

# Addressing Credit and Basis Risk Arising From Hedging Weather- Related Risk with Weather Derivatives

Patrick Brockett  
([brockett@mail.utexas.edu](mailto:brockett@mail.utexas.edu)),  
and  
Linda Golden  
([mkl1g@mail.utexas.edu](mailto:mkl1g@mail.utexas.edu))

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# Agenda for Talk

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- **Weather risks and weather derivatives**
- **Development of weather derivative market**
- **Basis risk and weather hedging**
- **Credit risk and weather hedging**
- **Effectiveness of hedging methods**
- **Results & Conclusions**



# Weather Risks and Weather Derivatives

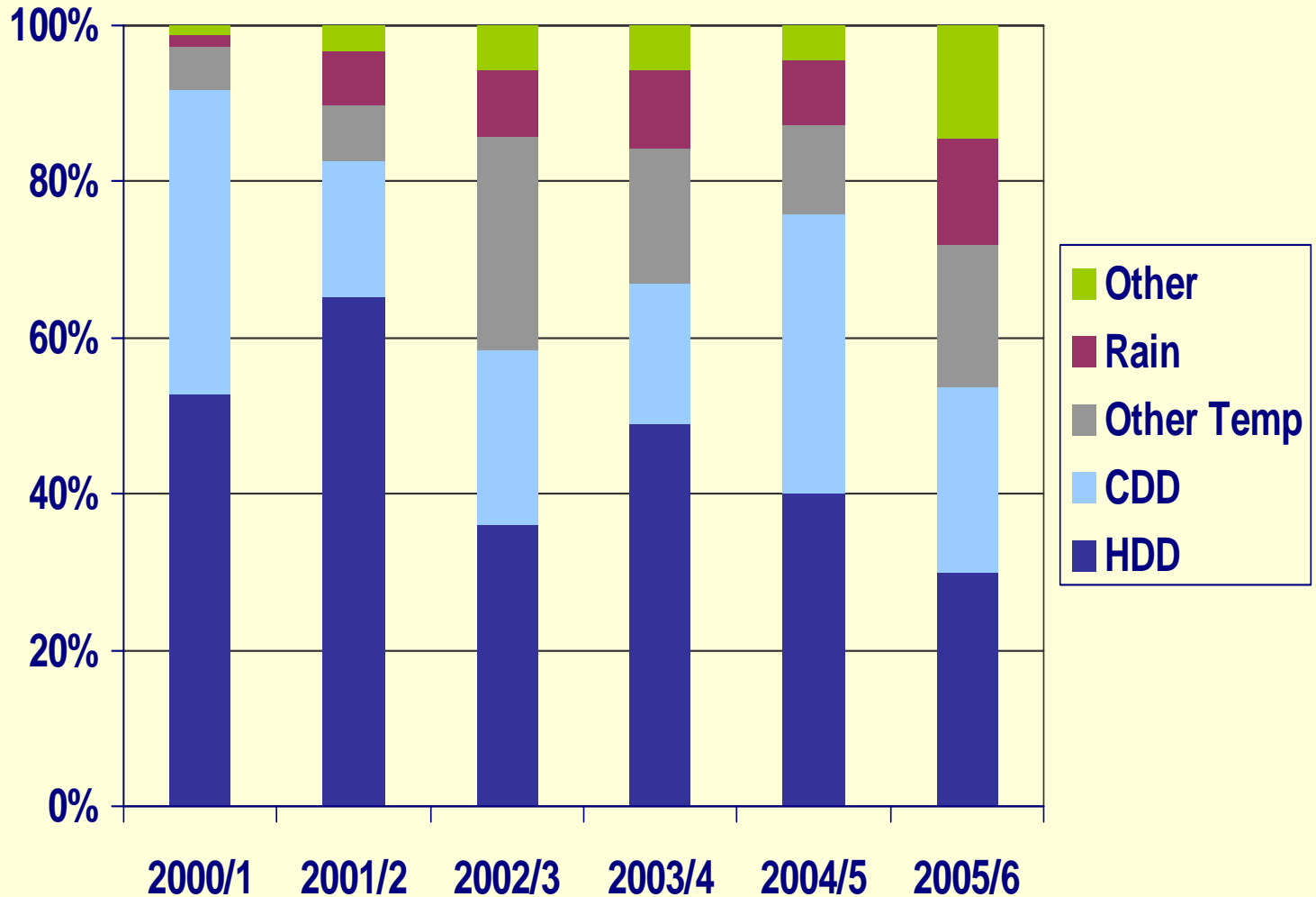
- **Weather risks are the uncertainty in cash flows and earnings caused by non-catastrophic weather events.**
  - Almost 1/3 of businesses affected by weather
- **Examples of weather risks: temperature, humidity, rainfall, snowfall, wind.**
- **Weather exposure is sensitivity of revenue (or cost) to weather indexes ( $DR/DW$ ).**
- **Weather risk is primarily a volume risk rather than a price risk.**



# Weather Risks and Weather Derivatives

- To mitigate against weather risks – **Weather Derivatives** – financial instruments based on a weather related index (like stock index derivatives use stock index like S&P 500 to mitigate against general economic risks)
- Example weather indexes: Heating Degree Days (HDDs), Cooling Degree Days (CDDs) for temperature risks.
  - Use 65°F as baseline. HDD and CDD are obtained by subtracting the day's average temperature from 65°F for HDD and subtracting 65°F from the day's average temperature for CDD values.
  - If temperature > 65°F in the winter, HDD is 0 (since don't need to heat);  $HDD = \max(65 - \text{temp}, 0)$ .
  - if the temperature < 65°F in the summer the CDD is 0 (since don't need to cool);  $CDD = \max(\text{temp} - 65, 0)$ .

# Distribution of Number of Contracts by Type: 2000/1 – 2005/6 (Excludes CME trades)



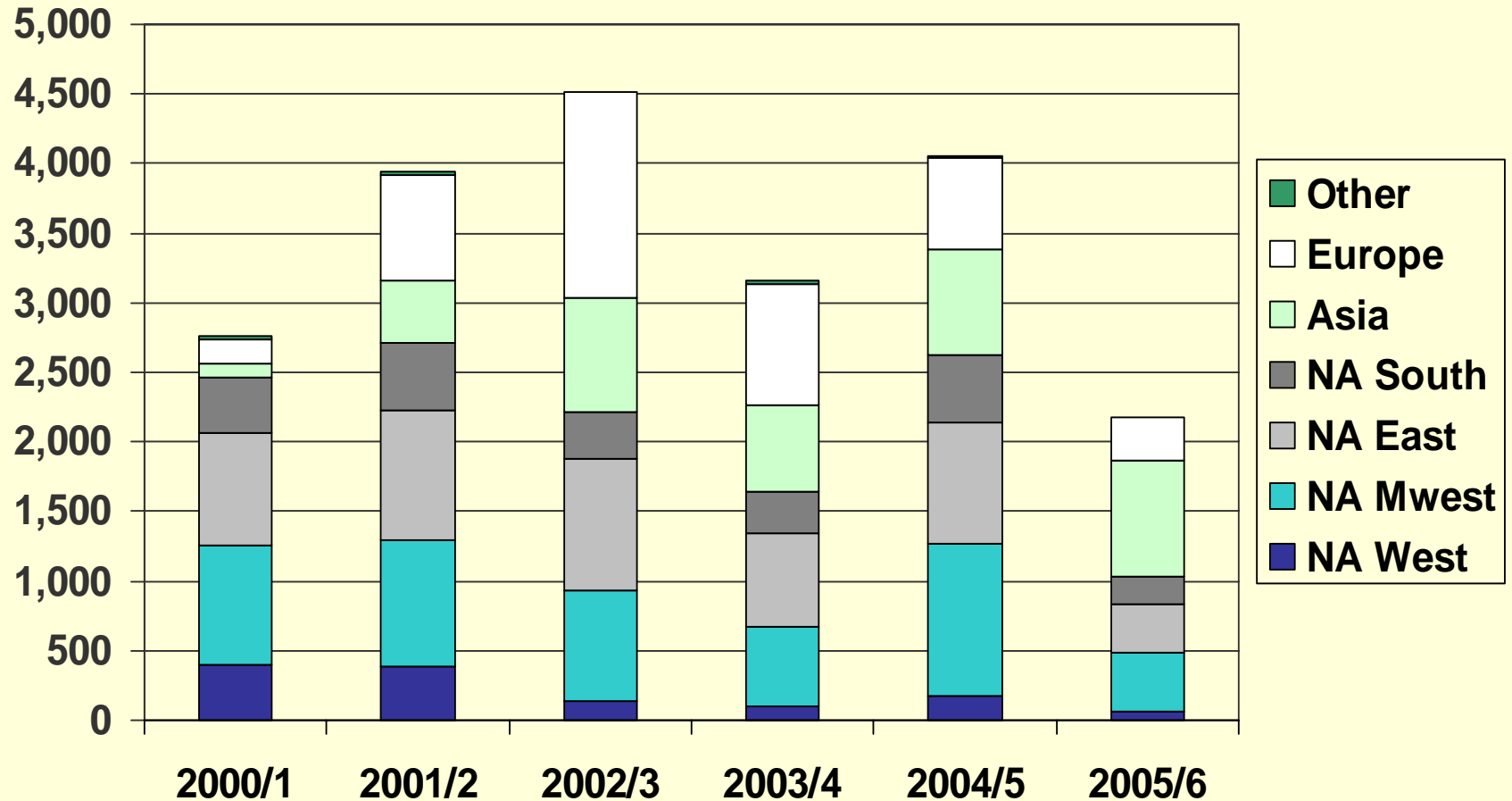
Source: Weather Risk Management Association 2006 Survey Results, Price Waterhouse Coopers



# Development of the Market

- **Currently, most are over-the-counter (OTC) contracts. Standardized weather derivative transactions on exchanges have grown substantially.**
- **CME reports 1,041,439 trades in summer 2005 and winter 2005-6 combined.**
- **2005-6 CME trades up over 300% compared to in 2004-5**
- **Exchanges where traded: Intercontinental Exchange, Swiss Re's ELRIX, CME (the Chicago Mercantile Exchange) and LIFFE (the London International Financial Futures and Options Exchange).**

# Distribution of Number of Contracts by Region: 2000/1 – 2005/6 (Excluding CME Trades)



Source: Weather Risk Management Association 2006 Survey Results, Price Waterhouse Coopers

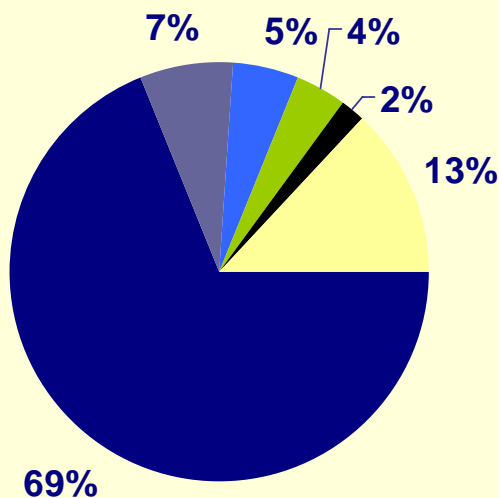


# Development of Weather Derivatives Market

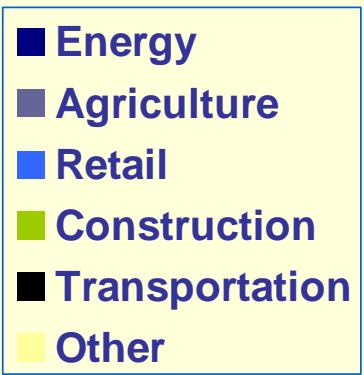
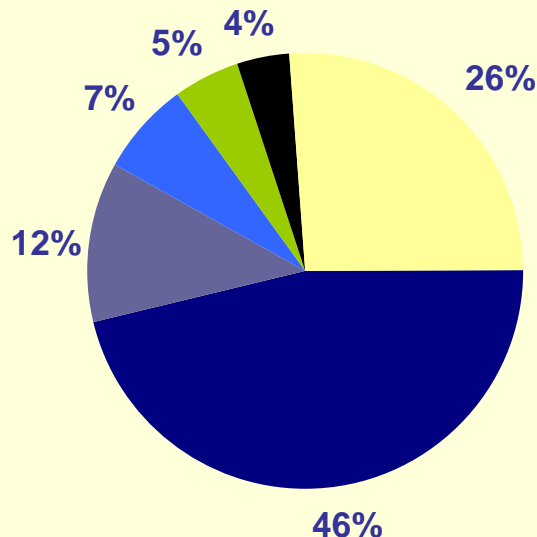
- **Weather derivatives market traces roots to deregulation of the U.S. energy industry.**
- **First trade based on the Heating Degree Days (HDDs) in Milwaukee for winter 1997-1998, with Koch Industries and Enron.**
- **More firms in diverse sectors now using weather derivatives**
  - E.g., XL Capital created weather derivative for The Rock Garden, a London restaurant, to protect against loss from colder-than-normal weather March 1-June 30, 2002.

# Distribution of Inquiries about Weather Risk Instruments, by Sector of Potential End-User

## 2005 Survey



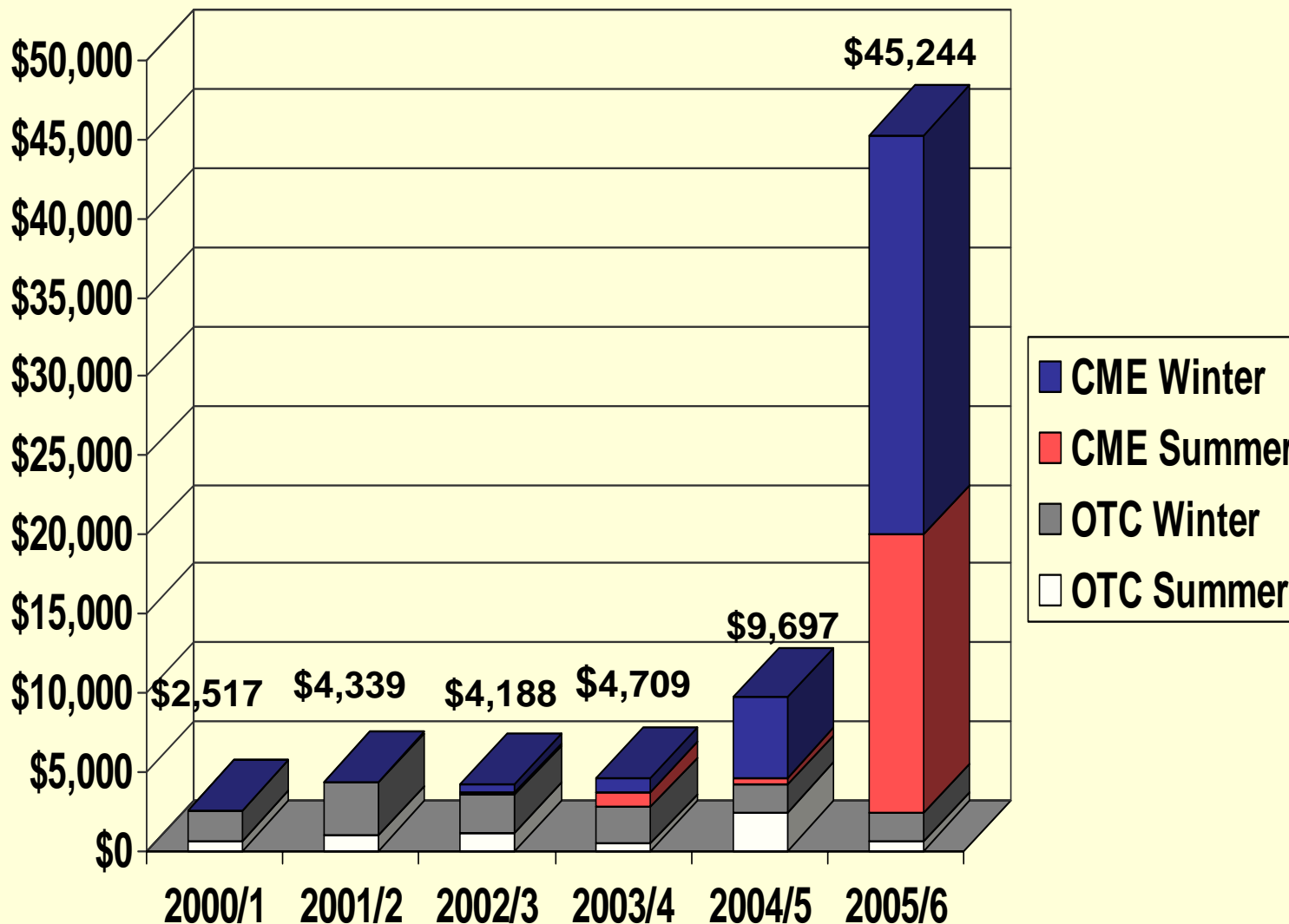
## 2006 Survey



Reported values weighted by number of trades reported by respondent.

Source: Weather Risk Management Association 2006 Survey Results, Price Waterhouse Coopers

# Total Notional Value of Weather Risk Contracts: 2000/1 -2005/6 (Millions of U.S.\$)



Note: CME Notional Values for all years have been revised to reflect CME-reported values.  
 Source: Weather Risk Management Association 2006 Survey Results, Price Waterhouse Coopers



# Development of Weather Derivatives Market

- On the demand side, energy sectors still represents the highest demand. However, other industries, including agriculture, insurance, tourism and retail also start to take note.
- On the supply side, various market participants offer weather risk management products, including energy trading firms, insurance companies, natural counterparties, and the capital market.



# Credit Default Risk in Weather Derivatives

- While OTC contracts can be written for almost any location, including most cities, the OTC contract exposes the hedger to counterparty credit risk. Prices are negotiated.
- Credit risk is the risk of loss in the event that a counterparty to a transaction fails to perform a contractual obligation.



# Basis Risk and Weather Hedging

- Exchange-based transactions provide price transparency and eliminate the counterparty default or credit risk, but can create significant basis risk for participants.



# Basis Risk and Weather Hedging

- **Basis risk** is the risk that arises due to the contract being written based on a weather index tabulated in a different location than the area the hedger wishes to cover.
- The exchange-based market for weather derivative in the US includes only around 15 cities. If you are not located next to one of these 15 weather stations, you have basis risk.



# Credit Risk and Weather Hedging

**To reduce basis risk, hedgers can use “basis derivatives”, such as basis swaps and basis options. However, being OTC contracts, they can bring the hedgers credit risk.**



# Basis Derivative Explained

We can try to compensate for basis risk in exchanged traded derivatives via a basis derivative that “corrects” for the difference between the local weather index  $t_l$  and the index  $t_e$  used by the exchange in creating a traded derivative. We create an OTC contract with strike price based on the difference in indices ( $t_d = t_l - t_e$ ). The “strike” value is  $T_d$  based on the index  $t_d$ . You can make linear (e.g., forward and future) or nonlinear (e.g., put or call option) contracts.



# Strategies for Hedging

To hedge against weather related loss, can choose from the following strategies:

- **Use location specific OTC derivative. This carries counterparty credit (default) risk but no basis risk.**
- **Use exchange-traded derivative based on a RMS regional weather index or on one of CME's fifteen city weather indices. Carries basis risk but no credit risk.**
- **Use combination strategy: Buy exchange-traded derivative to mitigate majority of weather-related risk at minimal credit risk, then supplement with OTC basis hedging derivative to decrease basis risk.**



# Evaluating Credit & Basis Risk Hedging

- We use utility-based hedging models from Golden, Wang and Yang (JRI 2007). Assume the enterprise is attempting to hedge negative effects of weather-related events on the quantity demanded of their product or service. We use a mean-variance approximation to utility;

$$U(W|\theta) = E(W|\theta) - \lambda\sigma^2(W|\theta)$$

where  $W$  is end of period wealth,  $\lambda$  represents the hedger's risk aversion and  $\theta$  is the proportion of the pay-off which will actually be paid on the contract.  $\theta$  is a Bernoulli variable (pays all or nothing) with  $E(\theta) = p$ .

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- Taking into consideration the possibility of credit (default) risk, final wealth using an OTC derivative on a local index is

$$W = q - E[h_{1-t_1}(\theta r_1^p - \theta r_1^c)] + h_{1-t_1}(\theta r_1^p - \theta r_1^c),$$

where  $h_{1-t_1}$  denotes the hedge ratio used for the local weather forward derivative contract,  $r_1^c$  represents payoff on a call option on the local index  $r_1^p$  represents payoff on a put option on the local index. This holds since default only occurs if the counterparty is forced to pay (when  $T_1 > t_1$ ), and does not (which  $\theta$  captures).



- Assume  $q = \alpha + \beta t_1 + \varepsilon$  where  $\varepsilon$  is the non-systematic quantity risk, which is assumed to be independent of the weather indices. The optimal hedging problem is:
- $\text{Max}_{h_1} E(W|\theta) - \lambda \sigma^2(W|\theta)$   
subject to  $P[\theta = 1] = p.$
- From this we can get the optimal hedge ratio  $h^*_{1-11}$ , and the minimum variance in final wealth  $V_{\text{min-11}} = \text{Var}[W(h^*_{1-11})]$   
subject to  $P[\theta = 1] = p.$



# Effectiveness of Hedging

- We can do this same type calculation to find the optimal hedge ratio and minimum variance in final wealth in the basis derivative case, and for non-linear financial instrument case.
- The hedging effectiveness of the linear basis hedging is measured by

$$\frac{V_{\min-ll} - V_{\min-lb}}{V_{\min-ll}}$$



- **This ratio express the extent to which the use of the basis derivative in conjunction with an exchange traded derivative (the hybrid strategy discussed earlier) has reduced the uncertainty in final wealth compared to the simpler hedging strategy of using a local weather index in an OTC contract with associated credit (default) risk.**



# Data

- **CME offers futures and options on futures for fifteen cities in the United States selected due to population, variability in seasonal temperatures, and use in OTC derivative trading.**
- **An alternative provider, RMS, has regional indices with data covering ten regions created using 10 cities in each region form the region index. Cities are selected to represent diverse meteorological patterns, predominant weather risk trading places, population, and correlations with other weather stations throughout the regions.**



- **Weather derivatives can be created based on indices from either index provider**
- **We used 87 cities and measured the hedging effectiveness of basis derivative hedging according to region, index type and season**
- **3-way ANOVA was run on effectiveness measures for 87 cities, separately for linear hedging and nonlinear hedging**



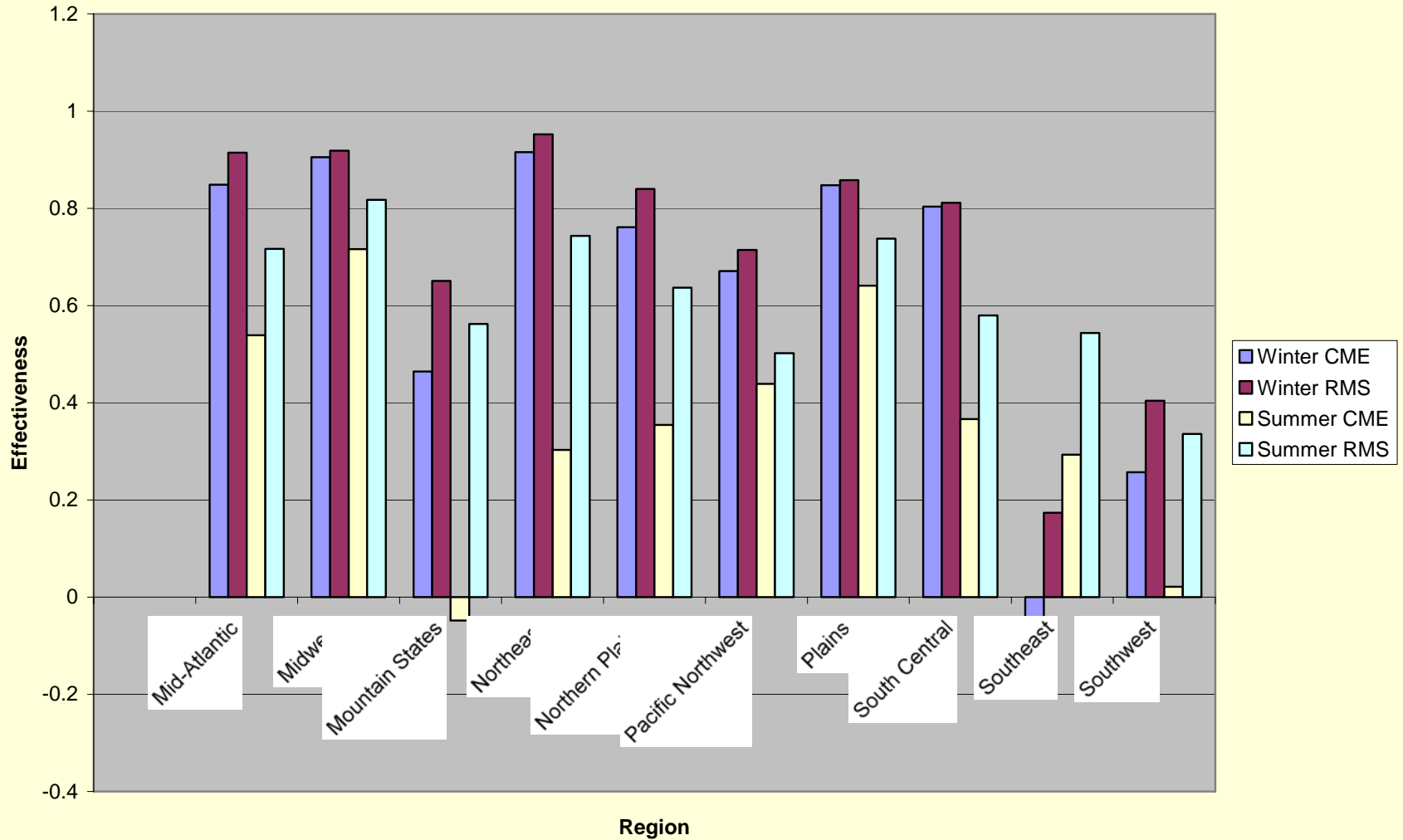
# Results

**Region, season and index explain a highly significant amount of the variance in the effectiveness of hedging uncertainty in either the linear hedging or the nonlinear hedging context ( $p < .0001$ ).**

**The main effects of region, index used and season were all statistically significant for both linear and nonlinear hedging methods, implying that levels of basis risk hedging effectiveness differed significantly across regions, seasons, and indices used.**

# Effectiveness of Basis Risk Hedging

Figure 1 Average Effectiveness Of Linear Basis Hedging





# Conclusion

- **Hedgers bear basis risk and credit risk when trading weather derivative contracts.**
- **We find both linear and nonlinear basis hedging are more effective for winter than summer, (which should be of use to hedgers)**
- **The effectiveness of hedging using a basis derivatives varies significantly by regions**
- **Generally, RMS regional indices are more effective than CME indices for basis hedging.**
- **Results have implications for the type of index to use for hedging weather related risk**