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Insuring Against Bad Weather: Benefits and Challenges in Light of Climate Change

By Ines Kapphan, ETH Zurich

Weather and the Economy

Weather affects almost all industries through both consumption and (directly or indirectly) production. In the power industry, energy demand rises with cooling needs in hot summers, forcing energy companies to produce electricity at higher costs, whereas the beverage industry benefits in hot summers from skyrocketing sales. Every industry faces a different form of weather risk.

A recent study by the National Center for Atmospheric Research (NCAR) in Boulder, Colo. shows that the productivity of the entire economy fluctuates with extreme weather events [1]. After mining, agriculture is the second most weather-sensitive sector. Weather sensitivity of different sectors ranges from 2.2 percent (for wholesale) to 14.4 percent (for mining). Considering the relatively small share of agriculture in total GDP (1.5 percent), its absolute weather fluctuations amount to US $15.4 billion (in year 2000 dollars) and are comparable to what is at stake in the utilities sector (US $14.8 billion). The financial sector, accounting for 20 percent of the total GDP, has by far the largest absolute weather sensitivity.

If the weather is good in one year for a particular sector, the same weather can mean bad times for another sector. When the sector-specific weather impacts are aggregated nationally, they tend to offset each other to some extent. The overall U.S. weather sensitivity is therefore smaller than the simple average of the individual

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sectors' weather sensitivities. Overall, the study found that U.S. economic output varies by up to $485 billion a year, or about 3.4 percent of the 2008 GDP, due to weather variability.

NCAR's findings show that adverse weather conditions could push the economy into a recession. In any year, a decline in the GDP by 3.4 percent represents an enormous amount of lost output. While protective action can help to mitigate some losses, other impacts, such as those owing to extreme weather events, may not easily be prevented. Insurance or hedging can reduce the financial impacts from bad weather.

Insuring Against Bad Weather

Weather risk can be managed either by weather insurance or weather derivatives, index-based financial products where payouts are triggered by an exogenous weather event. For derivatives, payments are not based on actual losses as with traditional insurance, but on observed weather data. Index-based weather insurance exploits the fact that weather observations can be used as a proxy for the losses suffered through reduced sales, lower production, or increased costs due to spiraling input prices.

Weather observations obtained from meteorological services are used to determine payouts. Once a predefined threshold (trigger) of the underlying weather index has been reached during a specified time period, the contract starts to pay out. A put option on rainfall, for instance, starts to pay out if cumulative precipitation falls below the trigger. A call on temperature during the winter months pays out if temperatures exceed a predetermined threshold. The buyer of the call pays a cash premium to the counterparty willing to assume the risk that the winter will be mild.

Weather derivatives can be settled quickly compared with loss-based insurance contracts. Weather insurance requires a proof of loss attributable to weather, which can be time-consuming. With weather derivatives, in contrast, the natural buyer has no guarantee that the derivative contract pays out when his business experiences weather-related losses. When using weather derivatives, natural buyers are thus left with so-called basis risk, i.e., the risk of not receiving payments, or inadequate payments, in the event of a loss. Basis risk can arise due to a number of reasons: spatial and temporal discontinuities in weather or an imperfect correlation of the weather index with revenues.

The major advantage of index-based insurance over traditional insurance is that problems arising from asymmetric information, such as moral hazard and adverse selection, are avoided and administrative costs are lower. When payouts are triggered by an exogenous event that is correlated with the insured output, these additional costs can be completely avoided as no incentives exist for the natural buyer to change his behavior. Weather derivatives constitute an innovative risk-transfer product to protect against weather-related revenue fluctuations.

The Origins of the Weather Derivatives Market

The first official weather transaction occurred between Enron Corporation and Koch Industries [2]. The two companies swapped the risk of abnormal temperature conditions in Milwaukee, Wis., during winter 1997-1998, with Koch getting a put on temperature falling below average conditions. Soon after, the Chicago Mercantile Exchange (CME) started to offer standardized weather derivatives in the form of options and futures for a number of major cities in the United States. Today, the CME group offers weather derivatives based on temperature, rainfall, frost, and snowfall for major cities in the U.S., Asia, and Europe. In 2005, the CME expanded its product portfolio with the introduction of hurricane futures and options, providing an alternative for insurers to transfer claims risk to the capital markets.

Over-the-Counter Versus Exchange-Traded Products

Weather derivatives are available for a wide range of weather risks. In addition to the exchange products, the over-the-counter (OTC) market offers alternative opportunities to buy weather derivatives tailored to a particular business need. While standardized derivatives possess the benefit that the exchange (e.g., CME) provides transparency and liquidity and eliminates counterparty risks, they are not ideal solutions for every business. Many companies possess complex weather risk that is uncorrelated with the weather in major cities and desire very specific weather hedges that are now available through the OTC market.

Weather Risk Management at the Corporate Level

The rapid expansion of the weather derivatives market was facilitated by the expanding scientific skill for modeling and predicting weather phenomena. The management of weather and climate risk requires sophisticated and reliable information about weather and its variability. Despite the technological advances made and the increasing number of products available, paired with the need to manage weather risk due to climate change, the number of companies managing weather risk is still low.

CME Group and Storm Exchange Inc., surveyed 205 senior finance and risk managers across a number of weather-sensitive companies in the United States [3] and found that 82 percent believe that the emergence of climate change with its accompanying volatile weather patterns mandates changes to their corporate risk management approach. And 51 percent admitted that their companies are not well prepared to cope even with the current weather risk, while only 10 percent of the respondents declared that their companies are already managing weather risk. Seldom have executives been so united in recognizing a threat to their businesses and at the same time hesitant about addressing it. One of the reasons companies hesitate to adopt weather risk management practices is the unfamiliarity with the weather marketplace. Companies seem to be uncertain about what type of weather contracts are needed given their unique exposure and in particular how to evaluate the trade-off between costs faced from obtaining protection and the benefits.

Hedging Effectiveness of Weather Derivatives

For the weather hedge to be most effective, all available information about a company's weather exposure should be used to structure an appropriate contract. In general, structuring a weather hedge can be decomposed into two components: the selection of the index and the parameters that define the payoff structure for a given index. In particular, the hedging effectiveness of weather derivatives depends on the quality of the index in predicting losses and on the parameters that define the payoff function (trigger, tick size, and cap). The "tick size" is the monetary value of one index point. The "trigger" is the threshold level beyond which the contract starts to pay out, and the "cap" specifies the maximum payout per contract.

To select a powerful index, the buyer needs to quantify the time period(s) during which his business suffers most from adverse weather conditions, i.e., which meteorological phenomenon is responsible for the fluctuations and the location(s) at which the weather matters. Based on this information, the underlying weather index can be designed. In order to minimize basis risk, the index has to possess a high correlation with the economic output to be hedged. Often an imperfect correlation of the index with losses is cited as the main drawback of index-based weather products and blamed for not adequately hedging weather exposure. While it is true that there is little scope for weather hedging if it is based on a poorly designed weather index, the way the payoff is structured matters as well for the hedging effectiveness.

The payoff function is determined through the choice of the trigger, tick size, and cap. When structuring the contract, the focus of buyers and sellers alike often lies on the relationship between the premium and the maximum payoff (cap). Contracts tend to be evaluated based on the ratio between the premium and the cap, with a premium ranging between 1/10 to 1/5 of the cap. Thinking about a weather derivative like a lottery, i.e. US $1 invested may yield benefits of US $5-10, neglects the fact that the likelihood of getting the maximum payoff depends on the probability of getting hit by really bad weather. Taking a closer look at such rules shows that they are not backed by considerations for efficiently reducing risk.

Weather derivatives are priced by assessing how often the contract would have paid out in the past. To compensate the seller for assuming the risk, a margin is added to the premium. With this logic, increasing a cap implies that more money is paid out in the event of really bad weather, causing the premium to increase. Usually adding tail risk coverage causes premiums to go up only slightly, because the probabilities of tail events are low. Lowering a cap decreases maximum payouts in the event of bad weather. To manage weather risk effectively maximum payoff needs to be adequate to compensate the losses in the event of bad weather.

The choice of the trigger level also affects the pricing of the contract. Increasing (lowering) the trigger level of a put (call) option causes premiums to go up, but it also implies that the insured is more likely to receive (small) payments at a higher frequency. The strike level thus determines the type of losses that are covered by the contract. For businesses with a low tolerance of revenue volatility a contract that generates smaller payments regularly can be valuable in order to smooth fluctuations in cash flows. If the weather hedge is intended to protect only against major events, the trigger can be set such that the contract pays out only under extreme weather conditions.

The buyer needs to assess how much his business suffers in the event of bad weather, i.e., the damages caused by a one-unit change in the weather index. When hedging with a standardized weather derivative from the exchange, this information helps to determine how many contracts to buy since the tick size is predetermined. For instance, at the CME the tick size of temperature-based contracts is equal to US $20 per heating degree day (HDD) or cooling degree day (CDD). In the OTC market, the tick size can vary.

Most weather derivative contracts assume a linear relationship between weather and the economic output at stake. For many businesses, it is fair to assume such a linear relationship. In the energy sector, heating and cooling demand varies linearly with weather. Crops are however affected in a non-linear manner by changes in temperature and precipitation conditions. Adequate risk management with weather derivatives for agriculture therefore requires a synthetic financial product that mimics the relationship between weather and yields. By combining for instance weather derivatives with different strikes and tick sizes, a weather derivative portfolio can be created where the portfolio payoffs compensate for the crop losses. Natural buyers thus need to carefully evaluate the outlined trade-offs and obtain a weather contract that efficiently meets the companies' objectives in managing weather risk. For the case of agriculture, Kapphan [4] has developed a mechanism that accounts for the non-linear impact of weather on crops and that can be used to obtain — for a given index — the parameters defining the payoff structure that delivers an optimal risk reduction.

Weather Risk Management and Climate Change

With climate change, the number of extreme events and the seasonal variability is expected to increase [5]. For weather-sensitive industries, climate change implies that new extreme events are expected to occur, causing damages that may exceed the extent of previously known damages. In addition, the frequency of extreme weather events is increasing and driving up weather-related losses. Munich Re [6], which maintains a comprehensive database of global natural catastrophes, shows that the number of extreme weather events like windstorms, floods, and forest fires has tripled since 1980 and the trend is expected to persist.

Many industries are seeing the first signs of climate change already today: Ski resorts are faced with less reliable snow conditions; rainfall and temperature variability affect agriculture output; transportation and airline companies experience more business disruption due to an increase in the number of snowstorms and floods.

The number of companies with weather risk on their balance sheets is rising, and the industry will see more natural buyers operating in the market. While these scenarios represent gloomy prospects for the industry, insurers (and re-insurers) are however faced with a new challenge. Climate change is putting an end to stationarity. The assumption that historical (data) records can be used to assess future probability does not hold any longer [7]. In particular, the changing occurrence and frequency of extreme weather events imply that historical return periods underestimate the likelihood of losses in the future. Climate change thus undermines a basic assumption that historically has facilitated risk management [8].

Traditionally, the insurance industry uses historical data to design and price insurance products. These modeling techniques are, however, ill-suited for understanding the implications of climate change [9]. Within natural catastrophe modeling, insurers couple climate models with catastrophe models to examine the financial implications of climate change on insured risk. With the current trend, insurers will need to respond by increasing premiums, possibly restricting coverage and increasing deductibles for their damage-based weather insurance products if the number of weather-related losses continues to increase.

Climate change also matters for the design and pricing of weather derivatives. With weather derivatives, the insurer only has to correctly estimate the underlying weather index distribution. Compared with traditional insurance, weather derivatives specify the maximum payout, i.e., the risk taker does not face the uncertainty of future claim payments exceeding historical ones. From the risk taker's point of view, weather derivatives are therefore becoming more attractive. For the insured, however, increased business disruptions due to more severe weather extremes imply that losses beyond the maximum payout specified by the contract are not insured. With climate change, to maintain a given weather risk management objective, the buyer therefore needs to adjust the cap as well as the trigger level over time.

Kapphan et al. [10] examine the effect of hedging weather risk for maize farmers with weather derivative contracts that are adjusted over time. Adjusted weather derivative contracts are derived by using simulated crop and weather data that includes the climate change signal. For the derivative design, multi-peril weather indices are constructed to predict the fluctuations in maize yields. To hedge the revenue fluctuations of maize growers, assuming a given risk management objective, the payoff structure is designed such that it yields optimal risk reduction [4]. Weather derivative contracts are simulated for today's (baseline) and future climatic conditions. To maintain a desired risk reduction over time, it turns out that the payoff structure will need to cover a wider range of weather events, i.e., the trigger decreases and the cap increases over time.

The benefits from hedging are then evaluated for a baseline scenario, representing today's climate conditions, and for future climatic scenarios to model the transition from today's climate to the projected climate prevailing around the year 2050. With climate change, the authors find that the benefits from hedging weather risk with adjusted contracts increase over time and more than double in 2050 compared with today's baseline. An increase in weather-related revenue variability makes hedging weather risk more viable. They also evaluate the profitability for the risk taker of assuming weather risk in a changing climate. When incorporating climate change projections in the pricing and design of the contracts, insurers can expect profits to increase by 240 percent from selling adjusted weather derivative contracts.

The hedging effectiveness of adjusted contracts is then compared with the benefits from hedging future weather risk with non-adjusted contracts. Non-adjusted contracts are derived using the current design and pricing approach of the industry, i.e., using backward-looking historical data. Similarly, the profitability of offering non-adjusted weather derivatives is evaluated for the risk taker.

Depending on the type of weather risks covered, it turns out that some non-adjusted contracts would make the insured farmers better-off than the adjusted contracts. In those situations, the risk taker generates losses from offering these products. Contracts that cause losses will however not be offered by the risk taker in the long run. The authors also found that some non-adjusted contracts make the insured farmer even worse off than in the situation without hedging. Contracts that do not achieve any risk reduction clearly will not be purchased by farmers.

The study shows that the increased weather variability makes hedging weather risk more worthwhile for both the insurer and the insured. Not adjusting the pricing and design of weather derivatives may not only generate losses for the risk taker, but it possibly undermines the risk reduction that can be achieved with weather derivatives. To capture the benefits of hedging weather risk in a more volatile climate, weather derivative providers need to revise their structuring and pricing in order to offer their clients efficient weather protection.

Putting an End to the Weather Excuse

In an era with a growing awareness that weather and climate change affect financial performance, companies should no longer be allowed to justify bad performance due to bad weather. Companies with a weather-dependent business can reduce their exposure to weather-related fluctuations by hedging. Weather risk thus should no longer be viewed as an idiosyncratic entrepreneurial risk. Weather management should become an integral part of corporate risk management. Income statements should show the weather exposure, and companies should actively manage weather risk in the same manner as they manage their foreign-exchange, interest-rate and commodity risks.

References

[1] U.S. Economic Sensitivity to Weather Variability, (2011), J. Lazo, M. Lawson, P. Larsen, and D. Waldman, *Bulletin of the American Meteorological Society,* June 2011

[2] What Every CEO Needs to Know about Weather Risk Management, (2008), Randy Myers, sponsored by Storm Exchange, Inc. & CME Group

[3] Survey: Finance Executives Say Global Climate Change Will Require Changes to Their Business Models, PRNewswire, *http://www.prnewswire.com/news-releases/survey-finance-executives-say-global-climate-change-will-require-changes-to-their-business-models-57540142.html*

[4] Weather Insurance Design with Optimal Hedging Effectiveness, (2011), I. Kapphan, ETH Zurich, Working Paper

[5] WMO Statement on the Status of the Global Climate in 2010, (2011), WMO, No. 1074, World Meteorological Organization, Geneva, Switzerland

[6] Munich Re, 2011

[7] Climate Change and Future Analysis: Is Stationarity Dying? (2008), B. McCarl, X. Villavicencio, and X. Wu, *American Journal of Agricultural Economics,* Vol. 90, No. 5, pp:1242-1247

[8] Stationarity is Dead: Whither Water Management? (2008), P. Milly, J. Betancourt, M. Falkenmark, R. Hirsch, Z. Kundzewic, D. Lettenmaier, and R. Stouffler, *Science,* Vol. 319, pp:573-574

[9] A Global Review of Insurance Industry Responses to Climate Change, (2009), *The Geneva Papers on Risk and Insurance Issues and Practice,* Vol. 34/3

[10] Climate Change, Weather Insurance Design, and Hedging Effectiveness, (2011), I. Kapphan, P. Calanca, and A. Holzkaemper, *IED Working Paper,* No. 17, ETH Zurich

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