder of the derivative. Therefore, insurance is used for events that have a very low probability of occurrence but can cause a lot of damage, while derivatives are used for events that have a very high probability of occurrence and lead to relatively little damage. However, some insurance firms in the Netherlands do offer a specific polis that compensates for the loss, in case a construction company has to give its workers a day of due to bad weather conditions. Analyzing these insurance is essential for a company in order to decide whether it should buy weather derivatives or take on insurance. Investigating the main differences will help to decide why and when a company should purchase derivatives.

This chapter will start with a chart that indicates the differences between the two products. Consequently I will analyze each difference and form an answer to my third research question:

- **How can derivatives provide an alternative for insurance?**

In the following chart the differences between insurance and weather derivatives are outlined to an example of Huault and Rainelli-Weiss (2011).
<table>
<thead>
<tr>
<th>Insurance</th>
<th>Derivatives market</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective</strong></td>
<td>• Protection against risk</td>
</tr>
<tr>
<td></td>
<td>• Protection against risk</td>
</tr>
<tr>
<td></td>
<td>• Exploitation of new financial opportunities</td>
</tr>
<tr>
<td><strong>Nature of the product</strong></td>
<td>• Tailored contracts</td>
</tr>
<tr>
<td></td>
<td>• Costs occur irrespective of the weather conditions</td>
</tr>
<tr>
<td></td>
<td>• Need of failing a claim in case of any damage. Damage needs to be directly related to the weather conditions</td>
</tr>
<tr>
<td></td>
<td>• Relative large risk premium</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Characteristics of the actors</strong></td>
<td>• Mutual identification</td>
</tr>
<tr>
<td></td>
<td>• Usually you deal with monopolists</td>
</tr>
<tr>
<td><strong>Nature of exchange</strong></td>
<td>• Interpersonal</td>
</tr>
<tr>
<td></td>
<td>• Untransparent</td>
</tr>
</tbody>
</table>

Overview of comparison between derivatives and insurance. To an example of Huailt and Rainelli-Weiss (2011)

Insurance contracts are usually designed to generate payoff in case of extreme weather conditions. Insurance contracts that protect construction companies in case of severe weather conditions are not common. Therefore this market is not competitive and premiums are likely to be high. This phenomenon is present because both the insurance firm and the construction company bear the same risk, unlike the two parties that enter a weather derivatives contract (Alaton, Djehiche and Stillberger, date unknown). They have a negatively correlated risk exposure with respect to the weather variable.

Like all derivatives, weather derivatives are used by speculators. This implies that weather derivatives can potentially be very volatile. A risk manager working for a construction company should avoid having a speculative position because it might endanger the companies’ solvability (Stulz, 2003). Therefore the focus should solely be on hedging the exposure, and not exploring weather contracts.
As a regular insurance contract pays off in case a claim is failed, a derivative generates payoffs irrespective of the eventual damage. In case the weather during the winter period is extremely mild, a construction company might face huge losses if it hasn’t anticipated on such events. Therefore a cap, to limit the maximum payoff, is recommendable. This should maximize the losses to a certain level. With a regular insurance there is no need for such products, because the costs are known in advance.

Although weather derivatives can be written on several variables, standardized contracts cannot fully cover a company’s exposure. Even though this form of basis risk can be minimized by changing the hedge ratio (Golden, Wang, Yang. 2007), it indicates that using weather derivatives as a hedging strategy brings basis risk, which is a mismatch between the underlying variable and the companies’ actual exposure (Stulz, 2003).

Another difference between the two products is that a weather derivative can be traded at any point in time. In case a construction company takes on a new project, it can easily buy or sell derivatives based on the new exposure. For insurance firms this process is far less easy and assumable costly.

A fiscal disadvantage of financial derivatives is that gains on a derivatives contract are subjected to turnover tax (art 3.25 wet IB 2001) for all Limited and Public Limited liability Companies.

In case of a regular insurance, the companies’ exposure can be evaluated by insurance experts who will then advice the company which insurance polis best fits the needs. However, a manager should be aware of the principal-agent problem, where the expert has a conflicting role (Himmelberg, Hubbard and Palia 1999). The principal-agent problem theory says that the advising expert has conflicting interest. His main task is advising companies on insurance policies, on the other hand he is eager to sell expensive insurances.

Trading weather derivatives does not have such problems. The CME tries to be transparent by using a clear rulebook, which indicated exactly what the rights and obligations of the traders are. The CME also guarantees a pay-out, therefore eliminating the credit risk that is present in Over The Counter (OTC) trading of weather deru. In times of financial difficulties, insurance firms might decide to lower their pay-out to customers. That could make it harder for firms to have their losses covered by the insurance firm.
As a result of all derivative contracts being standardized, transparency on this liquid market is high. This is the opposite for insurance policies. Because of the highly client specific details it is hard to compare two individual insurance policies. The actual monthly or quarterly premium that is due each period is dependent on many factors. For instance: (i) coverage, (ii) excess and (iii) primary and secondary preconditions. This makes it hard to compare insurance policies with one another.

6 Hedging strategies
In this final chapter I will give several examples of construction company XYZ that uses financial derivatives to hedge against unwanted weather conditions. All numbers that are used in the contract are based on regulations from the CME Rulebook. Meteorological information is coming from the weather station observations of Schiphol, Amsterdam in the Netherlands. This particular weather station is also the only station in the world for which it is possible to buy Frost Day contracts for. All examples will be based on Futures contracts. This is because Options are expensive, and without accurate weather forecasts is can be argued that buying Options is a form of speculating. It cannot be expected from construction firms that they possess such knowledge. Furthermore, a CRO (Chief Risk Officer) within a firm, should always strive to minimize cash flow volatilities due to the cold weather. For that purpose Futures are more suitable, if a company exactly determines what their costs are when projects are closed down due to the weather.

Remember that the definition of a Frost Day is rather complex. This is because there are multiple moments a day the temperature us measured. If one the measured values is below a threshold level, the day is actually referred to as Frost Day. A complicating factor is that for each and every moment that the temperature is measured; the temperature threshold differs. Also, weekend days and holidays should be excluded from the calculations. Therefore I retrieved information from the website of the CME website itself regarding the number of Frost days per period.

6.1 examples
The following examples are based on existing Frost Days futures and Heating Degree Day futures that are traded on the CME exchange. Prices, settlement procedures, and further specifications are all according to the CME rulebook.
Based on the weather conditions in the Netherlands it is not likely for construction companies to hedge themselves using a seasonal Frost contract or a seasonal HDD contract. This is because the weather conditions in the Months March and November are normally 6.2 and 6.7 (Royal Dutch Meteorological Institute, 2012) degrees Celsius respectively. This relatively mild weather does not contribute to the exposure construction companies have during the winter season. Therefore a monthly contract is the preferred option here.

At first, a company should quantify its exposure in terms of Heating Degree Days or Frost Days. Consequently, it has to determine which weather station has the highest correlation with the temperatures on the construction site. In this example, the CRO of construction company calculated that for the months January and February, they need the following contracts to hedge their exposure. This can come forth out of contractual agreements with contractors, by which XYZ is obliged to complete a certain project by the end of February.

### Examples of HDD Futures contract with, and without Cap

<table>
<thead>
<tr>
<th>Location</th>
<th>HDD Future (long)</th>
<th>HDD Future (long)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amsterdam, Schiphol Airport (WMO 6240)</td>
<td>Amsterdam, Schiphol Airport (WMO 6240)</td>
</tr>
<tr>
<td>Buyer</td>
<td>XYZ</td>
<td>XYZ</td>
</tr>
<tr>
<td>Accumulation Period</td>
<td>January 2012</td>
<td>February 2012</td>
</tr>
<tr>
<td>Tick size</td>
<td>€ 20,- per HDD</td>
<td>€ 20,- per HDD</td>
</tr>
<tr>
<td>Settlement level</td>
<td>425 HDDs</td>
<td>400 HDDs</td>
</tr>
<tr>
<td>Actual Level</td>
<td>410.10</td>
<td>505.05</td>
</tr>
<tr>
<td>Payoff at maturity</td>
<td>((410.1-425) \times 20 = -/-298)</td>
<td>((505.05-400) \times 20 = 2.101)</td>
</tr>
</tbody>
</table>

Based on historical averages the number of HDDs for the month January is set at 425. When purchasing the futures contract, XYZ pays 425 times 20 Euro. After several weeks it turns out the temperature for the month January is rather mild. With these weather conditions construction company XYZ has no trouble continuing their work. As a result, XYZ receives only 410.10 times 20 Euro, resulting in a loss of € 298,- on each contract. The following month XYZ experiences a lot of difficulties due to the weather. It cannot complete the project, and on top of that is XYZ obliged to give their builders a day off. These immense costs are compensated by the payoff of the long futures contract, which pays 2.101 Euro for each contract.
The same result can be realized with Futures contracts. The difference is that the tick size (the minimum price fluctuation on the CME Frost Days index) is a lot higher than HDD futures. Nevertheless, for construction companies it might be more attractive to buy Frost contracts instead of HDD futures. This is because the costs for construction companies are more likely to be correlated with the payout of Frost futures, because of the mandatory day off for laborers on cold winter days. Also, Frost contracts exclude weekend days, which makes them more suitable for construction companies.

7 Results
This paper focused on the use of weather derivatives for construction companies. Because of the specific weather exposure of construction companies, this preliminary research gave insight in the various aspects of hedging the weather for this type of companies. First of all it is recognized that the use of weather derivatives requires specialized knowledge. Determining a company’s exposure with respect to the different variables for which contracts can be traded is a specialized skill. Furthermore, if a company wants to hedge it exposure based on ongoing and new projects, a risk manager within the company has to actively manage and control a companies’ derivatives portfolio.

As an alternative to weather derivatives, a company could take on an insurance that could pay out if laborers have a mandatory day off due to the weather. Some of the benefits concentrate on the outside expertise that the insurance firms can offer. Another argument is that for a
regular insurance contract, all costs are known in advance. However, where derivatives are priced in a competitive environment, it is likely that for insurance policies a large risk premium is paid. This is due to opaque pricing strategies and a monopolistic market.

Another focus area of weather derivatives is the unclear pricing methods for the various kinds of derivatives. As discussed, there is no uniform way of pricing a weather derivative. Consequently I can state that the use of weather derivatives is a very good alternative, but not for all companies. Considering the amount of expertise that is needed in order to be successful in the field of weather risk management, derivatives contracts are only recommendable for large sized companies. They should be able to attract a specialized person that is familiar with derivatives trading. Based on the experience in the field of agriculture, tourism and energy, weather derivatives have proven to be a very effective tool for in minimizing cash flow volatility. For smaller companies it seems that flexibility in their planning and organization is the most important asset. By doing so, they can hedge themselves by systematically decreasing its exposure to cold weather conditions.

Further research in the field of risk management should focus on techniques that could be used to quantify a company’s exposure to certain weather variables. As this is a crucial to successful weather risk management, this research would be very useful.
Descriptive statistics

Risk determinants

\[ Risk = \sum_{i} P_i \times K_i \]

Normalized Expected value

\[ \mu = \frac{[z - E(z)]}{[\text{Vol}(z)]} \]

Volatility

\[ \sigma = \sqrt{\frac{\sum_{i=1}^{n} [z - E(z)]^2}{n - 1}} \]

Determinants for number of HDD’s

\[ HDD = \sum_{i=1}^{N} \max (0, 65^\circ F - T_i) \]

Determinants for number of CDD’s

\[ CDD = \sum_{i=1}^{N} \max (0, T_i - 65^\circ F) \]

Arithmetic average

\[ T_i = \frac{T_i^{max} + T_i^{min}}{2} \]

Probability of event i

\[ P_i \]

Impact of event i

\[ K_i \]

Expected value of variable z

\[ E(z) \]

Maximum and minimum recorded temperature on day i

\[ T_i^{max}, T_i^{min} \]
References

Alaton P., Djeiche B., and Stillberger D. (Date unknown) On Modelling and Pricing Weather derivatives


Weather Risk Management Association (2011) see industry surveys on the following link: http://www.wrma.org/members_survey.html