Commodity Modeling:
View from the trenches

Alexander Eydeland

Toronto, 2010

Oil prices reach $147/bbl

1/11/2009

60 Minutes:

… many people believe it was a speculative bubble, not unlike the one that caused the housing crisis, and that it had more to do with traders and speculators on Wall Street than with oil company executives or sheiks in Saudi Arabia

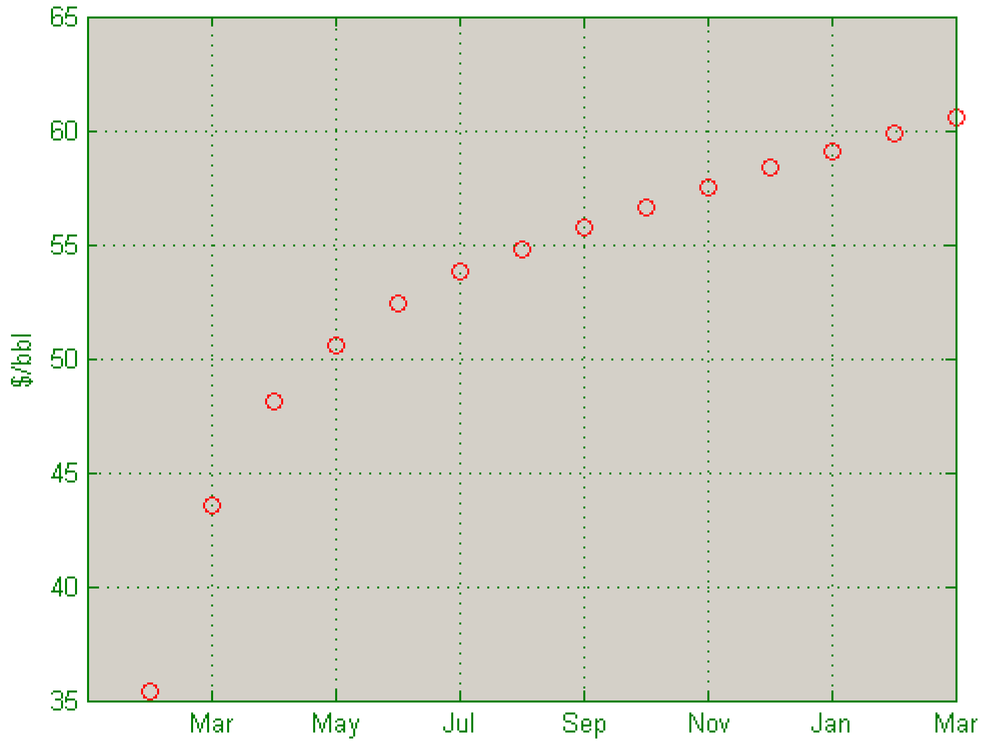
First reported 03/11/2009

Dow Jones & Company Inc

Trafigura: May Have Best Earnings Ever In Fiscal 2009

- SINGAPORE -(Dow Jones)- International commodities trading firm **Trafigura** Beheer B.V. is potentially on track to post its best results ever in fiscal 2009 on lower oil prices and contango markets, a company executive said Wednesday.

WTI futures contracts: Jan. 15, 2009



Making Money in Contango Markets

$F_{Feb'09} = 35$ $/bbl $F_{Feb'10} = 60$ $/bbl

Strategy: On Jan. 15, 2009

- Borrow $35 ➔ Buy 1 bbl ➔ Store
- Short Feb'10 futures contract (1 bbl)
- Lock-in profit: $25 - Interest Payment
  - *Interest Payment = $35*r*
  - *If r = 10%*

    Interest Payment = $3.5/bbl   Profit = $21.5/bbl

Same strategy in higher price environment

$F_{Feb'09} = 125$ \$/bbl $F_{Feb'10} = 150$ \$/bbl

Strategy: On Jan. 15, 2009

- Borrow $125 ➔ Buy 1 bbl ➔ Store
- Short Feb'10 futures contract (1 bbl)
- Lock-in profit: $25 - Interest Payment
  - *Interest Payment = $125*r*
  - *If r = 10%*

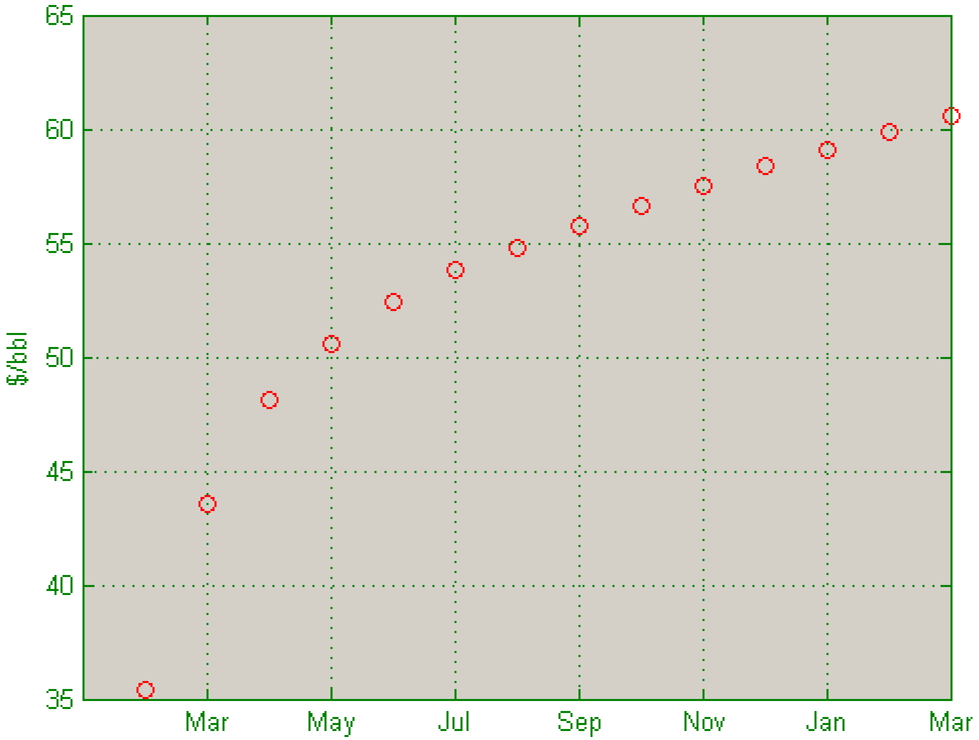
  Interest Payment = $12.5/bbl *Profit = $12.5/bbl*

Summary: to generate profit

- Needed asset (storage)
- Needed strategy:
  - Long Feb’09 contract
  - Short Feb’10 contract
  - Or long Feb-Feb calendar spread

What if you need to lease from Aug to Dec
How much will you pay for this lease on Jan 1?

- $F_{Aug} = 55$ \$/bbl $\quad\quad F_{Dec} = 58$ \$/bbl



This is what the trader will do

On Jan 1

- Buy Aug/Dec spread:
  - Long Aug futures contract
  - Short Dec futures contract
- On Aug 1
  - buy 1 bbl for $55/bbl and store it
- Wait till Dec and then sell 1bbl for $58
- Lock-in $3/bbl. Can pay for storage up to $3/bbl

This is what the quant will do

- On Jan 1 sell Aug/Dec spread option:

$$Payout\_at\_exercise = \left[F_{Dec} - F_{Aug} \right]^{+}$$

- Exercise date Jul 31
- Interest rates are ignored for simplicity (should not be)

Why is this better?

- The value of this calendar spread option

$$V = \left(F_{Dec} N\left(d_1\right) - F_{Aug} N\left(d_2\right) \right) \cdot DiscFactor$$

$$d_1 = \left[\log \frac{F_{Dec}}{F_{Aug}} - \frac{\sigma^2}{2} T \right] \Big/ \sigma\sqrt{T} \quad \sigma = \sqrt{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2} \quad d_2 = d_1 + \sigma\sqrt{T}$$

  - *V =4.4677 $/bbl*
  - It is always greater than the spread because the spread is its intrinsic value

The benefit:

- Storage bid can be increased to $4.46/bbl increasing the likelihood of winning the deal. We can also keep a greater profit.
- Is there the risk? What if on Jul 31

  F_{Aug} = 65 \$/bbl F_{Dec} = 80 \$/bbl

  and we owe $15/bbl to the option holder

- No worry: We have storage ➔ On Jul 31

  Buy Aug crude for 65 $/bbl and simultaneously

  Sell Dec crude for 80 $/bbl using Dec futures contract

  Lock-in $15 $/bbl to repay option holder

In reality …

- Sell portfolio of spread option
- Satisfy a number of physical constraints
  - Injection rates
  - Withdarawal rates
  - Do not inject more than max capacity
  - Do not withdraw from the empty tank
  - etc

But seriously folks

- There is no spread option market now: we cannot sell spread option directly
- We must design a strategy of replicating selling the spread option
- Similar to Black-Scholes delta-hedging strategy

So, what do commodity quants do?

- Looking for value in physical/financial deals and assets
- Looking for strategies of extracting this value
- Looking for strategies to reduce the risks

Mysterious hedges

APRIL 1, 2009

The Wall Street Journal

Airlines Return to Hedging

"Carriers are relying increasingly on instruments that reduce the burden of rising oil prices, but leave open the option of purchasing fuel at market rates should costs fall back."

"The airline is using a mechanism known as a call option"

Average Price Options

Payout function

$$g\left(F_1(t), F_2(t), \ldots, F_n(t)\right) = \left[\frac{1}{N}\sum_{i=1}^{N} F_{\nu(i)}(t_i) - X\right]^+$$

$F_{\nu(i)}(t_i)$ is the nearest contract at time t_i

Valuation Methods

- Moment matching – the most common methodology:
  - Choose distribution (e.g., lognormal) dependent on *m* parameters which are determined by matching *m* moments of the target distribution
  - Approximation; fast; stable Greeks
- Monte-Carlo simulations
  - Accurate; slow; unstable Greeks

Popular Variations

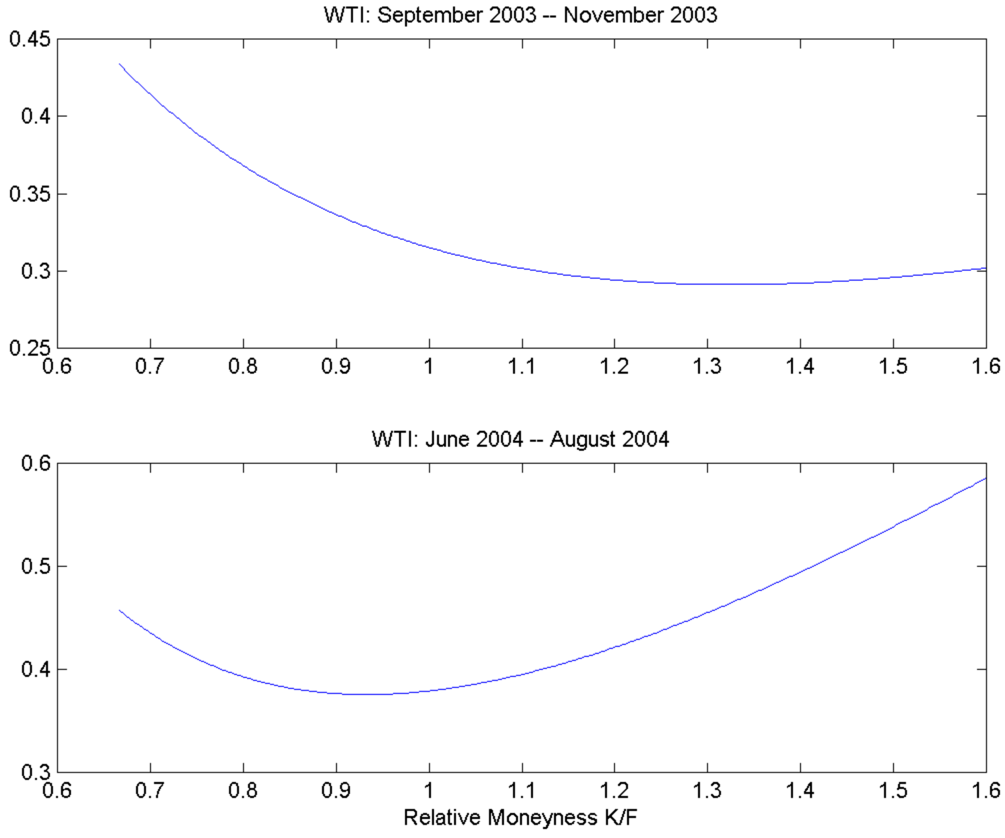
- Baskets of APOs
- Options on baskets of APOs (the simplest one is a swaption)
- TARN (Targeted Accrual Redemption Note).
  - Investor expects high-yield short-term returns while assuming long-term risks of poor performance
  - Example: two strips of Asian oil options. One is the strip of long calls with close to at-the-money strikes and the other is the strip of short puts with much lower strikes. Structure ceases to exist if positive payout reaches a predefined aggregate level. Investor benefits if the price of oil stays at the current level or goes up

What else the quants do?

- Designing products that meet client’s objectives

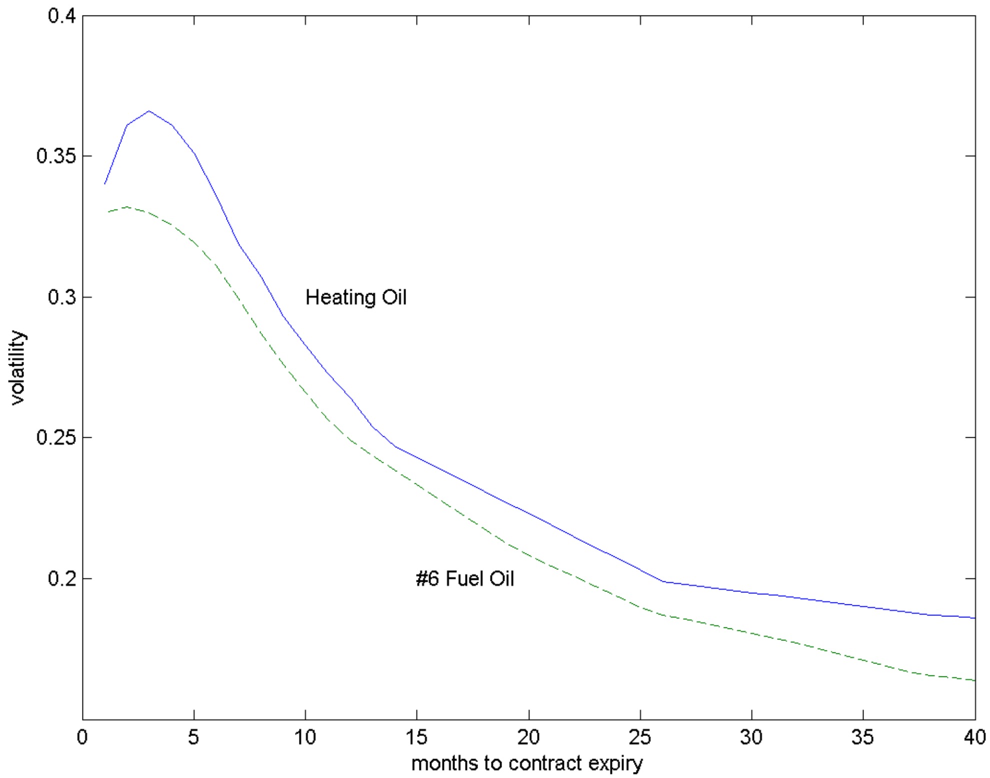
What we need to know and capture in our models

- Volatility smile



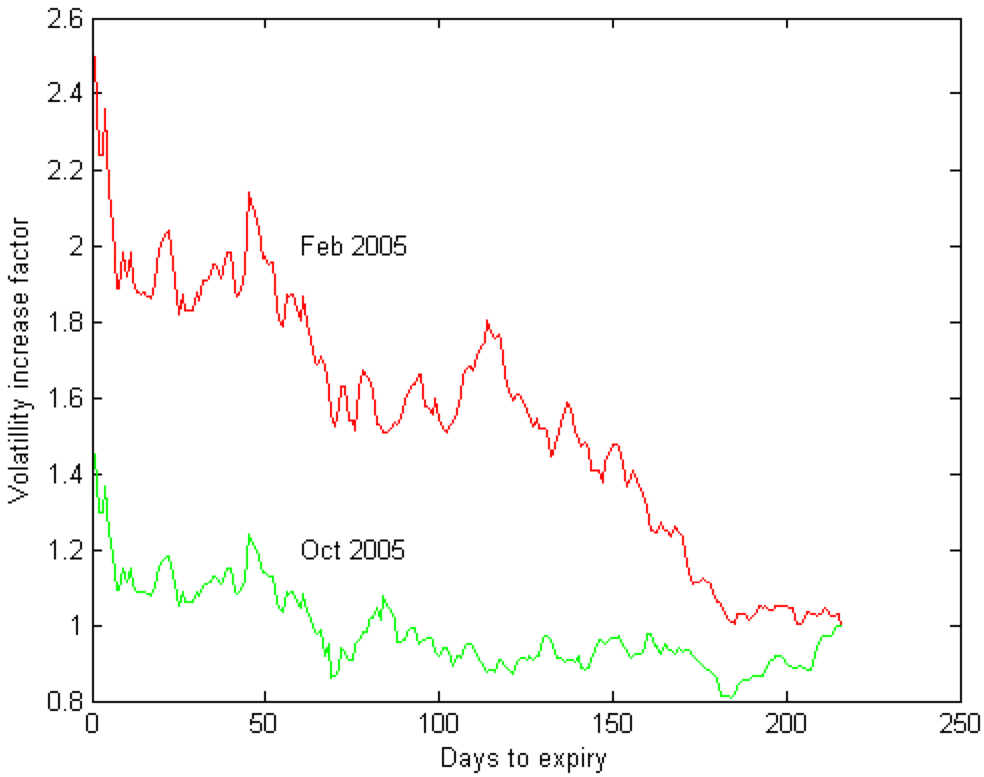
Samuelson effect

- #2 Heating Oil and #6 Fuel Oil At-the-Money Implied Volatility Curves on 21/10/2003



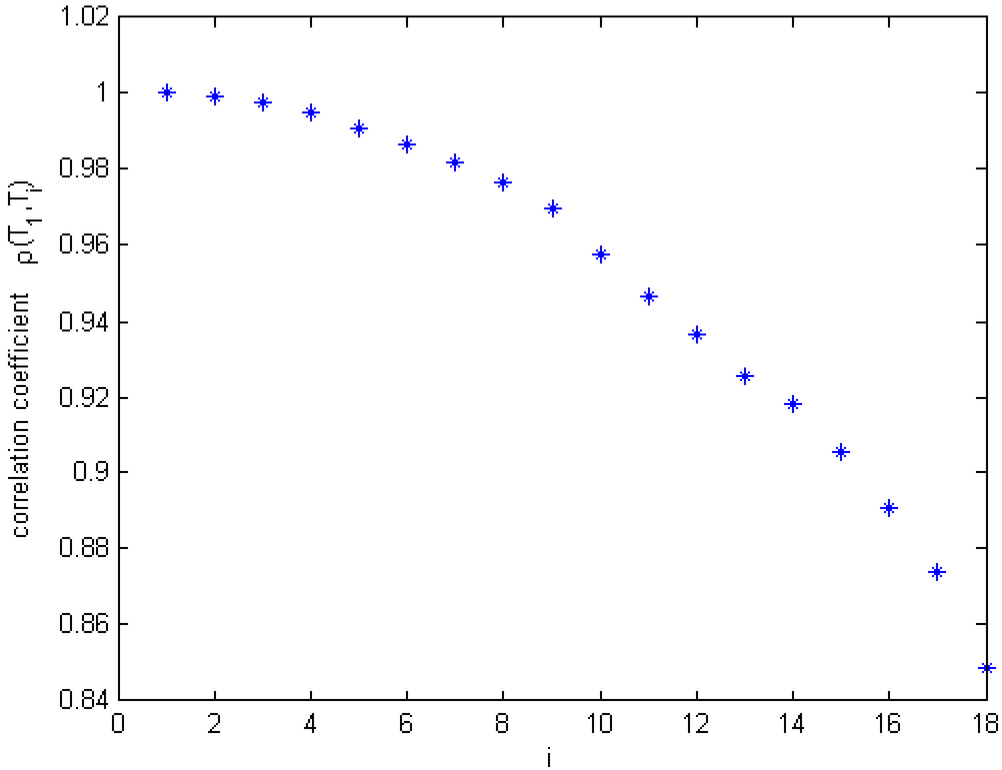
Samuelson effect

- . The historical graphs of the implied volatility ratios $\frac{\sigma_{impl}(T;t_1)}{\sigma_{impl}(T;t_0)}$ of WTI futures contracts as a function of time to expiry $T\text{-}t_1$



Correlation structure

Correlation between returns of Jan ’05 NYMEX heating oil (HO) futures contract and Feb’05 - Dec’05 HO contracts



Quants also do this

- Analyzing markets to find stable empirical properties
- Use this information to develop the best pricing methodology

… and this

- Back-testing of model performance (!)
- Most importantly, hedge performance

New Commodity Markets and Products

- Emissions: EUA, CER, etc.
- Markets for green products
- Ethanol, markets for energy-related agricultural products
- New markets for electricity products, such as markets for various ancillary services

New Products

- Baskets:
  - Options on basket price
    - basket components may include crude, NG, equity indices, bonds, etc.
  - Rainbow or Best-of basket products
    - pays the best annual return of the basket components
  - Himalayan option
    - every year pays the return of the best performing basket component and then this component is removed from the basket

New Products: Complex tolling deals

- Tolling deals
  - call on power with strike price dependent on the cost of fuels, emission and variable costs = option on spread between power prices and prices of fuels and emission
  - basket of correlated commodity products (three or four products in the basket)
  - objectives:
    - power operator will guarantee stable cash flows stream (option premium) typically from an institution with higher credit rating
    - power plant operator may also use these options to hedge against adverse power and fuel market movements
    - marketers use these options to financially replicate power plant operation without taking on operational and other risks associated with running the plant

Complex Tolling Deals: Examples

- Unit Contingent Toll with Callback on High Gas
  - Standard Toll: Buyer has the right to call for power. When the right is exercised the buyer pays the cost:

    Number MWh x Price of 1MMBtu of NG x Heat Rate + costs

  - Callback: Seller has the right not to deliver power during not more than 10% of all hours of the year (if a specified unit is forced out)

- Tolling Deal with Limited Number of Start-ups during the year - complex path-dependent option

- Tolling deals with a fuel substitution option and emission costs

Tolling deals with ancillary services

- Every day the toller can simultaneously bid into the electricity market, as well as into a number (3-5) ancillary services, such as “regulation-up”, “regulation-down” and various reserves
- The toller must decide on volumes and bid prices

Tolling deals with ancillary services

- To determine volumes and prices, the toller must solve complex nonlinear problems
- The toller must understand engineering constraints to avoid unfeasible solutions

Risk management challenges

- Potentially high sensitivity to correlation between electricity and ancillary services prices
- Even higher sensitivity to such difficult to determine parameters as probability of ancillary service being deployed after the bid for this service has been accepted
- Potentially damaging “negative gamma” of the deal

New Products: Load following deals

- Load following deal is an agreement to supply the variable amount of energy for every hour in the future time period for a fixed price.
- The amount of power in each particular hour is determined by the demand in the service area and is not known at the time of entering the deal

New Products: Load following deals

- The cash flow generated by serving the load portfolio is a difference of hourly contractual revenues and hourly energy costs

$$C = \sum_{Months,\, Days,\, Hours} \left(L_{m,d,h} P^{Contract} - L_{m,d,h} P_{m,d,h} \right)$$

Risk Management Challenges

- Potentially strong non-linearity (if the correlation is high)
- Complex correlation structure
- Inability to hedge all risks, particularly, risks associated with load fluctuations and load shape dynamics or migration
- Need new approaches to valuation

One approach to load following

- Similar to the method in Eydeland, Wolyniec, “Energy and Power Risk Management”, 2002, instead of modeling power and load directly, model the evolution of a factor underlying both load and power, i.e. temperature
- Express load and power as a function of temperature plus noise using nonlinear regression for load and hybrid fundamental/closed form model for prices

One approach to load following

- Advantages: load/power correlation is an output not input; modeling is straightforward and defendable on fundamental grounds
- Still even this method does not produce perfect hedging methodology since load variability generally cannot be hedged, and because of the mismatch between the hedge instruments and the deal to hedge

Risk Management Challenges

- In the situations when there are unhedgeable risks a typical approach is to create dynamically a portfolio of tradable instruments that on every hedge step minimizes the variance of the combined deal/hedge portfolio
- The hedge portfolio in these cases varies depending on the choice of hedge instruments

New Products: Certified emissions reductions (CER)

- Certified emissions reductions (CERs) are created through emissions reducing projects in developing countries, and can be used by European emitters to meet their EU emission obligations.
- The principal difference between traditional EU emission credits (EUAs) and CERs is due to the fact that CERs are not delivered until the project achieves emission reduction and those emission reductions are certified.

Risk Management Challenges

- Forward contracts on CERs, as well as swaps, carry additional uncertainty related to the delivery of the CERs at settlements
- Several major stages in the life of a CER can be identified: UN registration, project implementation, ongoing delivery. A successful passage of each of these stages increases the probability of successful CER delivery, and hence, of success in entering a forward contract or a forward starting swap
- Alternatively, the failure to complete any of these stages will result in canceling of the forward or swap

Risk Management Challenges

- The deal depends on unhedgeable parameter
- Again, one risk management approach is to use tradable instruments to minimize the variance of the deal value conditional on the distribution of this parameter

Correlation Risk

- How to measure correlation risk?
- Eydeland, Galeeva and Hoogland in "Measuring correlation risk for energy derivatives", 2008, proposed several methods to measure correlation VaR
- The methods differ by different approaches to perturbing the correlation matrix

Correlation VaR

1. Bootstrap method: Monte-Carlo re-sampling method
2. Perturbing individual correlations
    - Perturbing angles in the angle representation of the correlation method
    - Advantages: a resulting matrix is a correlation matrix as well (non-negative definite, ones on the diagonal)

Correlation VaR

3. Perturbing eigenvalues of the correlation matrix

- These perturbation methods allow us to compute sensitivity of a given portfolio to correlation

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