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MEASURING AND MANAGING WEATHER VARIABILITY

Protecting Businesses from WeatherRisks

by Jean-Louis Bertrand, Laura Hershey & Miia Parnaudeau

METEOPROTECT

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BACKGROUND

Foreword

Gabriel Gross, President and CEO, Meteo Protect
Catherine Leblanc, Director General, ESSCA School of Management

This past year, global average surface temperatures exceeded all previous on record to reach the symbolic and significant milestone of 1°C above the pre-industrial era. Consistent with a long-term trend, human-induced global warming has fueled and substantially increased the probability of many extreme weather events and the severity and duration of unfavourable weather conditions.

As 70% of firms in industrialized countries are exposed to everyday weather anomalies for a total amount of sales ranging from 25-35% of annual GDP, unfavourable everyday weather can destroy up to $500bn in the United States and €400bn in Europe each year. With the accumulation of years of increasing unseasonal weather and extreme weather events, the consequences of climate change have had a major impact on every sector and business activity. For example, in the agricultural sector, droughts and heat waves have contributed to a 10% reduction in global production of cereals over the last 40 years. Other activities with the same degree of weather sensitivity as agriculture include forestry and fisheries, but almost as significant is the impact of weather anomalies on public services, retail and transport, and manufacturing and industry.

In 2014, Meteo Protect and ESSCA School of Management partnered to survey risk managers of the Fortune 500 companies across Europe to ascertain the extent to which they were aware of their companies' precise weather risks and were using financial hedging solutions to reduce their weather risk exposure. At that time, we found that 85% of risk managers perceived weather to have an impact on business, but only 56% knew the precise relationship, and 40% were considering hedging their losses in order to protect their EBITDA versus 5% seven years earlier.

Bearing in mind that industry was in the dark about the extent of their financial risks related to weather, we followed this with research of the potential impact of climate variability on business sectors, measuring inter-annual weather variations, testing the sensitivity of quarterly Gross Value Added (GVA) to quarterly temperature and precipitation anomalies applied to five countries across Europe. We found that weather anomalies impact the UK more than any other leading economic EU country (including Germany, Spain, France, and Italy), and climate impacts on GVA for temperature in the UK alone total 7,9 billion Euros.

We then dug deeper, ranking the impact of climate variability on UK retail sectors, and developed a stepped data-mining procedure that leads to weather-sensitivity rankings per season, per weather variable, per retail sector. We found that, overall, monthly sales growth and weather variations are strongly correla ted for 63% of UK retail sectors, but even more sectors are exposed in spring (73%) and winter (64%). Whilst we concentrated on the UK, given it has the highest sensitivity to the weather amongst the leading economic players in Europe, our weather sensitivity ranking can be applied to any country, and any sector.

This research report takes our analysis in a slightly different direction. Whereas previous papers demonstrated the relationship between economic sectors and the weather, indicating the correlation between them, and modeling it to provide the percentage of sales affected positively or negatively by a deviation in the norm, this paper explores the impact of changes in weather to find the maximum potential loss caused by adverse weather (or "WeatherRisk") for any business sector. This new equation offering the historical and average losses as well as WeatherRisk is available due to our researchers including climate-change adjusted weather distribution into the models.

This innovative approach allows risk managers to have a full understanding about the impact of daily deviations from expected or seasonal weather, to be able to plan ahead, for the first time, the total extent of their exposure to the weather, and in turn, to be able to determine how much of this risk they should hedge in order to secure their sales and EBITDA. This can be done, of course, at the same time as they assess the changes they need to make to their operations and business practices to mitigate risks attributed to climate change.

This is particularly relevant given the heightened attention to the effects of climate change on all sectors of society at the recent Cop21 climate conference in Paris at the end of the year. Businesses are facing increased scrutiny of their contribution to climate change by governments needing to meet emissions targets. However, the reality is that the effects of climate change are already impacting business profits, and investors and shareholders alike are also applying pressure, demanding climate vulnerability assessments to study the weather risks to which the business in which they have invested is exposed, and how the company is mitigating these risks.

It is our hope that by presenting new models to determine weather-sensitivity, we are providing companies the means to assess their own, in turn to build business resiliency to climate change through a range of risk management solutions.

Executive summary

As 2015 set a global record as the warmest on record for land and ocean surface combined, with the last record being made just the year before, both public and private sectors around the world have noted that the impacts of climate change are significant, not just in record high global temperatures, but in the frequency and intensity of weather anomalies. At the same time, as governments and companies alike experience the financial consequences of climate change, the discussion of how to address climate change has now expanded from mitigation, including reducing carbon emissions, to adaptation, including minimizing risks and building resiliency to climate change.

In October 2015, Meteo Protect released "A Path to Resilience: Ranking the Impact of Climate Variability on UK Retail Sectors", which developed a stepped data-mining procedure that leads to weather-sensitivity rankings per season, per weather variable, per retail sector. This weather sensitivity ranking can be applied to any country, and any sector, indicating the correlation between them by percentage of sales affected positively or negatively by a deviation in the norm from seasonal or expected weather.

However, in speaking to risk managers, we noted that they consistently wanted to know not just how they are affected by deviations in the norm, but what the worst case scenario, or maximum risk, is as a result of the weather. This report provides this assessment of any company's average and maximum "WeatherRisk" in addition to the impact of daily deviations from expected or seasonal weather. With our previous research papers, we showed how risk managers can understand the impact unseasonal weather has had on their performance in a given year, remove this impact to obtain the performance at normal climate conditions, and plan the following year much more accurately without integrating past weather effects into forecast business budgets. With this paper, managers now know how weather affects this budget going forward through the measurement of the WeatherRisk.

They can now implement a weather risk management policy, including making changes to operational and business practices, and transferring their risk through financial risk hedging solutions, in order to increase their climate resiliency.

This report is based on several lines of research, including:

- Finding the most relevant weather variables to explain changes in sales, operating costs, or profits using daily weather observations;
- Providing a weather-sensitivity ranking by sector and weather variable;
- Modelling the relationship between weather variables and sales;
- Determining the average and maximum historical losses caused by unfavorable weather conditions; and, finally;
- Calculating the potential maximum loss, this new equation defined by the researchers as "WeatherRisk".

In order to test these lines of research, we use a case study of the German retail sector. Specifically, we analyzed the relationship between changes in retail sales and deviations from normal temperature, precipitation, humidity rate for German retail over the period January 1994 and September 2015. For each season, and for each weather-sensitive retail category, we model the impact of changes in weather on the sales of each retail category whenever the correlation between sales and weather is strong enough. We then estimate the WeatherRisk to which each sector is exposed in case of adverse weather.

KEY FINDINGS

Existing research into the relationship between the weather and sales profits and losses is inadequate to address today's climate risks.

The role of weather in economics is a relatively new field, confined primarily to understanding the role of the weather on consumer mood and behavior, to analyzing the impact of specific weather events, or to analyzing the role of a limited array of weather variables as to how they impact a business.

The relationship between weather and commercial activities has remained unstudied, leaving risk managers with a limited understanding of the extent of the weather sensitivity of their business. Risk managers have remained satisfied with using weather to explain profit losses, and to economists attributing market gains to favourable conditions.
This research vacuum has become rapidly more consequential as the effects of climate change have exponentially increased in the last 30 years.

The majority of risk managers only understand and insure climate risks pertaining to high impact but low occurrence events such as natural catastrophes. Without the research and modelling tools to determine the precise relationship between weather and sales profits and losses, risk managers only mitigate the risks of traditionally insurable perils such as catastrophes and property damage affected by weather. While these are high impact events, they are not usually frequently occurring, nor do they impact all business sectors or geographic regions. Moreover, they do not cover the full impacts of the weather, such as accounting for reduced sales and increased operating or sourcing costs. In this way, low impact but high frequency events that can have material effects such as weather being unseasonable for many weeks, go unanalyzed, unmitigated and uninsured. However, with climate change, it is precisely this kind of unseasonal disparity between the norm and unfavourable conditions that characterize the climate today.

Risk managers can now provide an analysis of their average and historic losses in sales due to weather, and compare the weather sensitivity of their sectors and regions to others.
Risk managers have long required a model by which they can calculate the contribution of weather to sales, showing the precise impact of daily deviations from expected or seasonal weather. Thus, Meteo Protect analysts developed a stepped data-mining procedure that leads to weather-sensitivity rankings per season, per weather variable, per retail sector.

This modelling tool has proven invaluable to risk managers as part of the risk identification step of their work. With this tool, risk managers can now model how sales, profits or costs change as a result of unexpected deviations from normal weather. This means knowing which weather parameters are most important to their business, and the precise relationship between these parameters and their business performance.

Risk managers can now provide an analysis of their potential maximum future losses in sales due to weather variability.

The benefits of knowing the historic relationship between the weather and sales and profits is invaluable in understanding a company's historic success and being able to evaluate and isolate the role of weather in the company's performance. However, although informative, this approach only measures what has come to pass. It doesn't estimate the risk going forward, based on the evolution of climate change.

Meteo Protect analysts therefore developed a new modelling tool in this paper, called WeatherRisk, which measures the losses a company may sustain resulting from weather variability. It provides a breakdown of the effects of any given risk for any given period within a defined confidence interval.

Researchers can now model minimum, average and maximum WeatherRisk in order to allow risk managers to see the worst case scenario and mitigate against it or hedge some or all of it.

This innovative approach allows risk managers to be able to plan ahead, for the first time, the total extent of their exposure to the weather.

Risk managers can now accurately determine how much of their WeatherRisk they wish to mitigate using financial hedging solutions and what adaptation measures they will take.

Just as different retail sectors and regions are impacted differently by each weather variable, the impact of a maximum potential loss will affect various businesses of various size and structure in different manners.

The key for a risk manager is to determine the level of the potential WeatherRisk respective to a company's margin and financial strength. The stronger the correlation between WeatherRisk and margin, the more likely it is that a risk manager will take steps to reduce or eliminate the WeatherRisk.

This can be done efficiently and inexpensively through the purchase of index-based weather financial hedging products, in derivative or insurance form. This affords a company the stability it requires to be able to invest in operational changes to reduce its WeatherRisk exposure, and to invest in efforts to reduce its carbon footprint and thus contribute to resolving the problem from a macro-economic perspective.

RECOMMENDATIONS

Companies should now consider voluntarily disclosing their climate change sensitivity to investors and stakeholders.

Voluntary disclosure on climate risks are increasingly demanded by investors and other stakeholders. Generally, the number of companies who have provided such public reporting in financial filings and sustainability reports have been limited, and those that do have done so with a low level of detail and precision as to their exact risk. When they include climate change issues, they generally speak to catastrophic events such as droughts and floods arising from climate change, and not to day-on-day weather variability as a result of climate change. Many investors and stakeholders may reconsider the level of return they are getting on their investments in view of this additional risk should they continue to ignore and not mitigate or transfer it to financial risk takers such as banks, insurers or reinsurers.

Just as critically, companies that measure and disclose their WeatherRisk are more likely to take steps to manage their climate change sensitivity strategically and to receive the critical support they require in allocating funds for this purpose. Moreover, in disclosing this information they are increasing awareness of business vulnerabilities and sensitivities from climate change and providing decision makers such as politicians and policymakers access to the data that delivers the insight required to drive change.

Similarly, companies should now consider disclosing their climate change resiliency measures

Companies who rely solely on conventional business continuity planning or risk management tools such as catastrophe insurance must now consider extending their business continuity and emergency management plans to address climate variability. Now that the tools are available to accurately assess the historic, average, and future WeatherRisk of a company, disclosing this sensitivity is just the first step. Naturally, investors and stakeholders are going to demand that following a WeatherRisk assessment, companies will take appropriate actions, including utilizing financial hedging solutions (such as insurance or derivatives), but also making operational changes such as upgrading infrastructure and equipment, and investing in new technologies and processes to manage and mitigate climate sensitivity, as well as to reduce the carbon footprint of the company and contribution to climate change.

In disclosing what climate change resiliency measures a company is taking in order to respond to its WeatherRisk, it is increasing awareness of the need for corporate leaders to take action in reduce climate change and build resiliency to it, to share best practices in both, to provide a benchmark for corporate peers, identify trends, and to create opportunities for others to contribute to the process by engaging investors, stakeholders and the public in coming together to contribute innovative solutions for more sustainable institutions, products and services.

Ratings agencies should now consider including climate change vulnerability as an individual weighting methodology in their rankings.

Without incorporating climate resiliency into their ratings methodologies in a substantial, transparent and comprehensive fashion, credit ratings agencies such as Moody's Investors Services and Standard & Poor's may be substantially miscalculating the risks of climate change to the corporate sector.

Presently, catastrophes seldom trigger ratings actions, and average, historic and maximum WeatherRisk is not considered at all. Thus, ratings agencies are likely miscalculating the credit rating and values of companies that are affected by climate variability. At the same time, they may be putting investors at risk.

While the ratings agencies have recently released reports addressing the emerging risks associated with climate change and the global efforts to halt it, and incorporated climate risks into certain aspects of its ratings, they should now consider providing climate resiliency its own methodology ranking.

Introduction

It's a record that no one wanted to see broken. Yet again, this past year (2015) was the warmest calendar year and the warmest 12-month period on record with a global temperature almost 1°C above the 20th century average[1].

[1] https://www.ncdc.noaa.gov/sotc/global/201513

Moreover, just as average temperatures are gradually rising, the succession of severe and exceptionally warm winters in Europe and the US between 2009 and 2015 demonstrates that the transition between the normal climate prior to 1990, and a new climate post-2050 is taking the form of a rollercoaster of severe, unseasonal weather patterns.

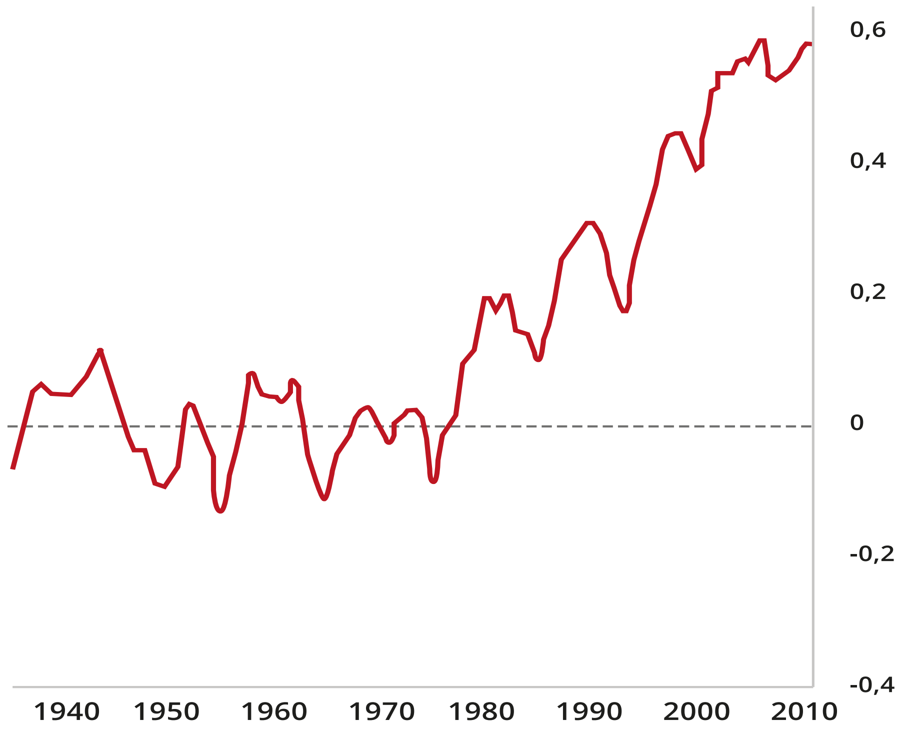


Figure 1: evolution of temperature anomalies (reference 1951-1980)

The World Meteorological Organization has recognized that climate change is aggravating naturally occurring climate variability and has become a source of uncertainty for climate-sensitive economic sectors, including the 70% of companies for which demand and/or supply are affected by changes in weather patterns. Indeed, whilst much work has focused on estimating the cost of climate change by the year 2050, the climate has already changed, with companies already feeling the effects of an increase in weather anomalies and higher year-on-year sales and profits swings. Climatologists, meteorologists, data scientists, Intergovernmental Panel on Climate Change (IPCC) members, politicians and a wide array of expert consultants are trying to convince the private sector that action needs to be taken now.

For, faced with the inability of the public sector to mobilize efforts to make climate a priority, everyone, including the United Nations, appears to have recently made a substantial shift in policy, calling upon private enterprise to address, if not solve, the problem. In support of this, a new tool has been made available to companies: the Strategic Development Goal (SDG) compass. The SDG Compass is supposed to "make it easy for every business in the world to align their strategies and manage the things that are going to help contribute to those SDGs and then be radically transparent about the progress made. Targets include strengthening resilience and adaptive capacity to climate-related hazards in all countries, and integrating climate change measures into national policies, strategies and planning. The United Nations stress the fact the climate change is now disrupting national economies, affecting lives, and costing people communities and countries.

How is climate change causing these impacts today and even more tomorrow? This is where things get very confusing. For all the relevant players, including the prestigious Intergovernmental Panel on Climate Change (IPCC), are using studies that attempt to qualitatively and sometimes quantitatively assess climate risk for a selection of industry sectors by the year 2050. Understandably, this is not what the majority of private enterprise would refer to as relevant for today or tomorrow. In fact, given that the average tenure of a departing S&P 500 company CEO is 8.1 years, it's more than four lifetimes away.

It is a reality of business that politicians should understand, as they, to some degree, face the same challenge as company executives: the constraints of a short-term mandate. In the business environment, the pressure is on delivering results this quarter, this fiscal year. Commitment of capital needs to return money very quickly. Not in 2030, nor in 2050. Companies exist to generate profit and maximize shareholders' value. Only to the extent that climate change is a threat to this objective will company executives start to think about ways to tackle the issue.

Compounding the problem, in the vast majority of cases, there is a lack of consistency between studies, combined with a low degree of accuracy on the evaluation of the risks, due to our inability to accurately forecast climate in 2050, or modify models in real-time to account for individual players' shifting actions and behaviours. Not only are we struggling to characterize the general climate environment a few years out, but nobody is in a position to precisely evaluate what climate change means for individual sectors, and individual companies. If you can't quantify what is at stake, how can you evaluate the need to invest into climate-related strategies, and the potential return these strategies will generate?

It is all about translating unseasonal weather into one actionable, objective, easy-to-understand metric. The easiest means of doing this is to focus on climate variability, defined as the deviation of observed weather from its normal long-term value. To act, weather risk management experts can provide the private sector with:

- A clear, objective and quantified measure of the average, historical and potential maximum losses caused by climate risks in a time horizon that is relevant to them and to their shareholders;
- Financial solutions that enable them to mitigate climate risk and buy time in the short term to adjust and implement business strategies in the long run, as they put in place the operational changes to build long-term climate resiliency.
- A clear and objective methodology to report and disclosure climate risks to shareholders, investors and analysts.

Having identified the impact of climate change on their business, utilizing financial instruments such as derivatives or weather insurance products to limit the impact of climate variability, companies can build resilience to climate variability and therefore climate change, while investing in the environmental solutions that scientists have already identified as necessary (such as replacing use of fossil fuels with renewables and restocking carbon sinks). Measuring and managing the impact of climate variability allows everyone, managers, investors and regulators, to better understand their exposure to climate and find operational and industrial solutions to lower this exposure and be more resilient to climate change. It serves to realize the extent to which climate risk can jeopardize short term and long term profits, which in turn becomes a drive to address climate-related issues on an on-going basis.

CASE STUDY

Applying the Key Finding: Case Study Germany

German weather is no exception to the global trend of rising temperatures. In 2015, every season was warmer than normal, and both November and December were the warmest months since systematic measurements began in 1881. The deviation from normal temperatures was on average +3.1°C in November and +5.2°C in December.

Similarly, German climate variability is increasing. We measure day-to-day variability by taking the difference between observed weather and its average value over 1981-2010. This difference is called an anomaly and can be either positive or negative.

The absolute value of the deviation, which is the distance to the average and therefore a positive number, is a better indicator to illustrate the phenomenon of increased climate variability.

In spring, temperature anomalies have increased at a rate of 0.19°C since 2000. Whilst the deviation was around 1°C in 2000, it is on average 4 times higher in 2015. In winter, the increase in the last 15 years was 0.15°C per annum. On average, the anomaly has doubled in 15 years.

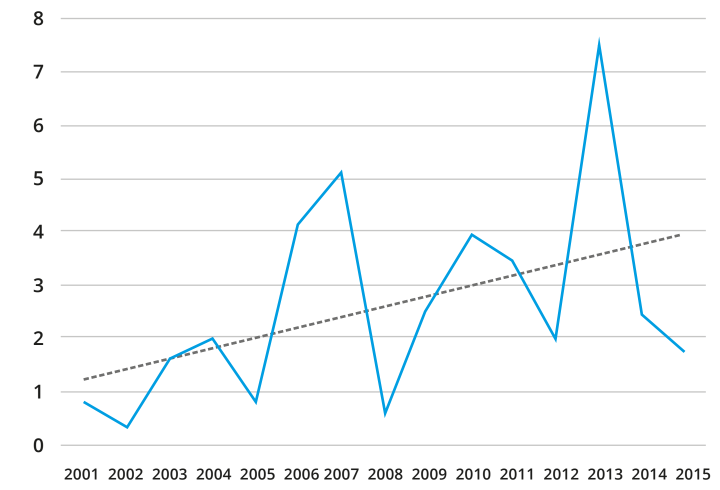


Figure 2: evolution of the absolute value of temperature anomalies in spring

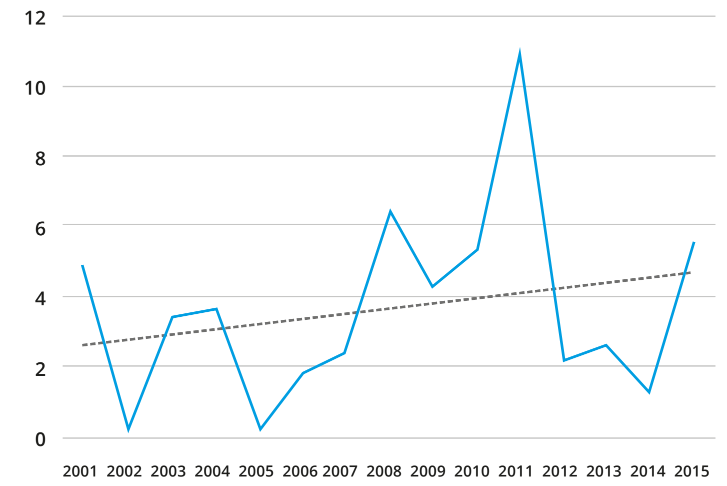


Figure 3: evolution of the absolute value of temperature anomalies in winter

ASSESSING & MANAGING WEATHER RISK

Weather and businesses

Since the beginning of civilization, humanity has been fascinated by the irrepressible and incomprehensible forces of nature, weather and astronomy. Thankfully, we've moved on from making sacrifices to the sun, worshipping godly personifications of the seasons and elements, and blaming natural catastrophes on divine intervention. Similarly, our means of forecasting the weather, and explaining the relationship between the weather and our environment has evolved from folklore and rudimentary instruments. Indeed, the fields of meteorology, climatology and atmospheric physics have made such substantive scientific and technological leaps forward that today the World Meteorological Organization, a specialized agency of the United Nations, has 191 member states and territories cooperating to monitor, understand and predict weather, climate and water, using an astonishing array of sensors, gauges, data logging and modelling, and remote sensing.

At the same time, however, academic research on the relationship between the weather and climate and society has been arguably slow to keep up and perhaps not considered as urgent or imperative a discipline, save for exploring the role of mankind in contributing to global warming and modelling the long-term impacts of climate change on civilizations.

For example, weather observations have been used in statistical models to understand the role of weather on mood and consumer behavior, but the relationship between weather and the economy has not been as extensively examined.

In retail, the role of weather may be considered somewhat straightforward, with the first research on the matter having been conducted in the 1950s and 1960s and still holding true today, it finding that weather affects and influence consumers, who in turn affect sales. Largely coming out of the United States, researchers were driven by the idea that weather information had growing economic value that could be used by managers to make better decisions in weather-sensitive sectors if only forecasts were more reliable and if we knew precisely how weather changes business activity. Analyzing US retail sales, they were able to calculate the correlations between deviations from seasonally adjusted retail sales and weather parameters and demonstrate which retail categories exhibited the highest correlations with temperatures. Unfortunately, whilst finding that weather has a powerful effect on demand, researchers consistently failed to quantify its importance, particularly over large geographical areas.

"EXISTING RESEARCH INTO THE RELATIONSHIP BETWEEN THE WEATHER AND SALES PROFITS AND LOSSES IS INADEQUATE TO ADDRESS TODAY'S CLIMATE RISKS."

By the 1990s, with the global warming debate raging and evidence of increased climate variability, a new interest in weather and economics emerged and the literature on business sales and weather is now a growing discipline of research. Most recently, a detailed study measured the impact of severe weather events on selected retail categories in certain geographic regions. Moreover, researchers completed an exhaustive study on US retail sales and weather. However, it only tested temperatures and no other weather parameter, did not measure the potential effects of intra-annual anomalies, and the level of aggregation of retail sales data was high (4 sub-categories of durable goods outlets and 6 sub-categories of non-durable goods stores) resulting in possible offsetting effects that made it difficult to pick up weather signals.

Consequently, the research's findings that deviations from normal weather had a modest role in explaining monthly sales fluctuations has been drawn into question. In fact, it has been inconsistent with repeated macroeconomic studies conducted between 2002 and 2011 demonstrating that 70% of all companies are exposed to climate variability, for a total amount representing a potential loss of 3.5% of GDP every year.

This paper sets out to address the limitations of existing research. Specifically, where others have modelled the impact of only one weather variable on retail sales and deviations, we look at temperature, precipitation and humidity. Further, we move beyond inter-annual anomalies by using monthly retail sales data. Our research relies on data and methodology that can be drawn and analyzed anywhere in the world, demonstrating that for each season, and for each weather-sensitive retail category, we can model the impact of changes in weather on the sales of any retail category and estimate the risk to which each sector is exposed in case of adverse weather.

CASE STUDY

Applying the Key Finding: Case Study Germany

In developed countries, retail sales are a very important driver of GDP. Whilst retailers have long known that weather can have a strong influence on sales, national statistics offices do not quantify and remove the effects of weather on sales. Rather, when National Statistics Offices publish their monthly retail sales figures, they refer to weather to explain unexpected growth performance either to say that the impact was positive or negative, but never do they quantify exactly what the contribution of weather has been.

For instance, December 2015 was unseasonably warm in Germany. Press reports stated that German retail sales dipped in December 2015, marking a weak end to the year and suggesting private consumption, which has been a pillar of support for Europe's largest economy, could lose steam in the fourth quarter. Mild weather had probably taken its toll on retail sales because consumers did not want to buy winter goods due to the spring-like temperatures experienced in December. No further information was provided on the actual loss caused by temperatures.

Using German retail sales as a case study, we demonstrate how to measure the effect of unseasonal weather on business performance. To do this, we analyse the retail sales data in Germany. In Germany, retail sales data measure the turnover in retail trade in Germany in the form of nominal and real (price-adjusted) index numbers and their change rates. As such, the data describes the development and not the actual level of turnover. We analyzed a selection of retail categories as defined by the national Classification of Economic Activities, 2003 edition - WZ03.

About 27,000 of the total of approximately 378,000 retail businesses report their monthly turnover to the statistical offices of the Länder, while another 700 large enterprises submit their data directly to the Federal Statistical Office. At the Federal Statistical Office, the data transmitted by the Länder offices and the data of large enterprises are compiled to obtain a federal result. The monthly turnover established in this way is related to a base value (currently base 2003 = 100). The rate of change is determined by comparing an index number with the respective index number of the corresponding month of the preceding year. To apply our research to Germany, we analyzed 17 individual retail sales categories provided by Destatis.

Retail category	
4711	Non-specialised stores with food, beverages or tobacco predominating (e.g. supermarkets)
4719	Non-specialised stores where sales of food, beverages and tobacco is not predominant (e.g. department stores)
473	Automotive fuel for use in motor vehicles and motorcycles
4752	Hardware, paints and glass
4753	Carpets, rugs, wall and floor coverings in specialised stores
4754	Electrical household appliances
4759	Furniture, lighting equipment and household articles not elsewhere classified
477	Other goods in specialised stores
4771	Clothing
4772	Footwear and leather goods
4774	Medical and orthopaedic goods
4775	Cosmetic and toilet articles
4776	Flowers, plants, seeds, fertilisers, pet animals and pet food
4777	Watches and jewellery
4778	Other retail sales of new goods in specialised stores
4779	Second-hand goods in stores
4791	Mail order houses (including internet retailers)

Table 1: list of German retail sectors used in the case study

In Germany, meteorological data is extracted from the Climate Data Center of Deutsche Wetterdienst (DWD). Since retail sales data are available at a national level and on a monthly basis, we aggregated weather data from local daily observations to an economically meaningful level using a fixed set of population weights as retail demand is driven by the population.

Region	Town	Weather Station	Population	Weight
Baden-Württemberg	Stuttgart	Stuttgart-Echterdingen	10 786 227	13%
Bavaria	Munich	Munchen-Stadt	12 595 891	15%
Berlin	Berlin	Berlin-Dahlem(FU)	3 501 872	4%
Brandenbourg	Potsdam	Potsdam	2 495 635	3%
Bremen	Bremen	Bremen	661 301	1%
Hamburg	Hamburg	Hamburg-Fuhlsbuttel	1 798 836	2%
Hesse	Wiesbaden	Frankfurt/Main	6 092 126	7%
Lower Saxony	Hanovre	Hannover	7 913 502	10%
Mecklenburg-Vorpommern	Schwerin	Schwerin	1 634 734	2%
North Rhine-Westphalia	Dusseldorf	Dusseldorf	17 841 956	22%
Rhineland-Palatinate	Mayence	Mannheim	3 999 117	5%
Saarland	Sarrebruck	Saarbrcken-Ensheim	1 013 352	1%
Saxony	Dresde	Dresde	4 137 051	5%
Saxony-Anhalt	Magdebourg	Magdeburg	2 313 280	3%
Schleswig-Holstein	Kiel	Kiel-Holtenau	2 837 641	3%
Thuringia	Erfurt	Erfurt-Weimar	2 221 222	3%
Total			**81 843 743**	**100%**

Table 2: weather stations and population weights

The national weather is the average weather of the 16 regional stations weighted by the population of each region. We used temperature, precipitation, and humidity rate. A linear trend calculation for each station was used to account for the potential effects of climate change. The calculation process for the national temperature index tempm,y for month m in year y is:

$$temp_{m,y} = \sum_{ws=1}^{16} \sum_{d=1}^{lm} \frac{1}{l_m} \frac{p_r}{p_{total}} temp^{D}_{d,ws,m,y}$$

Where $TEMP^{ano}_{m,y}$ is the average detrended D temperature of the day d in the weather station ws of the 16 regional stations, for month m in the year y, l_m is the number of days with the month m, p_r the regional population and finally p_{total} the total population.

Weather anomalies are calculated by taking the difference between the observed weather and its 30 year- average (here 1986- 2015) as recommended by the World Meteorological Office (WMO).

We define $temp^{D}_{d,ws,m,y}$ as the national temperature anomaly for month m in year y. It is given by the difference between the monthly national temperature $temp_{m,y}$ and the average of the same index over 30 years as follows (Bertrand et al., 2015).

$$TEMP^{ano}_{m,y} = temp_{m,y} - \frac{1}{30} \sum_{y=1986}^{2015} temp_{m,y}$$

This computation is reproduced for the two other weather variables involved in our study: precipitation and humidity rate.

Low impact, high occurrence risks matter

When the majority of risk managers consider climate risks, and even climate change, they are considering the probability and likely impact of a "catastrophe" befalling their business, or what the property insurance industry refers to as the impact of an unusually severe natural or man-made disaster. Catastrophic meteorological events generally include tropical cyclones, extratropical storms, local storms, and regional storms and monsoons, whilst catastrophic climatologic events refer to heatwaves and drought, as well as wildfires following prolonged dry spells (other natural catastrophes are generally classified as geophysical events, such as an earthquake, tsunami, volcanic activity, or hydrological events such as a flood or mass movement). In all cases, the test of the severity of an event being classified catastrophic by the insurance industry involves two thresholds being met: the number of policyholders and insurance companies affected, and the financial extent of the claims being met (commonly $25 million USD). Thus, catastrophes are, by definition, high-cost, but low-probability events.

In fact, they are presently at their lowest probability. There was a reduction in the development of tropical cyclones in the North Atlantic again in 2015, with this number being below average since 1995. This past year's reduction is due in part to the natural climate phenomenon El Niño, but the overall trend of losses from natural catastrophes being unusually low for the last twenty years may be attributed the development of effective early warning systems, precautions being taken, and those storms that did develop fortuitously not hitting densely populated regions.

Conversely, the impacts of unseasonal weather and severe weather events, including excessive rain, limited wind, cold fronts, heat waves, and all matter of other weather perils that are not customary given the historical weather patterns of a region, are indisputably on the rise. The Intergovernmental Panel on Climate Change (IPCC) reports that the frequency of heat waves has increased in large parts of Europe, Asia and Australia, and the number of heavy precipitation events has increased in the majority of land regions, but particularly in North America and Europe. The intensity and the frequency of unseasonal weather patterns and deviations from "normal" weather, have doubled in the last twenty years and the IPCC warns that the risks associated with extreme events will continue to increase as the global mean temperature rises.

The effects on the agriculture sector in many regions around the world have been representative of how an entire economic sector struggles to cope with the "new normal" in weather. The accumulation of years of increasing unseasonal weather and extreme weather events has had a significant impact on agricultural production across the world, but with El Nino being particularly strong in 2015, the results have been devastating. Examining the crop production of cereals alone in the last 40 years, droughts and heat waves have contributed to a 10% reduction in global production. In Alberta, Canada, for instance, the provincial government has declared the drought experienced in spring and summer 2015, which affected about 80% of the province's farmers and reduced the year's harvest by 25% below the five-year average, to constitute a "disaster", a designation that allows farmers to access further compensation.

Similarly, in Central America, the region's main harvest saw a decline of as much as 60% of maize and 80% of beans due to prolonged dry weather, resulting in the governments of El Salvador, Guatemala, Honduras and Nicaragua to distribute agricultural aid packages to assist farmers try to recover in subsequent plantings, and distributing direct food aid to help families cope with severe food shortages.

In some areas of Europe, farmers experienced the reverse; a cold, wet summer led to an increase in pests and diseases, slower ripening of crops, poor quality produce and low yields across Northern UK. In France, the temperate winter conditions that saw 2015 close led fruit trees to bloom a second time, a harmful phenomenon that depletes and weakens the trees, making them more susceptible to pests and diseases. India saw a host of extreme weather conditions throughout the year, which saw a prolonged dry season with sporadic temperatures turn to storms of hail, rain and winds hitting various regions across the country. The country's staple crop, onions, increased in price by up to 40%, 2,035 farmers leave the agriculture sector every day, and suicides among farmers attempting to sustain a livelihood in the beleaguered conditions are becoming an epidemic.

Whilst the connection between weather and the agriculture is obvious, the impacts of climate variability impact every industry sector, with unfavourable weather and severe weather events increasing production costs, causing lost sales, reducing revenues, and reducing GDPs. The supply of raw materials may be affected, transport and logistics affected, infrastructure and physical assets damaged, and a host of indirect impacts. Poor countries are particularly vulnerable to such climatic risks, in terms of relative economic losses, fatalities and hardship suffered, though the absolute monetary losses are more significant in highly developed countries. In developed economies, weather variability can cost up to 3.5% of GDP. In the United States alone, daily weather variability can cost up to 500 billion dollars, almost none of which is insured. In contrasting the financial implications of weather variability to catastrophes, it is fairly clear that the private sector's focus on catastrophes over weather variability is misguided.

In 2014, 25bn USD was attributed to weather extreme events, half of which was insured. In 2015, worldwide losses were 90bn USD of which 30 were insured.

Indeed, in all countries, it remains that companies are obliged only to insure their operations against the consequences of natural catastrophes and the physical damage they cause and even in the most developed nations, unseasonal weather remains a largely unconsidered and unaccounted for risk. For instance, a number of national non-profit organizations that advocate for climate risk disclosure and sustainability challenges arising from climate change, such as Ceres and the Carbon Disclosure Project (CDP), as well as international organisations such as the United Nations Environment Programme Finance Initiative (UNEP FI), take the approach that climate risks of businesses generally fall into four main categories: physical risks, reputational risks, regulatory risks, and litigation risks. Whilst acknowledging that physical risks extend beyond catastrophes, and even severe weather events, to refer to changes in temperature and other examples of unfavourable weather and their impact on their business operations including supply chains, these organisations do not suggest that a means exists to analyse them. Consequently, even the largest companies in the most advanced nations have not necessarily conducted a fulsome climate risk assessment, and even when assessments are conducted, they are limited to catastrophic events and the physical impacts of climate change.

"THE MAJORITY OF RISK MANAGERS ONLY UNDERSTAND AND INSURE CLIMATE RISKS PERTAINING TO HIGH IMPACT BUT LOW OCCURRENCE EVENTS SUCH AS NATURAL CATASTROPHES."

CASE STUDY

Applying the Key Finding: Case Study Germany

The primary focus of the risk report section in corporate annual reports is to provide a useful information to shareholders, potential investors and, more generally, all company stakeholders. For financial analysts and shareholders, useful information means any information that is likely to have an influence on company's results and financial performance. Because risk and return are the foundation of finance, the higher the risk, the higher the required rate of return.

In Germany, the KonTraG (Corporate Sector Supervision and Transparency Act) was introduced in 1998 and the German Accounting Standard (GAS 5 Risk Reporting) was added in 2001. As a result, risk reporting is mandatory in Germany. Disclosing information concerning the business performance and its associated risks is a legal requirement. If it is not exactly clear as to what needs to be disclosed and how, however. International Accounting Standards provide general accepted guidance to ensure that investors and shareholders are properly informed and in a position to make an informed financial decision with respecting to keeping, selling or buying shares in the company.

German companies are required to disclose their risk management system to identify risks (GAS 5.15) that are relevant to their business, to provide qualitative and quantitative information on each risk and risk category (GAS 5.16, GAS 5.18, GAS 5.20), to explain the risk policy and to describe the mitigating strategies that have been implemented to reduce the exposure to these risks (GAS 5.21). Since the introduction of KonTraG and GAS 5, a number of studies showed that the quality of risk disclosure information improved but remained generally poor. Some studies concluded that GAS 5 requirements were in fact not met by a large proportion of listed German companies.

We reviewed the latest annual reports of the DAX 30 companies to find out how weather risks are reported and analyzed by German listed companies. We analyzed in particular two sections of the report: the **Management's Discussion and Analysis** (MD&A) and the Risk and Opportunities sections. The MD&A section is provided to put accounting results in perspective, and gives the reasons as to why business performance was better or worse than expected.

Although the format of reporting is discretionary, the EU directive 2003/51/EG requires a true and fair view of the management commentary. The Risk and Opportunities section provides the risk categories and individual risks to which company results are exposed, in particular. Risks most frequently mentioned include market risks, financial risks, political, legal and socio-economic risks, and operational risks.

The analysis of DAX 30 companies with respect to weather risks shows very clear-cut results. The man agement of 70% of the companies make reference to weather conditions when discussing the financial performance. Yet, only 17% of the same management team disclose weather as a risk likely to affect financial performance in the Risks and Opportunities section.

Unfortunately, disclosures of weather risks by German listed companies are consistent with what we observed in other countries. A vast majority of shareholders and investors have no detailed information on the exposure of sales and profits to unseasonal weather, with the exception of energy companies.

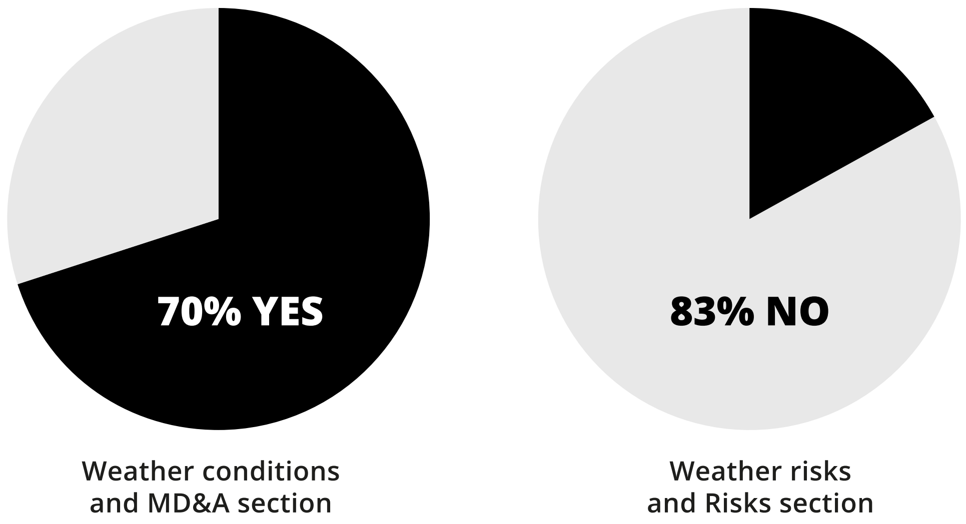


Figure 4: analysis of DAX30 companies' annual reports

The contribution of weather to the business activity

In order to manage traditional market risks in an effective way, companies apply a systematic evaluation methodology, to allow adequate prioritization as well as allocation of resources.

Risk are evaluated by looking at two dimensions: the potential financial impact and the likelihood that the impact materializes over the next budget period (usually twelve months).

Figure 5: Risk management cycle

The methodology applied in weather risk management is very similar. It is a general procedure that allows risks to be identified, evaluated, handled, monitored and reported. Normal seasonal weather does not cause unexpected losses, as the value of seasonal weather is known, expected, and can therefore be anticipated, and managed.

In the risk identification step we model how sales, profits or costs may change as a result of unexpected deviations from normal weather, and we write this relationship. Risk identification is about establishing the formula which expresses sales, costs or profits, or any business activity indicator, as a function of weather parameters. When this is done, we are in a position to determine the contribution of weather to sales, past and future.

Risk assessment requires examining two dimensions: potential impact and probability that it will materialize within a given time horizon. The determination of the potential impact is done in the quantification step. The objective is to determine the potential loss caused by adverse weather. A typical approach consists in plugging historical weather data in the model determined in the identification step. Weather markets usually use a minimum of 30 years of daily data to calculate the historical average and maximum observed losses caused by adverse unseasonal weather. The assessment of the probability of occurrence is done in the next section.

Identifying risks and how they influence the company results is quite straightforward in the case of foreign exchanges or interest rates. If a Euro-based company buys raw material in US dollars, the risk to which the company is exposed is the EUR/USD exchange rate, and the relationship between costs and EUR/USD is very simple: a 1% appreciation of the USD versus the EUR leads to an increase of 1% in raw material costs. The same applies to interest rates. If the company borrows at LIBOR plus a margin, the risk to which it is exposed is LIBOR, and a 1% increase in LIBOR translates into a 1% increase in interest expenses.

Identifying risks and how they influence the company results in the case of weather is less direct, but is still easy to do if the proper methodology is applied. As previously stated, when analyzing a company's exposure to weather, we are in fact interested in understanding how deviations from normal weather affect the business. Normal weather is the average weather.

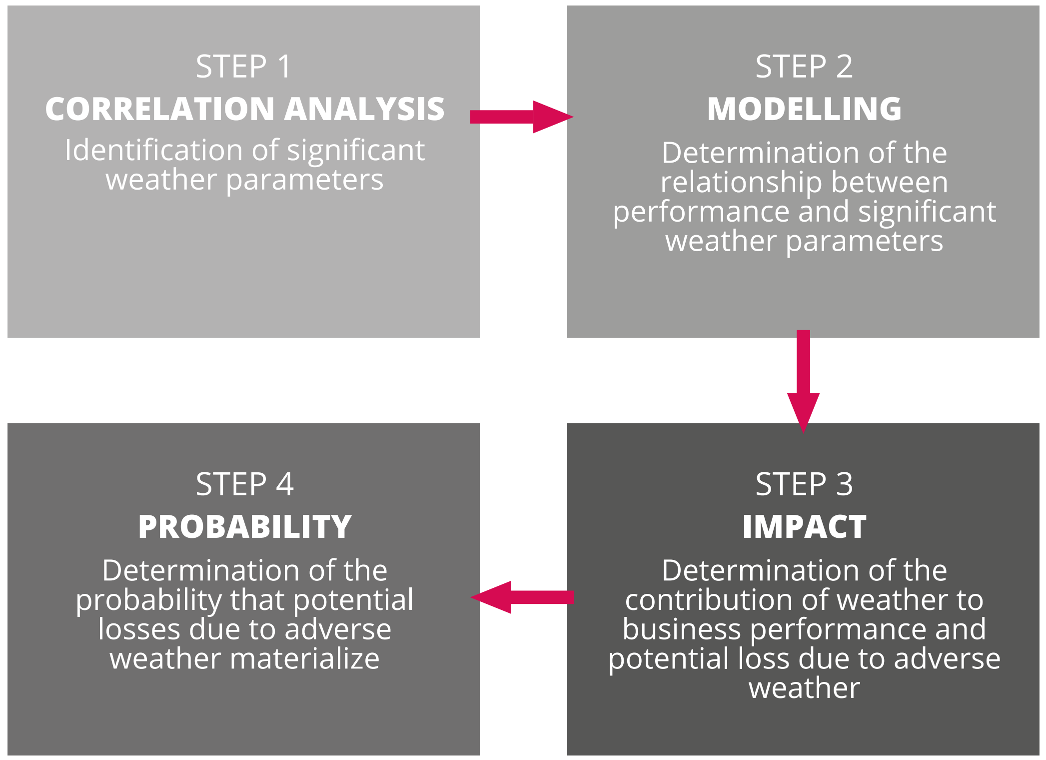


Figure 6: Methodology

For the temperature on a given day, its normal value is the arithmetic average over the last 30 years for that given day. The deviation on that day is the difference between the observed temperature on that day and its normal value. Since the weather is local, weather stations must be selected to fit the geographical business activity of the company. If business activity covers large areas, which is usually the case, regional of national temperatures are built by weighting weather observations.

In the case of consumer goods for instance, population is often used to weight temperature data in the creation of the regional or national temperature. At this stage, it is important to remember that a weather station measures hundreds of parameters every day. If we simply consider temperature, the station measures the maximum and minimum temperatures of the day, but can also measure the temperature every hour or more frequently. But the station also measures wind at different heights, precipitation or humidity rate, sun hours, cloud cover and so on. Weather data can also come from satellite or radars. So it is potentially a lot of data to handle, and all the more reason to be systematic in the selection of the most impacting weather variables.

In the first step, we create a series of weather variables and systematically cross-analyze company's data with weather data to select only the weather variables that have a statistically very significant impact on company's performance (sales, profits, costs, etc.). In most cases, one or two weather variables are enough to capture the impact of weather.
In the next step, we model the relationship between and the weather variable(s) selected in the first step. The relationship between weather and business activity is not always linear, and thresholds can exist. A classic example is beer consumption. Below a certain temperature, temperature has little influence on consumption. Above, the effect of temperature on sales increases until the next threshold, from which consumption stops to increase because the temperature is simply too hot. So, just as in the first step, we test various types of models to find the relationship that best fit company's performance.

"RISK MANAGERS CAN NOW PROVIDE AN ANALYSIS OF THEIR POTENTIAL MAXIMUM FUTURE LOSSES IN SALES DUE TO WEATHER VARIABILITY."

CASE STUDY

Applying the Key Finding: Case Study Germany

In order to provide an analysis of the average and historic losses in sales due to weather in Germany, and compare the weather sensitivity of various sectors, we concluded a three-step weather risk assessment.

For the first step, we test the correlation between temperature, precipitation and humidity rate anomalies for each retail category and each season. In practice, we do this by testing, for each month m of season s, the correlation between monthly weather anomalies and sales growth ($\Delta S_{m,s} = \frac{S_{m,s} - S_{m,s-12}}{S_{m,s-12}}$).

We find that monthly sales growth of 66% of the 17 retail categories are significantly correlated with at least one weather variable, which is consistent with our findings on UK retail. Temperature accounts for 44% of the correlations (40% for UK retail). An additional 22% (23% for UK retail) of retail categories are correlated to at least one weather parameter other than temperature. Weather relates to the percentage of retail categories that are sensitive to one or more weather variables.

	Spring	Summer	Autumn	Winter	Average
Temperature	50%	39%	39%	50%	44%
Precipitation	56%	39%	33%	17%	36%
Humidity Rate	33%	33%	33%	39%	34%
Weather	61%	67%	67%	67%	66%

Table 3: percentage of retail sectors that are correlated with weather

The correlations for temperatures anomalies are displayed in Table 4. The level of significance of the correlations is provided by the number of stars: significativity levels of 1%, 5% and 10% significance levels are ***, ** and * respectively. Correlations provide a first indication of the strength and the direction of a relationship, the closer to 1, the stronger the tie. Overall, correlations range from +0.58*** to -0.73*** for temperature, from +0.32*** to -0.52*** for precipitation, and from +0.43*** to -0.45*** for humidity rate. A retail category can be considered weather-sensitive if sales in this category display a statistically significant correlation with one or more weather variables.

Spring	
Flowers, plants, seeds, fertilisers, pet animals and pet food	0.58***
Footwear and leather goods	0.54***
Hardware, paints and glass	0.47***
Clothing	0.46***
Other goods in specialised stores	0.32***
Carpets, rugs, wall and floor coverings in specialised stores	-0.25*
Furniture, lighting equipment and household articles not elsewhere classified	-0.28**
Watches and jewellery	-0.32**
Electrical household appliances	-0.35***
Summer	
Non-specialised stores with food, beverages ...(e.g. supermarkets)	0.26**
Other goods in specialised stores	-0.28**
Carpets, rugs, wall and floor coverings in specialised stores	-0.35***
Clothing	-0.40***
Footwear and leather goods	-0.47***
Mail order houses (including internet retailers)	-0.49***
Furniture, lighting equipment and household articles not elsewhere classified	-0.53***
Autumn	
Hardware, paints and glass	0.57***
Clothing	0.53***
Furniture, lighting equipment and household articles not elsewhere classified	0.45***
Flowers, plants, seeds, fertilisers, pet animals and pet food	0.40***
Electrical household appliances	0.33***
Footwear and leather goods	0.30**
Mail order houses (including internet retailers)	0.28**
Other goods in specialised stores	0.26**
Carpets, rugs, wall and floor coverings in specialised stores	0.23*
Non-specialised stores with food, beverages ...(e.g. supermarkets)	-0.23*
Textiles	-0.22*
Mail order houses (including internet retailers)	-0.38***
Non-specialised stores ... (e.g. department stores)	-0.56***
Footwear and leather goods	-0.59***
Other goods in specialised stores	-0.61***
Clothing	-0.73***
Winter	
Hardware, paints and glass	0.57***
Clothing	0.53***
Furniture, lighting equipment and household articles not elsewhere classified	0.45***
Flowers, plants, seeds, fertilisers, pet animals and pet food	0.40***
Electrical household appliances	0.33***
Footwear and leather goods	0.30**
Mail order houses (including internet retailers)	0.28**
Other goods in specialised stores	0.26**
Carpets, rugs, wall and floor coverings in specialised stores	0.23*

Table 4: temperature anomalies correlation factors

STEP 2

For each category, season and selected variable, we model the relationship between sales and weather anomalies and test the robustness of each model (t-test and Durbin-Watson). The model we use is

$$\Delta S_{m,s} = \beta W_{m,s} + c + \varepsilon_{m,s}$$

The β coefficient, if statistically significant, measures the extent to which sales are impacted. On average, the β coefficient is significant for 54% of German retail categories. Winter is the season for which we can model the weather-sensitivity relationship (61%).
All statistically significant coefficients are displayed in Table 6. As an example, in spring, sales in hardware, paints and glass increase by 1.64% for every 1°C (line 1, column 1 of Table 6).

	Spring	Summer	Autumn	Winter	Average
Temperature	39%	28%	28%	44%	35%
Precipitation	44%	28%	28%	17%	29%
Humidity Rate	28%	22%	33%	33%	29%
Weather	44%	56%	56%	61%	54%

Table 5: percentage of retail categories for which β is significant

Spring	Temp. %/C	Precip. %/mm	Temp. %/C
Hardware, paints and glass	1,64	-0,10	-0,60
Electrical household appliances	-1,10	0,06	NS
Furniture, lighting equpt and household articles ...	-0,56	0,04	NS
Other goods in specialised stores	0,39	-0,03	NS
Clothing	1,05	-0,06	-0,24
Footwear and leather goods	1,96	-0,14	-0,54
Flowers, plants, seeds, fertilisers, pet animals and pet food	2,05	-0,12	-0,49
Second-hand goods in stores	NS	0,40	2,08
Summer			
Carpets, rugs, wall and floor coverings in specialised stores	-1,83	NS	NS
Other goods in specialised stores	-0,36	0,02	NS
Clothing	-0,98	0,04	0,26
Footwear and leather goods	-1,12	0,04	0,26
Mail order houses (including internet retailers)	-1,12	0,03	0,31
Furniture, lighting equipment and household articles	NS	0,04	0,27
Autumn			
Non-specialised stores ...(e.g. department stores)	-1,38	0,04	0,45
Other goods in specialised stores	-0,64	0,02	0,27
Clothing	-1,90	0,05	0,73
Footwear and leather goods	-2,08	0,06	0,68
Mail order houses (including internet retailers)	-0,65	NS	NS
Watches and jewellery	NS	-0,05	NS
Textiles	NS	NS	0,76
Electrical household appliances	NS	NS	0,50
Winter			
Hardware, paints and glass	1,23	NS	NS
Carpets, rugs, wall and floor coverings in specialised stores	0,85	NS	-1,19
Electrical household appliances	0,54	NS	NS
Furniture, lighting equpt and household articles	0,75	NS	-0,34
Clothing	0,68	NS	-0,40
Footwear and leather goods	0,49	0,04	NS
Flowers, plants, seeds, fertilisers, pet animals and pet food	0,67	NS	-0,58
Mail order houses (including internet retailers)	0,36	NS	NS
Automotive fuel for use in motor vehicles and motorcycles	NS	-0,07	NS
Second-hand goods in stores	NS	0,42	NS
Non-specialised stores...(e.g. supermarkets)	NS	NS	0,15
Hardware, paints and glass	NS	NS	-0,88

Table 6: β coefficients per category per season (NS: Non Significant)

STEP 3

We subject each model to historical data to determine the average and maximum losses caused by adverse weather. The average loss is obtained by taking the arithmetic average of all negatively impacted years.

The maximum loss is the loss that corresponds to the most unfavourable weather conditions over the last 30 years.

Spring	Average 30Y-Loss	Maximum 30Y-Loss
Hardware, paints and glass	-1,3	-11,6
Electrical household appliances	-1,1	-5,5
Furniture, lighting equpt and household articles ...	-0,6	-2,8
Other goods in specialised stores	-0,3	-2,8
Clothing	-1,1	-7,7
Footwear and leather goods	-1,9	-14,2
Flowers, plants, seeds, fertilisers, pet animals and pet food	-2,0	-14,8
Summer		
Carpets, rugs, wall and floor coverings in specialised stores	-0,6	-12,5
Other goods in specialised stores	-0,2	-2,5
Clothing	-0,6	-6,9
Footwear and leather goods	-0,7	-8,0
Mail order houses (including internet retailers)	-0,7	-8,0
Autumn		
Non-specialised stores ...(e.g. department stores)	-1,2	-10,6
Other goods in specialised stores	-0,7	-5,1
Clothing	-2,0	-14,8
Footwear and leather goods	-2,1	-16,2
Mail order houses (including internet retailers)	-0,7	-5,2
Winter		
Hardware, paints and glass	-2,4	-13,2
Carpets, rugs, wall and floor coverings in specialised stores	-0,9	-8,3
Electrical household appliances	-0,9	-5,6
Furniture, lighting equipment and household articles not elsewhere classified	-1,5	-8,1
Clothing	-1,4	-7,3
Footwear and leather goods	-0,8	-5,1
Flowers, plants, seeds, fertilisers, pet animals and pet food	-1,0	-6,9
Mail order houses (including internet retailers)	-0,7	-3,9

Table 7: temperature Average and Maximum Historical Losses (% sales)

Several retail categories are exposed to losses caused by adverse weather (ie Hardware, paints and glass). Footwear and leather goods are exposed to losses every season of the year. The maximum historical loss for the sector was 14.2%, 8.0%, 16.2% and 5.1%, respectively for spring, summer, autumn and winter. The losses were caused by warmer than normal summers and autumns, and colder than normal springs and winters.

None of the maximum losses took place within the same year, but over the last 30 years, there were 4 years for which the weather was unfavourable on all four seasons. For the purpose of this case study, results have been presented to display the average and maximum losses are presented for each individual weather variable. It would of course be possible to combine the compounded effect of weather variables by selecting all negative and the worst year according to all weather criteria. For simplicity and concision, we do not present total average and maximum loss caused by weather.

Spring	Average 30Y-Loss	Maximum 30Y-Loss
Hardware, paints and glass	-1,1	-5,9
Electrical household appliances	-0,7	-4,1
Furniture, lighting equpt and household articles ...	-0,5	-2,6
Other goods in specialised stores	-0,3	-1,5
Clothing	-1,0	-4,1
Footwear and leather goods	-1,9	-8,7
Flowers, plants, seeds, fertilisers, pet animals and pet food	-1,6	-7,6
Second-hand goods in stores	3,3	-19,6
Summer		
Furniture, lighting equipment and household articles	-0,6	-3,7
Other goods in specialised stores	-0,1	-1,3
Clothing	-0,2	-3,4
Footwear and leather goods	-0,2	-3,4
Mail order houses (including internet retailers)	-0,1	-2,6
Autumn		
Non-specialised stores ...(e.g. department stores)	-0,4	-2,4
Other goods in specialised stores	-0,3	-1,2
Clothing	-0,8	-3,2
Footwear and leather goods	-0,9	-4,0
Watches and jewellery	-0,8	-6,4
Winter		
Automotive fuel for use in motor vehicles and motorcycles	0,3	-2,9
Footwear and leather goods	-0,4	-3,1
Second-hand goods in stores	2,6	-23,4

Table 8: precipitation Average and Maximum Historical Losses (% sales)

Spring	Average 30Y-Loss	Maximum 30Y-Loss
Hardware, paints and glass	-1,1	-6,3
Clothing	-0,6	-2,7
Footwear and leather goods	-1,2	-5,9
Flowers, plants, seeds, fertilisers, pet animals and pet food	-1,0	-5,2
Second-hand goods in stores	3,7	-34,4
Summer		
Furniture, lighting equipment and household articles…	-1,0	-6,5
Clothing	-0,5	-5,9
Footwear and leather goods	-0,5	-5,7
Mail order houses (including internet retailers)	-0,7	-6,9
Autumn		
Non-specialised stores …(e.g. department stores)	-1,0	-5,0
Textiles	-1,6	-8,3
Electrical household appliances	-1,2	-5,6
Other goods in specialised stores	-0,8	-3,1
Clothing	-1,9	-8,3
Footwear and leather goods	-1,7	-7,7
Winter		
Non-specialised stores…(e.g. supermarkets)	-0,2	-1,5
Hardware, paints and glass	-1,4	-7,7
Carpets, rugs, wall and floor coverings in specialised stores	-1,2	-9,7
Furniture, lighting equipment and household articles not elsewhere classified	-0,6	-3,0
Clothing	-0,7	-3,6
Flowers, plants, seeds, fertilisers, pet animals and pet food	-0,6	-4,7

Table 9: humidity Rate Average and Maximum Historical Losses (% sales)

WeatherRisk as a measure of the maximum potential loss

In the previous section, we calculated the impact of adverse weather. In this section, we estimate the probability that this impact materializes to evaluate the potential loss caused by adverse weather. To do this, we apply the same concept that is used for other market risks: Value at Risk.

The concept of Value at Risk first appeared in the 1980s. Foreign exchange, interest rates and commodity price volatilities started to increase at a very fast pace, causing all sorts of problems to risk managers. There was an urgent need to find a way to measure the potential consequences of this rising volatility on company results and on banks.

Dennis Weatherstone, who was then the Chairman of JPMorgan, was not happy with the reports he was getting to assess the risks of the bank. They were excessively long and difficult to interpret. The 1987 crash led him to request a much simpler report aimed at answering a simple question: how much could JPMorgan lose on their investment portfolios between the close of business day and the opening the next day?

In response, JP Morgan's risk analysts identified all of the market variables that had an impact on the bank results, second, they quantified the relationship between each of these variables and the bank results to establish all the models (step 1 to Step 3). This is where JP Morgan analysts made the difference. They looked at the history of every market variable and built a distribution of possible values of this variable that fitted the historical distribution. For each variable, they looked for the threshold values for which the variable was either lower or higher 95% of the time. Depending on the position of the bank for each variable, one of the two threshold values was then used to determine the maximum potential loss with a 95% confidence level. And finally, because foreign exchange, interest rates and commodity prices were somewhat connected, they took into account these correlations before adding all of these potential losses together. The single potential loss number they produced was then published on a daily basis in a report and sent it every day at 4.15pm to M. Weatherstone. The report became known as the 4.15 report. And the potential loss was called the Value at Risk.

Value at Risk is a measure of the maximum potential loss in a given period of time within a given confidence interval, initially 95%, corresponding to two standard deviations. In other words, Value at risk is a measure of the "business as usual" risk. It does not provide the worst possible loss, but only the maximum loss if volatility stays within two standard deviations.

By analogy, we define WeatherRisk as the potential maximum loss resulting from weather variability on a given risk for a given period within a defined confidence interval. Figure 7 displays an example of the histogram of temperatures (in grey). These are historical values. To determine the threshold value (T95%) we can simply look for the value within the history of observed values that is greater than 95% of the observations. If the history of observations is not sufficiently long, we can build a distribution that best fit historical and find in a similar way the threshold value that splits the distribution area at 95% of the total area. One method commonly used for temperature anomalies are related to Monte-Carlo or Normal Inverse Gaussian distributions. We then use this threshold value in the model to obtain the corresponding WeatherRisk number. In this case, WeatherRisk is the maximum potential loss caused by adverse weather within a given period with a 95% confidence level.

"RISK MANAGERS CAN NOW PROVIDE AN ANALYSIS OF THEIR POTENTIAL MAXIMUM FUTURE LOSSES IN SALES DUE TO WEATHER VARIABILITY."

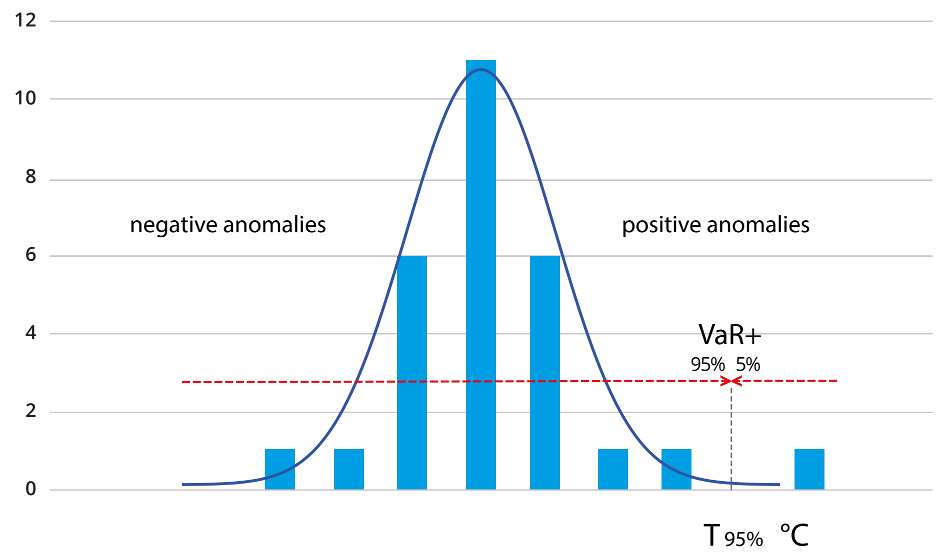
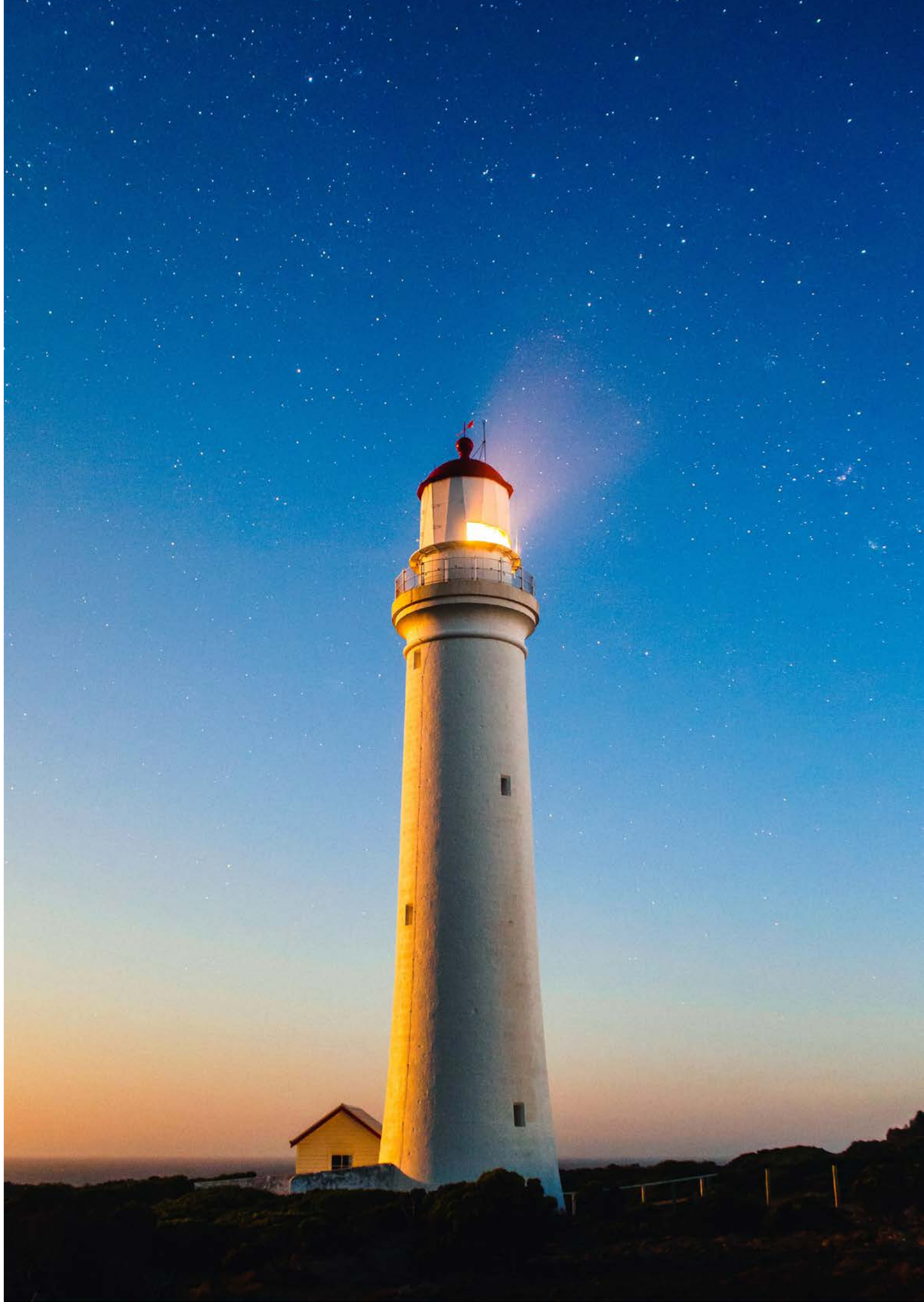


Figure 7: Histogram of temperature anomalies

Again, by analogy to Value-at-Risk, Total WeatherRisk is the "sum" of all WeatherRisks, taking into account the possible correlations between weather anomalies. In a model that uses several weather variables, the distribution of all possible combinations whether historical or simulated is used to determine the 95% level, which is then inserted in the model.

This number is the number that a risk manager wants, as it will drive his decision in terms of how much risk he wants to hedge and transfer out of the company. The relative importance of WeatherRisk dictates how much of the risk a company can afford to keep and how much of the risk it needs to transfer to maintain a sustainable risk-return balance going forward.



CASE STUDY

Applying the Key Finding: Case Study Germany

For each season and each weather variable, we use the historical distribution of weather anomalies to determine the 95% threshold values. To illustrate this step, Figure 8 displays the frequency diagram of temperature anomalies in autumn. 95% of autumn temperature anomalies are below 3.7°C (VaR+). Similarly, 95% of autumn temperature anomalies are above -4.1°C (VaR-). 3.7°C is used in the models to determine WeatherRisk for all retail categories in autumn for which a positive temperature anomaly is adverse weather.

In Germany, all weather-sensitive retail sectors are adversely impacted by warmer-than-normal temperatures. If a sector is adversely impacted by a negative temperature anomaly, we would use -4.1°C in the models to determine the WeatherRisk value.

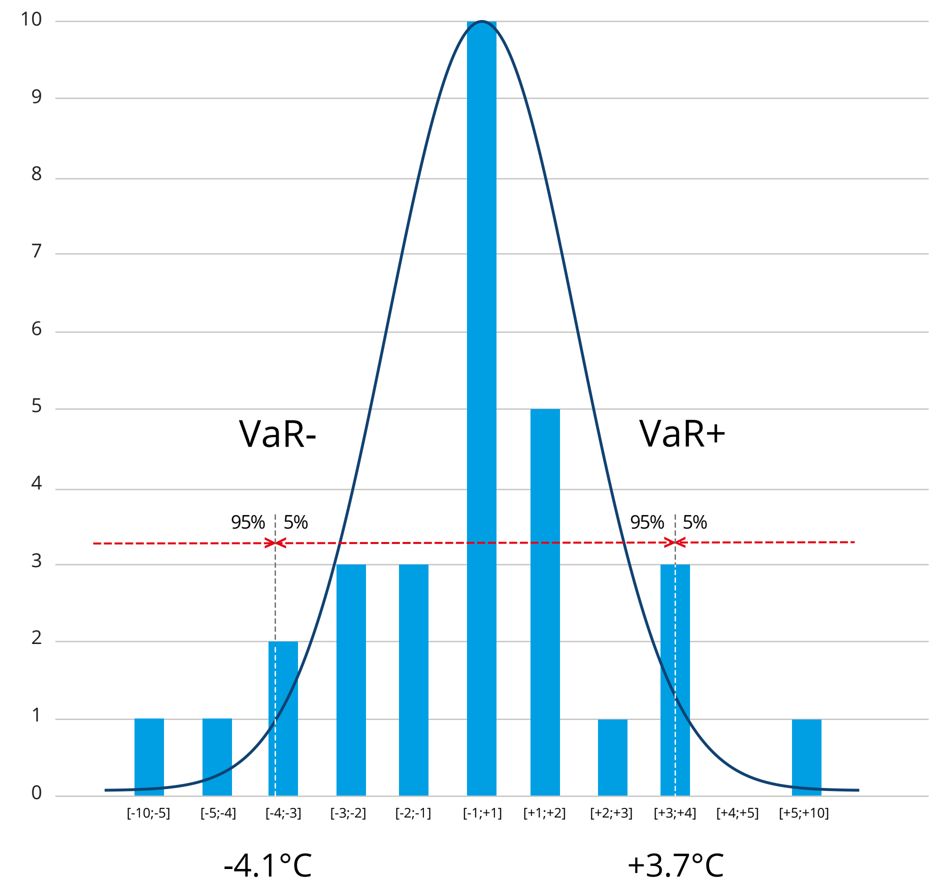


Figure 8: Distribution of cumulative temperature anomalies - autumn

WeatherRisk for each weather parameter, season and retail category are displayed in Tables 10 and 11 for temperature and precipitations. The average loss per season does not exceed 2.5% of sales, but WeatherRisk can exceed 10%. More importantly, if weather are adverse for more than one season, losses add up.

If we take footwear and leather goods as an example, WeatherRisk caused by temperatures in spring is -11.9%, -5.2% in summer, -7.6% in autumn and 4.7% in winter. The probability for the weather to be adverse for all seasons is relatively low (13% in the last 30 years), but the probability to be adverse for at least two seasons is a lot higher.

Some retail categories are exposed to precipitation or humidity rate in addition to being exposed to temperatures. In autumn and winter, we can consider temperature and humidity rate to be independent from a statistical standpoint, which means that a retail category exposed to both has a total WeatherRisk which is close to the sum of both temperature and humidity rate WeatheRisks. As an example, Total WeatherRisk for footwear and leathergoods in autumn is -14.9% of sales (temperature WeatherRisk of -7.6% and humidity rate WeatherRisk of 7.3%).

Spring	WeatherRisk
Hardware, paints and glass	-9,3
Electrical household appliances	-5,5
Furniture, lighting equpt and household articles ...	-2,8
Other goods in specialised stores	-2,2
Clothing	-6,2
Footwear and leather goods	-11,4
Flowers, plants, seeds, fertilisers, pet animals and pet food	-11,9
Summer	
Carpets, rugs, wall and floor coverings in specialised stores	-7,9
Other goods in specialised stores	-1,6
Clothing	-4,5
Footwear and leather goods	-5,2
Mail order houses (including internet retailers)	-5,2
Autumn	
Non-specialised stores ...(e.g. department stores)	-4,9
Other goods in specialised stores	-2,4
Clothing	-7,0
Footwear and leather goods	-7,6
Mail order houses (including internet retailers)	-2,5
Winter	
Hardware, paints and glass	-12,2
Carpets, rugs, wall and floor coverings in specialised stores	-7,6
Electrical household appliances	-5,2
Furniture, lighting equipment and household articles not elsewhere classified	-7,5
Clothing	-6,8
Footwear and leather goods	-4,7
Flowers, plants, seeds, fertilisers, pet animals and pet food	-6,3
Mail order houses (including internet retailers)	-3,6

Table 10: influence of temperatures on sales

Spring	WeatherRisk
Hardware, paints and glass	-5,7
Electrical household appliances	-3,1
Furniture, lighting equpt and household articles ...	-2,0
Other goods in specialised stores	-1,5
Clothing	-4,0
Footwear and leather goods	-8,5
Flowers, plants, seeds, fertilisers, pet animals and pet food	-7,4
Second-hand goods in stores	-13,4
Summer	
Furniture, lighting equipment and household articles	-2,6
Other goods in specialised stores	-0,9
Clothing	-2,3
Footwear and leather goods	-2,3
Mail order houses (including internet retailers)	-1,7
Autumn	
Non-specialised stores ...(e.g. department stores)	-1,9
Other goods in specialised stores	-1,0
Clothing	-2,6
Footwear and leather goods	-3,3
Watches and jewellery	-3,5
Winter	
Automotive fuel for use in motor vehicles and motorcycles	-2,4
Footwear and leather goods	-2,1
Second-hand goods in stores	-13,5

Table 11: influence of precipitations on sales

Again, the purpose of this case study is to illustrate the method in a simple a clear way. Consequently, results been presented to display WeatherRisk for each individual weather variable. It would be possible to combine the compounded effect of weather variables and integrate the correlations between weather anomalies to build the historical weather distribution of a combination of several weather anomalies. The principle to calculate Total WeatherRisk using this combination remains the same.

Hedging weather risks

Just as different retail categories and regions are impacted differently by each weather variable, the impact of a maximum potential loss will affect various businesses of various size and structure in different manners. WeatherRisk measures the potential maximum loss caused by weather for a given period if the weather stays within two standard deviations. The maximum historical loss provides additional information in the case that the weather is exceptionally severe. As weather variability is rising, standard deviation is increasing too. Stress test scenarios can be designed to supplement WeatherRisk and the maximum historical weather loss. Stress tests are easy to build because our methodology provides the relationship between the company's financial performance and weather.

We use this relationship to answer two questions depending on the company's risk management objectives and financial constraints: how much would the company lose if the weather adversely deviates by more than two standard deviations (eg. 10%, 15% or 20%)? What weather conditions would cause the company to lose more than a certain amount? Answers to these two questions are found by simply subjecting weather data to the relationship established in the second step of our methodology. With our methodology, a risk manager may determine if WeatherRisk is material to the company's financial strength and objectives, and just as importantly, if the volatility in earnings caused by weather is acceptable to the company, to the shareholders and to investors.

WeatherRisk management can be done efficiently and inexpensively through the purchase of index-based weather financial hedging products, in derivative or insurance form, depending on the local tax, legal and accounting situations. These instruments can be offered to businesses, agricultural cooperatives, municipalities and others as weather derivatives or as insurance products. Index-solutions are not new; they were initially introduced in the energy market in the United States some 20 years ago to compensate energy distribution companies in the case a temperature threshold was crossed which would result in lower sales of heating or cooling products by consumers. However, with significant advances in data processing, modelling, and forecasting, these products have evolved substantially and are now cheaper, more effective and more widely available than ever.

Index-based weather insurance triggers a payment linked to a weather variable, and not to the losses incurred. The index can be a temperature threshold, rainfall levels, sunshine duration, wind speed, or any other weather variable or combination of variables that represent the weather risk your business is exposed to. Payment is simple and automatic, requiring no field loss assessment, claims adjustment, or other administrative procedure. Rather, compensation is triggered only to a defined, externally verified, weather event. It covers any period, measured in hours, days, seasons or years. Independent of client behaviour, index insurance has very low settlement cost, and is not subject to moral hazard or to adverse selection.

"RISK MANAGERS CAN NOW ACCURATELY DETERMINE HOW MUCH OF THEIR WEATHERRISK THEY WISH TO MITIGATE WITH FINANCIAL HEDGING SOLUTIONS AND WHAT ADAPTATION MEASURES THEY WILL TAKE."

The cover is designed to compensate exactly or partially the losses incurred through adverse weather conditions. The compensation may be fixed when the weather index exceeds a predefined value or progressive if the losses caused by the weather increase in line with the index value. As with any index-based insurance, it is when a pre-defined index value is exceeded that the loss, in traditional insurance terms, occurs. Having identified the impact of climate change on their business, utilizing financial instruments such as derivatives or weather insurance products to limit the impact of climate variability and to reduce its WeatherRisk exposure, companies can build resilience to climate variability and therefore climate change, while investing in the operational solutions that scientists have already identified as necessary.

Further, a cost-benefit analysis can be undertaken to appraise the costs of adaptation and their associated benefits in order to compare different adaptation options. In addition to upgrading existing infrastructure, companies will likely recognize opportunities to build resilience against future climate changes at lowers cost when designing new facilities.

Of course, the costs of inaction can then be properly assessed as well. The Stern Review on the Economics of Climate Change, a 700-page report released for the British government in 2006 by economist Nicholas Stern, chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics (LSE), is most well-known for examining this "business as usual" scenario, and estimating that it could cost between 5-20% of global consumption per capital every year going forward. Measuring and managing the impact of climate variability allows everyone, including managers, investors, and regulators, to better understand their exposure to climate and find operational and industrial solutions to lower this exposure and be more resilient to climate change. It serves to realize the extent to which climate risk can jeopardize short term and long term profits, which in turn becomes a drive to address climate-related issues on an on-going basis.

CASE STUDY

Applying the Key Finding: Case Study Germany

In 2014, German shoe manufacturers achieved total sales of 2.518 billion euros compared to the 2.313 billion euros in 2013. The sector's three market leaders Deichmann, Hamm-Reno, and Schuhhaus Siemes account for more than a third of the footwear retail turnover in Germany. German households spend an average of 300 euros on shoes and shoe care. As a comparison, Austrian households spend around 100 euros more on these products per year.

Official 2014 statistics registered 39 companies in the shoe industry. Overall, Germany has about 80 small, medium and large production facilities in the German shoe industry, but not all of them are registered in official statistics. In 2014, German shoe industry companies employed an average of 11,632 persons, compared to the 11,611 employed in 2013. As in the year 2013, the average number of employees per company increased once again in 2014. If 283 (+27) persons worked in a company in 2013, one year later that number increased to 298 (+15) persons. This corresponds to an average employment increase of +5.3% per company.

Uncertainty prevails in most of the shoe industry, so that expectations were rather subdued for the next six months. This was also confirmed by the general business activity index of the IFO Institute. Although the mild winter weather 2014, in particular, explained the weak sales experienced by shoe retailers, a restraint was expected for the upcoming ordering rounds of the shoe industry. The tensions and unsolved crises abroad, especially in Russia and Ukraine, also contribute to uncertainty in the industry .

We consider a footwear retail company specialized in formal and evening shoes, as well as wellness footwear. In this retail group, the most strategic months are November and December, for which they realize a large proportion of their annual sales and profits. The mild winter 2014 prevented from achieving profit targets, and the high concentration taking place in the German footwear market requires the company to continue on a solid profitable path so that this family owned company can continue to remain independent.

Above all, the company wishes to cover some of the potential losses in case of a second consecutive warm winter. Using company and industry data combined with weather data in the cities where the company operates, we find that the relationship between sales and temperature is

$$\Delta S_{nov,dec} = -2.83 TEMP_{nov,dec} + c$$

Sales at normal weather conditions for November and December are 50 million euros. WeatherRisk for that period is 8.8% or 4.4m euros, and the maximum historical loss caused by warmer than usual temperatures was 13.9% or 7m euros (2011).
Since the net margin for this company is normally 8.3% (but dropped to 3.4% in 2014), the risk manager wants to buy an insurance or some sort of weather-based financial protection against a warm 2015 November and December.

There are essentially two types of strategies. The first one is about transferring 100% of the risk to a risk taker. A financial instrument, called a swap, is structured to guarantee sales or profits at normal weather conditions. If temperatures are warmer than normal, the risk taker pays the company an amount set in advance that is proportional to the difference between observed and normal temperatures. If temperatures are colder, the company pays the risk taker. This cover is usually structured so that there is no upfront payment for the company.

The second strategy, which is more common in retail, consists in receiving a cash flow in case of adverse weather, whilst retaining 100% of increased sales in case of favorable weather.

The corresponding financial tool is an option. In exchange of an upfront payment (called a premium), the company has the right to get paid if the weather is greater or lower than a predetermined threshold value (called a strike). In this example, the company gets paid if temperatures rise above a predetermined temperature (for example normal temperatures). When the option pays if the observed index is higher than the strike, it is called a call option (otherwise it is a put option).

The cost of the option is close to the probability that the risk materializes. If the company wants to be paid from the first 0.1°C above normal temperature, the probability that it happens is almost 50%. Therefore, the cost of the option would be close to 50% of the maximum payout, which is extremely high and uneconomic.

Some simulation work are required to determine the optimal level from which the company needs to be compensated against adverse weather. Based on its financial situation, the risk manager decides that the company can afford to absorb a sales loss of 5% (retained loss of 2.5m euros) and is therefore looking for protection if the loss in sales caused by temperature anomalies exceeds 5%, in other words in temperature anomalies exceed 1.8°C. The risk manager buys a Call option which pays if temperatures exceed 1.8°C. The payout is progressive and equal to 1.42m euros per 0.1°C above 1.8°C. The maximum payout is set at 4.5m euros (7m euros of maximum historical loss less retained loss of 2.5m). The cost of the protection is 0.6% or 0.33m euros.

In 2015, the temperature anomaly was 4.2°C, causing a loss of 11.74% of sales or 5.9m euros. The payout for the company was 2.4°C (4.2°C – 1.8°C) times 1.42m euros= 3.4m euros.

Because the company had this cover in place, it was able to stay focused on the business, and continued to advertise. But as importantly, the company now has a clear understanding of the role that weather plays in their own business, they can plan more accurately the following year without using previous years' figures polluted by past weather impacts, and they also know that dedicated financial products exist to make sure that, year after year, weather will not negatively affect the sales.

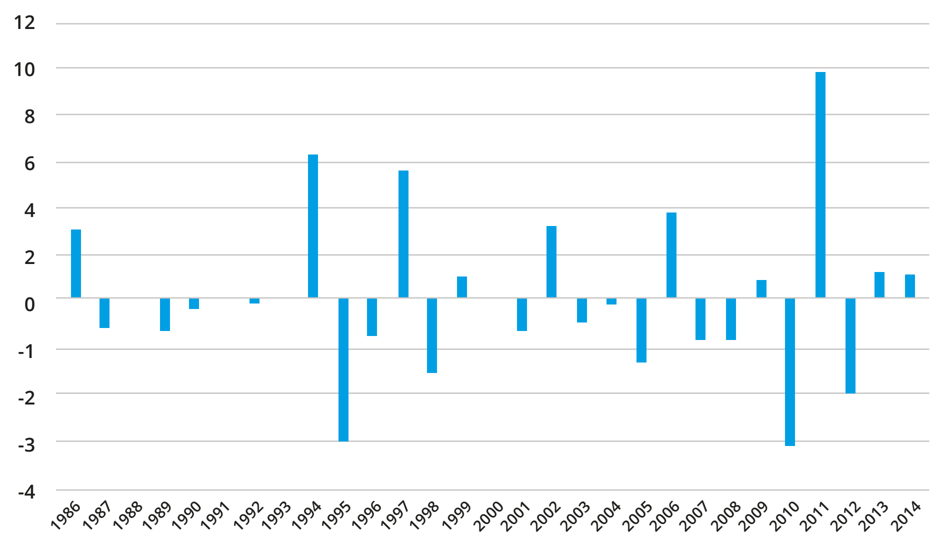


Figure 9: temperature anomalies 30 years (°C)

RECOMMENDATIONS

Weather risks disclosures

Accounting Standard IFRS7 was issued in August 2005. IFRS7 requires disclosure of the information used by key management to measure and manage risk, and requires all companies to report in their external financial statements the metrics they use internally to manage and measure financial risks. IFRS 7 also requires disclosure of how their results would have been affected if market conditions, such as the level of interest rates, exchange rates, commodity, equity or other price risks, were to move by reasonably possible amounts from where they were at reporting date.

Weather is not explicitly listed in IFRS7, but the spirit of IFRS7 implies that changes when weather affects sales, costs or profits, would require a sensitivity analysis be performed and disclosed in the same way that it is done in the case of currencies and interest rates.

In February 2010, the U.S. Securities and Exchange Commission issued guidance for companies on climate change-related information they should be voluntarily disclosing to investors, based on the pre-existing legal obligation that companies should disclose material risks to investors, following a systematic materiality analysis by the company of its climate risks. This guidance was limited to disclosing items that can be quantified or assigned a dollar value, such as the financial implications to the company of a "cap and trade" system or other legislative or regulatory change brought about in order to reduce emissions. Thus, it was limited to companies in sectors that are high emitting such as power companies.

The response has generally been since that time for companies to provide boilerplate statements suggesting examples of financial consequences to the company of operational changes and financial costs that may arise from existing and future laws and regulations.

Overall, the number of companies who have provided public reporting in financial filings and sustainability reports have been limited, and those that do have done so with a low level of detail and precision as to their exact risk.

The implications of so many companies not reporting such a substantial risk as that associated with weather variability and severe weather events has many investors and stakeholders, including the world's largest public pension funds, asset management firms and private equity investors, deeply concerned, as companies remain over-valued, and retaining a high level of unmitigated risks. In not undertaking a systematic climate risk assessment, these companies lack a strong understanding of the related risks and opportunities, the strategic focus to manage them, and the reporting mechanisms in place to disclose these to their stakeholders.

Consequently, in April 2015, G20 Finance Ministers and Central Bank Governors asked the Financial Stability Board (FSB) "to convene public- and private- sector participants to review how the financial sector can take account of climate-related issues". On 4 December 2015, the FSB announced that it was establishing an industry-led disclosure task force on climate-related risks Task Force to develop voluntary, consistent climate-related financial disclosures for use by companies in providing information to lenders, insurers, investors and other stakeholders. The Task Force will consider the physical, liability and transition risks associated with climate change and what constitutes effective financial disclosures across industries. By end-2016, the task force is expected to publish for consultation its recommendations for voluntary disclosure principles and leading practices.

Weather risk management disclosures

Companies who rely solely on conventional business continuity planning or risk management tools such as catastrophe insurance must now consider extending their business continuity and emergency management plans to address climate variability.

Now that the tools are available to accurately assess the historic, average, and future WeatherRisk of a company, disclosing this sensitivity is just the first step. Naturally, investors and stakeholders are going to demand that following a WeatherRisk assessment, companies will take appropriate actions, including utilizing financial hedging solutions (such as index-based weather insurance or derivatives), but also making operational changes such as upgrading infrastructure and equipment, and investing in new technologies and processes to manage and mitigate climate sensitivity, as well as to reduce the carbon footprint of the company and contribution to climate change (eg. stress-resistant crops, water desalination, off-grid water supply, remote energy supply, efficient lighting, dispersed electricity transmission, climate resilient power transmission and distribution, weather prediction and early-warning).

Companies that measure and disclose their WeatherRisk are more likely to take steps to manage their climate change sensitivity strategically and to receive the critical support they require in allocating funds for this purpose. Specifically, the disclosure of climate risks and opportunities can reassure investors about future growth and risk management, as well as avoid reduced credit as well as access to finance. In fact, some financial institutions (such as the IFC and Barclays) are already started integrating climate change risk considerations into their investment diligence processes.

Further, there are now 1200 signatory members of the Principles for Responsible Investment, including financial services industry ratings agencies, and others such as MSCI and Morningstar, representing over $35 trillion in assets under management, demonstrating that institutional investors are concerned about the qualitative and quantitative materiality of ESG considerations in evaluating and comparing risk across the credit markets.

Moreover, in an Institutional Investors Group on Climate Change survey, asset managers who manage greater than USD $14 trillion stated that 69% considered climate change a material risk that influenced their selection decisions. CDP (formerly Carbon Disclosure Project) supports 722 institutional investors holding US$ 87 trillion in assets in revealing the climate risk in their investment portfolios. In the future, preferential financing terms, reduced insurance premiums, and other advantages may be granted companies taking proactive steps to improve their climate change resilience.

In disclosing what climate change resiliency measures a company is taking in order to respond to its WeatherRisk, it is increasing awareness of the need for corporate leaders to take action in reduce climate change and build resiliency to it, to share best practices in both, to provide a benchmark for corporate peers, identify trends, and to create opportunities for others to contribute to the process by engaging investors, stakeholders and the public in coming together to contribute innovative solutions for more sustainable institutions, products and services.

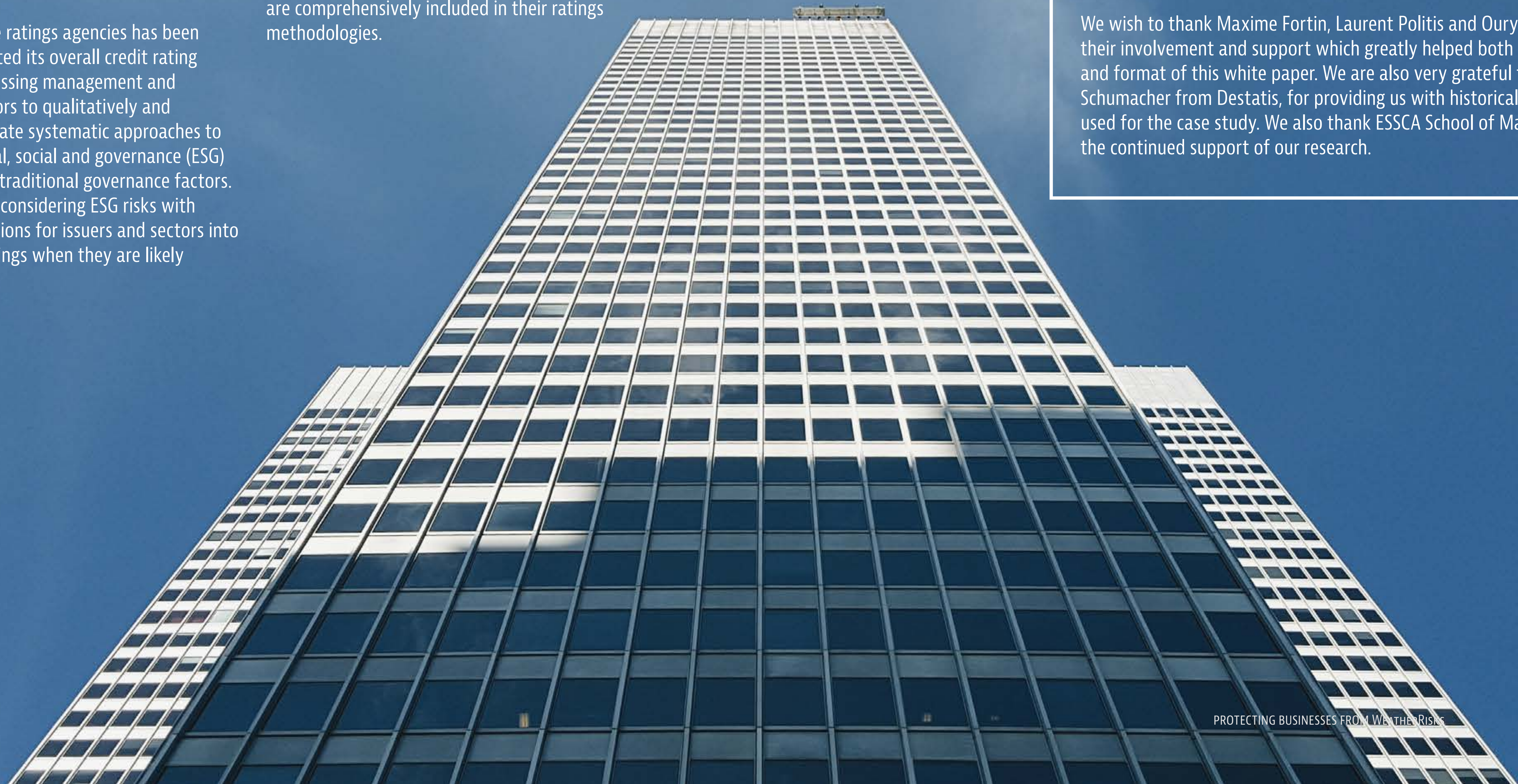
Rating agencies and weather risks

Without incorporating climate variability resiliency into their ratings methodologies in a substantial, transparent and comprehensive fashion, credit ratings agencies such as Moody's Investors Services and Standard & Poor's may be substantially miscalculating the risks of climate change to the corporate sector.

Presently, catastrophes seldom trigger rating actions, and average or maximum historical weather variability losses or WeatherRisks are not considered at all. Thus rating agencies are likely miscalculating the credit ratings and values of companies that are affected by climate change. The implied consequences for the world economy are vast; some have compared the exposure of the global financial system to climate risks to the 2008 credit crisis, when banks overvalued "subprime mortgages", with ratings agencies drastically overestimating the value of fossil fuel assets today.

Indeed, progress by the ratings agencies has been slow; in 2014 S&P updated its overall credit rating methodologies for assessing management and governance credit factors to qualitatively and quantitatively incorporate systematic approaches to including environmental, social and governance (ESG) risks incorporated into traditional governance factors. Moody's followed suit, considering ESG risks with material credit implications for issuers and sectors into its long-term credit ratings when they are likely to affect the probability of default of a debt issuer or expected credit loss in the event of default. However, in both cases, analysts suggest that of the ESG factors, governance is given much more importance than environmental or social factors.

Following the conclusion of the Paris climate conference in December 2015, both credit rating agencies released reports addressing the emerging risks associated with climate change and global efforts to stop it. S&P's focused primarily on how increased natural catastrophes could affect companies' creditworthiness. Moody's outlined its approach to assessing the financial impact of environmental risks as being incorporated into industry specific criteria. Neither has demonstrated that climate risks are comprehensively included in their ratings methodologies.



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REFERENCES

Agnew, M. D. and Palutikof, J. P. (1999). The impacts of climate on retailing in the UK with particular reference to the anomalously hot summer of 1995. International Journal of Climatology, 19(13):1493–1507.

Agnew, M. D., Thornes, J. E., 1995. The weather sensitivity of the UK food retail and distribution industry. Meteorological Applications 2, 137–147.

Applebaum, W. (1951). Studying customer behavior in retail stores. The Journal of Marketing, pages 172–178.

Battersby S., 2012, Running wild, New Scientist, 32-37

Barndorff-Nielsen, O. (1997). Normal Inverse Gaussian distributions and stochastic volatility modelling. Scandinavian Journal of Statistics, 24:1–13.

Barrieu, P. and Scaillet, O. (2010). Uncertainty and environmental decision making, chapter A primer on weather derivatives, pages 155–175. Springer, Heidelberg, Germany.

Bertrand, J-L, Parnaudeau, M., 2015, Ranking the Impact of Climate Variability on UK Retail Sectors: A Path to Resilience (October 19, 2015). Available at SSRN: http://dx.doi.org/10.2139/ssrn.2675965

Bertrand, J-L, and Parnaudeau, M., 2015, The Impact of Climate Variability on the Private Sector (September 9, 2015). Available at http://dx.doi.org/10.2139/ssrn.2658061

Bertrand, J-L, Brusset X., Fortin M., 2015, Assessong and hedging the cost of unseasonal weather: case of the apparel sector, European Journal of Operating Research, 244(1), 261-276

Bertrand, J.-L. and Sinclair-Desgagné, B. (2012). The Oxford Handbook of Business and the Natural Environment, chapter Environmental Risks and Financial Markets : A Two-Way Street. Oxford University Press, London, United Kingdom.

Bloesch, J. and Gourio, F. (2015). The effect of winter weather on US economic activity. Economic Perspectives, 39(1).

Bloomberg, M. R., Paulson, H. M., and Steyer, T. F. (2014). Risky business: the economic risks of climate change in the United States. Report.

Cao, M., Li, A., Wei, J., 2003. Weather derivatives: a new class of financial instruments. available on the SSRN 1016123.

Coburn, J., Donahue, S. H., & Jayanti, S. (2011). Disclosing climate risks and opportunities in SEC filings. A guide for corporate executives, attorneys & directors.
Cunningham, M. R., 1979. Weather, mood, and helping behavior: Quasi experiments with the sunshine samaritan. Journal of Personality and Social Psychology 37, 1947–1956.

Dell, M., Jones, B. F., Olken, B. A., September 2014. What do we learn from the weather? the new climate-economy literature. Journal of Economic Literature 52 (3), 740–798.

Goldstein, K. M., 1972. Weather, mood, and internal-external control. Perceptual and Motor Skills 35 (3), 786–786.

Grieser J., 2016, December 2015 broke a string of long-standing heat records in Western Europe, The Washington Post, January 5

Howarth, E., Hoffman, M. S., 1984. A multi-dimensional approach to the relationship between mood and weather. British Journal of Psychology 75 (1), 05–23

IPCC (2014). Climate change 2014: Impacts, adaptation and vulnerability. Report Intergovernmental Panel on Climate Change.

Jorgenson, D. O., 1981. Perceived causal influences of weather: Rating the weather's influence on affective states and behaviors. Environment and Behavior 13, 239–256

Katz, R. W., and Murphy, A. H. (1997). Economic value of weather and climate forecasts. Cambridge University Press.

Larsen, P. H., 2006. Estimating the sensitivity of U.S. economic sectors to weather, Working Paper, Cornell University.

Lazo, J. K., Lawson, M., Larsen, P. H., Waidmann, D. M., 2011. U.S. economic sensitivity to weather variability. Bulletin of American Meteorological Society 92, 709–720.

Linden, F., 1962. Consumer markets: merchandising weather. The Conference Board Business Record 19 (6), 15–16.

Linsmeier, T. J., Pearson, N. D., Mar-Apr 2000. Value at risk. Financial Analysts Journal 56 (2), 47–67.

Merna, T., Al-Thani, F. F., 2011. Corporate risk management. John Wiley & Sons

Murray, K., Di Muro, F., Finn, A., Popkowski Leszcyc, P., 2010. The effect of weather on consumer spending. Journal of Retailing and Consumer Services 17, 512–520.

Pafka, S., Kondor, I., 2001. Evaluating the riskMetrics methodology in measuring volatility and Value-at-Risk in financial markets. Physica A: Statistical Mechanics and its Applications 299 (1), 305–310.

Parsons, A. G., 2001. The association between daily weather and daily shopping patterns. Australasian Marketing Journal 9, 78–84.

Prettenthaler, F., K¨oberl, J., Bird, D. N., 2016. Weather value at risk': A uniform approach to describe and compare sectoral income risks from climate change. Science of the Total Environment 543, 1010–1018.

Riskmetrics (1996). J. P. Morgan technical document. 4th edition, New-York.

Sanders, J. L., Brizzolara, M. S., 1982. Relationships between weather and mood. Journal of General Psychology 107, 155–156

Starr-McCluer, M., 2000. The effect of weather on retail sales. Tech. rep. Steele, A. T., April 1951. Weather's effect on sales of a department store. Journal of Marketing 15, 436–443.

Steele, A. T. (1951). Weathers effect on sales of a department store. Journal of Marketing, 15:436–443.

Steinker, S., Hoberg, K., 2014. The influence of weather in online retailing - an empirical analysis.

Stenek V., Connel R., Firth J., Colley M., 2010, Climate risk and business: practical methods for assessing risks, International Finance Corporation

Toeglhofer, C., Mestel, R., Prettenthaler, F., 2012. Weather value at risk: on the measurment of non-catastrophic weather risk. Weather, Climate, and Society 4 (3), 190–199.

WMO (2013). WMO statement on the status of the global climate in 2012. Report 1108, World Meteorological Organization.

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