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WEATHER DERIVATIVE MARKETS

A couple of decades ago weather related risk could only be covered by purchasing insurance facilities. As result of the convergence between insurance markets and capital markets and the process of securitization, weather derivative markets were born. Weather products can play an important and efficient role in alleviating weather related risk in case of private enterprises. They also can be used by countries and international organizations for example to avoid serious humanitarian catastrophes. Weather products can also directly reduce climate change by supporting the financing of renewable energy and infrastructure upgrading projects. The study gives an overview about the opportunities in weather derivatives.

KEYWORDS: WEATHER DERIVATIVES, WEATHER RISK, HEDGE, PRICING MODELS

JEL: G13, G32, Q54

1. THE BEGINNING OF WEATHER DERIVATIVES TRADING

The main use of weather derivatives is to hedge against weather related risks for a period shorter than one year. The over-the-counter (OTC) market of weather derivatives dates back only to 1997, when the first deal was struck between the now notorious Enron Corporation and Koch Industries (Brockett et. al., 2007). The exceptionally cool winter in 1997/98, due to the strong El Nino effect that year, pointed to the fact that weather risk is a real threat to the revenue and profits of enterprises and gave momentum to the development of the weather derivatives market. Before that, the only way to hedge against weather risk was to purchase insurance policies from insurers. However, as a logical consequence of the convergence between the insurance and the securities markets, the general trend of securitization and increasing counterparty risk the trading of weather derivatives started on the Chicago Board of Trade – which is now a part of the Chicago Mercantile Exchange (CME) – in 1999 (Considine, 2000). According to the estimate of the U.S. Department of Commerce, 30% of the United States' economy but at least US$ 1 trillion of revenues is exposed to weather risks[1]. CME estimates that about one third of the US economy is affected by weather risk (CME, 2009), which translates into more than US$ 4 trillion calculating with the US annual GDP number in 2010. Compared to these numbers, the traded volume of weath-

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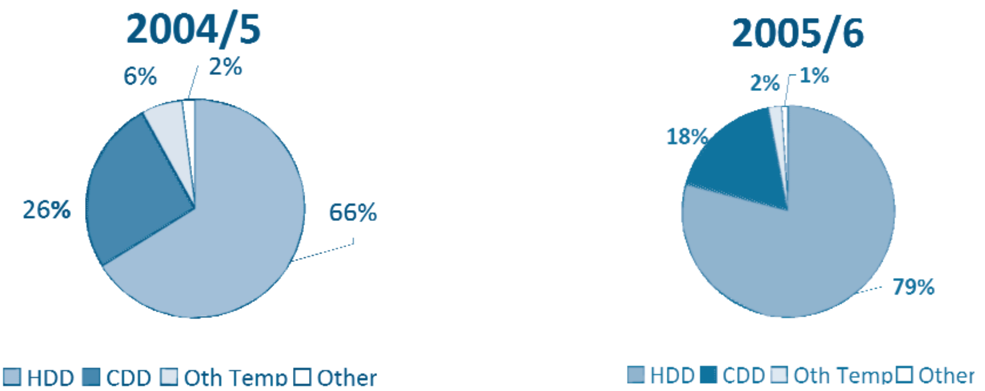
1 Source: http://www.guaranteedweather.com/WeatherRisk.aspx, downloaded on 13 March 2011

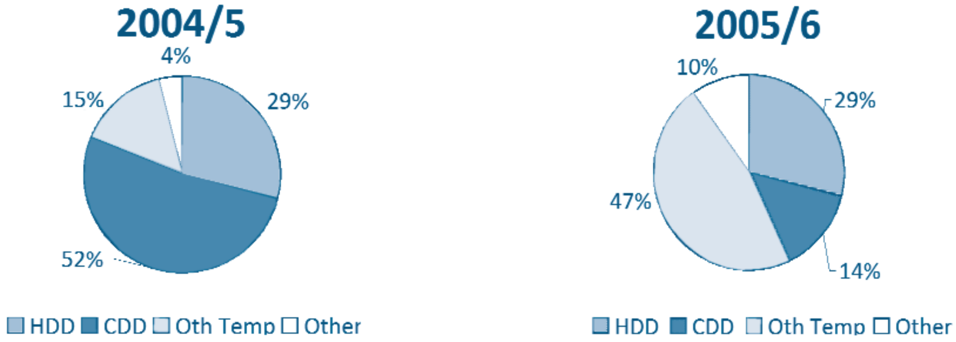
er derivatives is still relatively low, meaning that there is significant space for market growth in spite that the weather market grew considerably since the second part of the nineties. According to a survey of the Weather Risk Management Association (WRMA), the annual volume of weather derivatives was US$ 19.2 billion in 2007 (USA Today, 2008), which means a sharp decrease after the US$ 45.2 billion peak volume in 2006. However, it is still considerably higher than the US$ 9.7 billion in 2005 and the US$ 4.7 billion in 2004. According to WRMA data, the sharp rise from the 2006 volume is due to the busier trading on the CME, while the value of deals on the OTC market slumped somewhat (WRMA, 2008). The lower volume in 2007 was a result of less extraordinary weather events than during the preceding years, however, this temporary pullback did not affect the longer uptrend in the volume of weather derivatives. A big part of the trading activity was transferred, however, from the OTC market to Chicago attracted by the liquidity on the CME created by speculators and other market players. As trading became more intense on the weather market, the composition and the relative weight of market players changed as well. It will be discussed in more detail in the third section.

As it was mentioned, the bulk of the trading volume is on the CME, where only standard products are traded. Among them, the most important weather products are the temperature derivatives. Traders have access also to hurricane, frost, snowfall and rainfall contracts. Around 98–99% of the trading volume, however, is generated by temperature contracts (Garman et al., 2000), so I will concentrate mainly on these products when talking about the pricing of weather derivatives. Figure 1 shows the composition of the traded volume on the CME and the OTC market combined by product types; figure 2 shows the same composition for the OTC market alone. Both figures show data taken from a survey conducted by PricewaterhouseCoopers in 2006. It can be seen quite clearly from the figures that on the CME the share of temperature products is overwhelming, while on the OTC market temperature products are the most heavily traded product category, however other products also have a significant proportion. Other products, however, still had only a 10% share in the OTC market in 2005/6.



Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html

Figure 1. Total notional value of weather risk contracts by product types

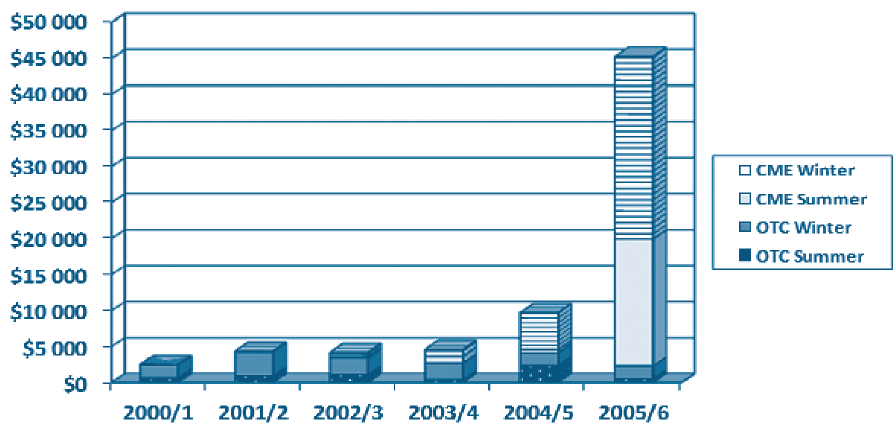


Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html

Figure 2 Notional value of weather risk contracts by product types on the OTC market

Note: On both Figure 1 and 2 HDD stands for heating degree days, while CDD stands for cooling degree days. Both represent standard temperature products based on HDD and CDD indices. These will be explained in more detail at the pricing of weather products in section 5.

The increasing liquidity on the CME (see Figure 3) also attracted hedge funds to the market. According to big market players, hedge funds nowadays have a key role in the weather market. In practice they act as market makers, meaning that they guarantee liquidity if anyone wants to buy or sell large quantities at the market price, so big trades will not change the market conditions if no other event occurs at the same time. A considerable part of the volume is generated by hedgers who intend to eliminate weather related risk, stemming from their natural exposure to commodities (e.g. mining and energy companies), as weather has an impact on the price of a wide range of commodities from agricultural products to energy products like heating oil, natural gas and electricity. This kind of trade is called cross-commodity hedging (Cundy, 2007). Another part of cross-commodity trading is done by speculators who look for temporary discrepancies between the two markets which can provide trading opportunities for them. As most players are active on both the weather and the commodity markets we can assume that the increasing volume on weather markets is at least partly due to heavier trading of some commodities.



Source: PricewaterhouseCoopers, 2006, http://www.wrma.org/members_survey.html

Figure 3 Total notional value of weather risk contracts (in millions of U.S. dollars)

2. DIRECTIONS FOR FURTHER DEVELOPMENT OF THE WEATHER MARKET

The first factor which is likely to spur the growth of the weather derivative market is global climate change, which is supposed to increase weather related risks worldwide. While the increasing emission of greenhouse gases and global warming are the first to come to our mind when we talk about global climate change, it also seems to make extreme weather events more frequent, alter precipitation patterns in space and time and weather could also become harder to predict as a result. All that would make it more important companies to hedge their weather related risks.

Another factor behind the increasing volume of the weather derivative markets is the growth of the alternative energy sector which is expected to accelerate in the future as conventional energy sources will become increasingly scarce and expensive and as safety concerns regarding nuclear energy will be more serious. While both the conventional and the alternative energy sector is affected by weather, the latter is much more exposed to it as in its case not only energy demand but also energy supply is influenced by weather. We should just think about wind energy for example, which is very dependent on wind conditions, solar energy which is dependent on the amount of sunny hours per year or hydropower which depends on precipitation levels (Cundy, 2007). As a result the spread of alternative energy production will also increase the demand for hedging against weather related risks.

Another source of growth could be the involvement of the developing world in the trading of weather products. That would be an absolutely rational move as agriculture has a much higher share in the economy of developing countries, so these countries face much more weather risk proportionally to the size of their own economies than developed countries. Yet these risks remain mostly uninsured today in the developing world. Consequently these countries could reap tremendous gains by starting to hedge against weather risk faced by their agricultural sectors. Moreover, that would not only mean pure economic gains but could save many lives in a lot of cases. The main reason why these risks remain unhedged is of course the lack of sufficient funds and technical expertise to be able to buy such policies or contracts on weather markets. These countries are not only poor and heavily dependent on agriculture, but their agricultural sector is underdeveloped. First of all land sizes are generally small as a high proportion of the population works in the agricultural sector, each owning a relatively small agricultural property. Therefore, owners of small pieces of land using outdated production techniques cannot pay for insurance at all. This serious problem can be alleviated by the action of international organizations; one possible way to help could be to use weather products. This will be discussed in section 7 in more detail. At the same time private insurance companies also have a strong interest to enter the market of developing countries to increase their global market share and their profitability. When these companies start to take on more and more risks in these countries, eventually they will want to pass on a part of it, which can be done through reinsurance but also can – above a certain market size and favorable market conditions – create the demand for standard weather products tracking weather events in certain regions of developing countries. These standard products can be traded on exchanges. An example for the growing importance of developing countries is the acquisition of the Indian Yes Bank by Swiss Re in 2006. The goal of the deal was to provide insurance products for small Indian farmers by combining the good local customer relations of Yes Bank and Swiss Re's expertise on the weather markets. Other companies with a good knowledge about the market also report the growing geographical reach of the market, mentioning Africa, South-America and other developing regions besides Asia (Cundy, 2007).

Another way to alleviate weather risk – which has not been discussed so far – is to sell catastrophe bonds. Such bonds were first issued by insurance companies to reduce their risk exposure by spreading it to others who are willing to take it for compensation. So catastrophe bonds were an alternative of reinsurance policies, a way to securitize risks by insurance companies. The most important difference between the two is that reinsurance can be bought only from reinsurance firms, while catastrophe bonds can be sold to a much wider public. Those who buy the bonds agree that in the case of a certain catastrophic event they will lose their investment or a part of it, or even the annual yield of that year. In exchange, however, they can reap higher than normal returns in those years when there is no extraordinary event. More developed catastrophe bonds combine several regions' risks. In this way, they reduce the risk of investors by forming a portfolio from regional catastrophe risks. Governments and international organizations have also issued catastrophe bonds. Mexico for example financed the foundation of a catastrophe fund by issuing such bonds; the fund is used to alleviate losses in case of earthquakes, floods and tropical storms. The World Bank started the "MultiCat" program in 2009, which makes it possible to bundle many countries and many catastrophe types together in a single bond program to further diversify risks and to reduce the cost of financing of the program this way (ICLEI, 2011).

3. PLAYERS OF THE WEATHER MARKET

Players of the weather market have different roles in the operation of the market and different motivations to enter it. Market makers are those big players who guarantee fair prices on the market at all times, even when the liquidity is relatively lower and as a result prices could significantly differ from the fair value or it would be hard to trade in larger quantities. These large players use their own sophisticated pricing models and proprietary long-term weather forecasts, which come in varying qualities (Considine, 2000). Brokers serve as intermediaries between the exchanges and market players, they execute trade orders given by their clients. Insurance and reinsurance companies hedge a part of their risk exposure on the market so they can be called the financial end-users of the market. These companies can also act as market makers on the market. Non-financial end-users are those companies which want to hedge their weather related risks; they can come from a wide range of industries (Garman et al., 2000). Currently the biggest volumes are traded by energy companies and utilities, but farmers, retailers, entertainment companies and the tourism sector are also significant players on the market (CME, 2009). A part of these companies – mainly energy traders – use hedge fund-type strategies. International organizations like the UN's World Food Programme and the alternative energy sector also have to be mentioned. A good example for the involvement of the latter sector is the former Merrill Lynch investment bank's wind product which was used during the financing of wind farms. The use of the wind product was beneficial for developers because if they had insurance against unsatisfactory wind speed, they could finance their projects at a lower interest rate. (Cundy, 2007) Hedge funds also play an increasingly important role in the market as they try to seek out market discrepancies and profit from those situations. Active individual traders can also be found among market players (CME, 2009).

4. RISKS ASSOCIATED WITH WEATHER PRODUCTS

Weather markets are characterized by two types of risks: counterparty risk and basis risk. The first is the risk that the other party becomes insolvent so it cannot fulfill its payment obligation. For example an insurance company cannot pay the insurance proceedings after an unprecedented and unexpected catastrophic event, because its funds are not sufficient to meet its obligations. Another reason behind insolvency could be when an insurance company loses a massive amount of money on its derivative positions. That happened with AIG, the biggest insurance company of the world of the time in 2008. AIG sold insurance against certain bonds' default on the OTC market – in the form of credit default swaps (CDSs) and collateralized debt obligations (CDOs) –, but it was not required to deposit any collateral on this market because it had the highest credit rating. When the company, however, was downgraded it suddenly had to post the collateral. That was well beyond the means of the company, so a government bailout was needed to be able to meet its obligation. It can therefore be seen that those positions were different from positions taken on exchanges as initially it was not backed by any collateral. It was, however, also different from conventional insurance policies which pay only when a certain trigger event occurs. CDSs and CDOs are tradable on the secondary market, so their prices are always changing reflecting the risk associated with each bonds' default. As a result, these contracts are acting like derivatives (futures), not like insurances (or options) and AIG could lose a lot on those derivative positions even when no bond default happened, only the investors' expectations changed dramatically. Therefore, counterparty risk arises when an end-user enters a contract with an insurance company. When trading on exchanges, however, that type of risk does not exist as exchanges have margin requirements (collateral must be deposited for every position) and investors' positions are marked-to-market every day which guarantee that each party's payment obligations are fulfilled regardless of their current liquidity position. The recent crises started in 2007 also proved that deals made on exchanges are much safer than OTC and other non-exchange deals as the fulfillment of those trades was never in question during the crisis. While the world's biggest insurance company, AIG, nearly went bust in 2008 only a government bailout could save it, no exchange had any insolvency issue during the crisis.

The other type of risk similar to exchange traded weather products is basis risk. This stems from the fact that in case of exchange traded products payout depends on weather conditions at a certain geographical location, which can significantly differ from weather conditions at the location where it matters for the buyer. This difference is due to the geographical distance between the two. In case of CME's, temperature product payouts are calculated using the temperature measured at a certain data collection point. Currently CME provides temperature products in case of twenty-four U.S., six Canadian, ten European and three Japanese cities[2]. Other data providers, however, use different methods to produce data, Risk Management Solutions (RMS), a consulting and data provider company, for example calculates ten regional temperature indexes in the U.S., all of which are average temperature data of ten major cities in the region. Temperature products can be constructed also with the use of RMS's regional indices, which can be used more efficiently to hedge weather risks according to Brockett et. al. (2007). As these indices are based on data measured in several locations, basis risk is lower than in case of data gathered in a single measurement location. Basis risk can be mitigated entirely by buying a tailor made insurance policy; in this case, however, one has to calculate with a counterparty risk. To reduce both types of risk, exchange traded weather contracts can be combined with insurance policies. Exchange traded contracts should be used to hedge against the bulk of the weather risk while a separate insurance policy can be purchased to mitigate basis risk. This combination can be very useful because, if the company can find an exchange traded product which correlates well with its weather exposure, and the geographical location of the weather products data collection point is not very far from the company's place of exposure, the bigger part of its risk can be hedged with the exchange traded product without taking on any counterparty risk. The remaining basis risk can be mitigated with an insurance which covers only the basis risk, which is considerably lower than the original weather exposure. In this case the entire weather risk is hedged with taking on only a minimal counterparty risk and no basis risk.

5. PRICING WEATHER PRODUCTS

On the CME, futures contracts and options on futures are traded. However the pricing of weather options is different from that of ordinary stock options, as the price changes of their underlying products is different that of the stocks. As a result, the Black-Scholes model cannot be applied to the pricing of weather options (Garman et al., 2000). I will discuss below the pricing of temperature options which gives 98–99% of the total weather market volume, however first I am describing the calculation and the workings of temperature indices.

2 Source: http://www.cmegroup.com/product-codes-listing/weather-codes.html, downloaded on 13 March 2011

5.1 TEMPERATURE PRODUCTS

The goal of temperature products is to help mitigate the risk stemming from the unpredictable energy demand due to the uncertainty of temperature during the winter heating and the summer cooling season. Winter temperature conditions (which strongly affect the heating demand during winter months) is quantified by calculating Heating Degree Days (HDD), while temperature conditions during the summer months (which also affect summer energy demand) is grabbed by Cooling Degree Days (CDD). Heating degree days are those days when the actual daily temperature is lower than a base temperature value, so most households and businesses are supposed to use some energy for heating. Cooling degree days are those when the daily temperature is higher than the base value, so air-conditioners are heavily used. This base temperature is 65 Fahrenheit in most cases which equals about 18.33 Celsius; however it can be higher in warmer climates. Daily HDD and CDD values are calculated as follows (Garman et al., 2000):

- Daily HDD = Max (0, base temperature – daily average temperature)
- Daily CDD = Max (0, daily average temperature – base temperature)
- It can be seen that daily HDD and CDD values can never be negative, so cumulative HDD and CDD values' lower bound is also zero. The daily values are cumulated for a certain period, which is normally one month or a heating/ cooling season, e.g. from November in a given year until March in the next year.

Other indicators can also be calculated besides the two aforementioned ones. One can calculate for example the energy degree days, which is the sum of the HDD and CDD values. In agriculture, growing degree days are defined as those when temperature is in a range favorable for the growing of crops.

In case of simple options, payouts are calculated by multiplying the difference between the strike HDD/CDD value and the cumulated HDD/CDD value for a certain period with a dollar value representing the size of the contract. Payouts are often capped to maximize the risks taken by the seller. From these simple options other more complex hedge or speculative instruments can be created.

5.2 PRICING MODELS OF TEMPERATURE PRODUCTS

Some pricing methods purely model the movement of HDD or CDD values, while others predict temperature levels and calculate the HDD/CDD values from them. The latter method seems to be more effective (Garman et al., 2000), as those models which ignore temperature data do not use our knowledge about temperature. For example, they disregard the fact that HDD/CDD values cannot be lower than zero; temperature values are mean reverting and can be predicted with certain precision by physical models.

The Black-Scholes model and the pricing of temperature products

The Black-Scholes model which is used for pricing stock options cannot be used for the pricing of weather options for the following reasons:

- Temperature events do not walk randomly like stock prices, as they are mean reverting. This means that temperature always stays near an average and cannot go very far from it, while stock prices does not necessarily obey such rule. Historical data shows that temperature returns back to normal levels every 2 or 3 days.
- In case of the Black-Scholes model, the value of the option is calculated from the price of the underlying product at the time when the option is exercised, while in the case of weather options, payout is usually determined by the average temperature of a period, so they are more similar to Asian options than European or American ones.
- Weather options are also frequently capped, meaning that profit is maximized for the holder of the option and loss is also maximized for the seller.

For the above reasons, in the case of weather options, alternative pricing methods shall be used instead of the Black-Scholes model.

The "Burn analysis"

One of the simplest pricing models is the "Burn analysis", which is based on historical data. This method calculates the cumulated HDD/CDD values for the past couple of years and based on that it is possible to calculate the hypothetical payout of the option in those previous years. Next the payout of each past year is averaged, which will give the option's fair value.

Monte Carlo based models

In case of the Monte Carlo based pricing models, many possible weather scenarios are ran on a computer, for which the corresponding HDD/CDD values are calculated. Based on the calculated HDD/CDD values, the payout of the option can be determined for each scenario and the option's fair price will be the average of the payouts, possibly weighted by the probability of each weather scenario. The advantage of this method is that a lot of model parameters can be defined before running the predictions. It is easy for example to build in price caps, the average difference in temperature can also be included between the data collection point and the relevant locations for the company, which are taken into account by the computer when calculating the fair price of the option.

6. WEATHER FORECASTING USING WEATHER DERIVATIVES

The public trading of weather derivatives on exchanges means that information relating to expected weather embedded in the pricing of weather derivatives became accessible through the use of simple models for everybody. Several companies and other organizations with large weather exposure have their own proprietary weather forecasting models of varying precision. These organizations use their own forecasts to decide when and at what price to buy or sell certain weather products, so they influence the market with these trades and at the same time reveal their insights regarding expected weather. Before weather products started to be traded on exchanges this information was accessible only for big OTC market players. Today, however, smaller market players can also use prices for weather forecasting. This information is especially valuable because it contains the outcome of several weather forecasting methods, so using this information is supposed to be less risky than picking just one model to forecast weather. How can market players create forecasts from public prices of the exchange traded weather products? A good example is natural gas market, where consumption strongly depends on temperature, so a given month's cumulated HDD value is strongly related to natural gas consumption in the same period. This is true, however, not only retrospectively, as HDD futures and option prices show correlation with the next couple of day's or week's consumption. Even with the use of a simple model, it was demonstrated by an analyst at the CME with the use of one month's HDD prices for the period between the fall of 2001 and the spring of 2003 (Kulkami 2011), natural gas consumption can be very well predicted for the next 20 or 30 days. This is a longer forecast period than the usual 2-week weather forecasts. It is not surprising, however, that 20-day forecasts prove to be more accurate than the longer 30-day forecasts, as in the latter case, the first temperature data for the first 10 days were facts, thus one third of the monthly HDD data was given. That also means that the uncertainty was considerably lower with for the monthly consumption, as consumption data were also facts for that 10-day period. 30-day forecasts explained more than 50% of the variance in natural gas consumption both for New York State's regional consumption and for the national data; 20-day forecasts were considerably more accurate by explaining roughly 80% of the consumption's variance. Forecast was, of course, a little more accurate in the regional case than for the national consumption data, however the difference in accuracy was lower for the 30-day than for the 20-day forecast. The forecasting power of HDD futures prices regarding natural gas consumption data shows that a considerable part of weather market players has useful weather forecasting models and the information drawn from these models is reflected in HDD futures prices. This information in turn, as discussed before, can be extracted from market prices and can serve as a relatively accurate and cheap prediction of temperature conditions.

7. WEATHER DERIVATIVES AND THE PUBLIC SECTOR

7.1 USING WEATHER DERIVATIVES TO AVOID HUMANITARIAN CATASTROPHES

Weather derivatives can also be a useful tool for governments and international organizations. So these products can not only be used to hedge weather related risks in the private sector. A transaction by the UN's World Food Programme received considerable publicity and thanks to that a lot of technical details are available unlike in the case of most transactions by governmental organizations, so this transaction can be cited as an example. The World Food Programme purchased a precipitation contract from Axa Re, a big reinsurance company[3]. The aim of the transaction was to ensure funds for a relief effort by the World Food Programme should the previous years' drought in Ethiopia continue into 2006. The deal covered the Ethiopian agricultural season, which is the period between March and October. Precipitation was measured in 26 locations throughout the country and precipitation levels on each data collection point were converted into crop water-stress indices, which were then combined into a national basket of indices. If this national index would have been higher than a certain trigger level, the option would have had a payout. That high level of the index meant very low precipitation levels associated with a very low crop yield. The option premium paid by the World Food Programme was US$ 0.93 million, while the payout of the option was capped at US$ 7.1 million. The biggest advantage of ensuring relief funds with the purchase of a weather derivative product versus the conventional way of collecting aid from different donors in case of emergency is that in the former case, funds are available quicker, as the insurer pays immediately when the crop-water stress index goes higher than the trigger level. It takes, however, several months to collect aids after a severe crisis has struck. This rapid availability considerably reduces the scale of the humanitarian catastrophe. According to evaluations the donor's money was used effectively when the above instrument was bought, as a US$ 7.1 million fund was purchased for the case of a severe drought for less than US$ 1 million. Eventually precipitation levels in 2006 were above average in Ethiopia, so the option was not triggered. It was proved, however, by the transaction that international organizations could supplement funds coming from donor countries with the use of the weather market. Axa Re demonstrated that it is possible to make deals on the weather market amid complex technical circumstances and data processing challenges. Naturally weather products relating to developing countries can be purchased only on the OTC market, as exchanges offer standard products only for regions in developed countries which attract a lot of businesses and have the potential to generate considerable volume. As a consequence, for OTC deals in the developing world, governmental organizations have to calculate with counterparty risk, which can be reduced however by for example the use of syndicated instruments in case of larger payouts.

7.2 FINANCING RESILIENCE UPGRADING PROJECTS

The financing of city and regional infrastructure upgrade projects is the other important field in the public sector where weather derivatives could play a role. Proper infrastructure upgrades can considerably contribute to alleviate damage caused by extreme weather events. In other words, they result in urban areas that are more resilient against climate change impacts. For example a modern water drainage system can reduce losses due to exceptionally heavy raining, or the building of escapements can prevent flooding. High risk of damage due to extreme

3 Source: http://www.wrma.org/risk_transactions.html, downloaded on 11 July 2011

weather events is considerably drawing back the economic development of a city or a region. As a result, low quality infrastructure reduces the income of local businesses, local authorities and national governments. An infrastructure upgrade that improves resilience against climate change impacts will mean lower expenditure for the public sector first of all, and boosts the region's growth potential by reducing investment risk for private businesses and attracting qualified workforce by providing higher living standards. This higher private sector growth also means more jobs and higher tax revenues. So this kind of infrastructure upgrading does not only results in lower expenses in the case of extreme weather events, but it can generate extra revenues in both the private and the public sector as well.

Such resilience upgrading projects, however, need considerable financing, which is perhaps one of the main impediments of these developments. Funds are usually the scarcest in those developing regions where infrastructure upgrading would generate the highest marginal return. Resilience upgrading projects can be financed in several ways. Conventional financing solutions can be used when a part of the cost saving, increased revenue or increased real estate value generated by the development accrues to investors. This situation is similar to when in the private sector, some kind of energy efficiency project is financed by a loan which is guaranteed by the increased value of the real estate, the cost reduction or the higher rental revenue associated with higher service quality the property can provide as a result of the development project. We can call that the mainstreaming of the development program financing (ICLEI, 2011). A typical example of such mainstreaming in the public sector is when the government makes conventional private sector financing feasible by guaranteeing set future profit margins for the utility which finances and operates the infrastructure, when the price what the utility can apply is regulated by the authorities. Other possibility is to use development loans drawn down and guaranteed by the national governments or the issuance of bonds by local governments for project financing, guaranteed by the increased revenue of the local government as a result of the upgrading project. Any risk of a catastrophic damage that could destroy a part or the entire infrastructure can be covered on the weather market e.g. by purchasing an insurance policy or can be securitized by the issuance of a catastrophe bond. Financing costs can be reduced also by structured financing which spreads investment risks.

Financing is the most difficult for those projects where mainstream financing methods do not work. They are those cases when a large share of the cost reduction or the additional revenues do not accrue to the investor company or to the local governments (ICLEI, 2011). In these cases, non-conventional financial instruments must be used: innovative, in some cases tailor-made financial products which can provide financing for those development projects. Such an innovation could be the introduction of a new generation of catastrophe bonds. Conventional catastrophe bonds were discussed earlier in section 2. In the case of conventional catastrophe bonds the advances are used to alleviate losses so the instrument is used passively. However, in the case of new generation catastrophe bonds, a part of the revenue would be used to finance resilience enhancing development projects. These developments would aim to strengthen the protection of the area against the adverse effects of weather related and other types of catastrophe. This way, the risk of bond investors will be lower and as a result the risk adjusted expected return on their investments could become higher given the same nominal payouts. There are examples for such use of bond advances in the healthcare sector, where bond revenues are not exclusively used to cover the cost of treatment, but also for the prevention of certain diseases. The same method could be used to finance infrastructure upgrading projects.

Another possible invention would be the issue of bonds working in a way similar to the so-called social impact bonds. In the case of social impact bonds, an agency or another organization undertakes to take measures to decrease the costs arising from a certain social problem, a part of which is returned back to the agency. From this revenue the agency is able to cover the interest and principal payment of the bond program. The program itself is financed by the advances of the bond issuance. There are, however, two important prerequisites of the issuance of such bonds, (1) an agency capable to lower the costs of a detrimental social issue, (2) and a saving bigger than the cost of operating the program. In this case there is an opportunity to negotiate how to distribute the revenue coming from the cost reductions among the government, the investors and the agency. Resilience upgrading projects could be financed by the issuance of such bonds, where the upgrade project creates an immediate saving for the community, like in the case of building better roads, which are more resilient against heavy rain or freezing, and in this way reparation costs can be reduced.

8. SUMMARY

There are various types of markets where weather related products can be traded. These are the insurance market, the OTC market, the bond market and exchanges. All of these markets have different characteristics; however, all of those can help cope with weather related risks. This paper described the main fields where weather products can have an impact on the economy and current and future living standards. First, it shall be mentioned that weather products can be used to avoid serious humanitarian disasters in developing countries, where unfavorable weather can still cause starvation and a spread of different diseases.

Second, climate change could increase the extent of weather related risks by making weather less predictable, more extreme and causing increasingly uneven rain patterns. While the permanent solution for these problems would be to stop climate change by reducing the current emission of greenhouse gases, a bigger financial reserve rendered to alleviate weather risk through weather derivative markets can provide protection against the loss stemming from unpredictable weather events. It also have to be noted that not all effects of climate change can be tackled by these additional funds. Permanent effects, like desertification and rising sea levels are problems which cannot be alleviated by weather products.

Third, as it was demonstrated, weather products, however, have also a direct effect on climate change by supporting the financing of renewable energy projects and by contributing to the financing of infrastructure upgrading projects which increase the resilience of cities against weather caused damages.

Finally, exchange traded weather products provide cheap and easy access for all market players to the information provided by sophisticated proprietary weather forecasting models used by big energy companies, hedge funds and other market players. The low-cost access to this information for smaller enterprises can intensify competition by creating a more level playing field, so could provide for a cheaper access to energy or other products for consumers.

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