Derivatives 2007

New Ideas, New Instruments, New Markets

Energy Derivatives after … Dec. 2, 2001

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OVERVIEW

- Derivative Structures in Energy for *Commercial* Users
  - A Taxonomy
  - Brief Comments on Valuation

- For non-commercial users (i.e., “Investors” and “Hedge Funds”), Derivative Structures Provide Exposure to Energy Prices

Structured Energy Derivative Products — Commercial Users

- Linear Instruments

Traditional	Exotic
1. Forward/Futures contracts	1. Load-Following Services
2. Exchange of futures for physicals ("EFP")	2. Cross-Currency Swaps (e.g., Yen WTI Swap)
3. Swaps: Fixed for floating; floating for floating	3. Proxy Swaps on Illiquid Indices (e.g., Japan Crude-Oil Cocktail)

- Non-Linear Structures

Traditional	Exotic
1. Conventional American and European call and put options	1. Strip of *Daily* options
2. Option Collars	2. Cross-currency Exposure
3. Average options	3. Three Types of Average Options: Average Value of a Futures Contract; Average Value of Spot Prices; Swaption
4. Capped swaps; Extendible swaps; Cancellable swaps; Contingent-premium structures	4. Packaged Products: Three-Ways, Participating
	5. Spread options: Transportation; Basis; Spark (Natural gas – Electricity); Crack (Crude oil – Crude products); Frac (Natural gas – Natural gas liquids); Storage
	6. "Swing" options, with/without "ruthless" exercise
	7. Weather derivatives

Electricity Full Requirement/Load-Following Services

- At the retail level, does *not* entail optionality
- In the absence of credit/operational risk, and if markets were complete, value is the discounted present value of $E^*(P_T \cdot Q_T)$
- Under joint LogNormality,

$$E^*(P \cdot Q) = F \cdot E^*(Q) \exp\left\{\rho\sigma_F\sigma_Q T\right\}$$

- Valuation challenges encountered whenever
  - A market price of volumetric risk entails $E^*(Q) \neq E(Q)$
  - Non-rectangular block intra-day load
  - Long-dated futures prices F are illiquid

Cross-currency swaps

A cross-currency swap is a commodity swap with the payoff in a different currency to that of the underlying commodity traded

An example would be a Yen WTI swap

There are multiple ways of applying the FX rate to the commodity price fixing used in computing the swap payoff

Cross-currency swap payoffs are often based upon the average of a number of previous months' average prices

Applying FX rates to commodity prices

1. Apply the spot FX rate to each day's commodity fixing

2. Compute the average commodity price over some fixing period, the average FX spot rate over another fixing period, and multiply these averages

3. Compute the average commodity price, compute the average of the inverse FX spot prices, and divide the commodity average by the inverse FX average

The monthly floating price is defined to be some average over previous months' prices

We typically use the notation (N,P,Q) to represent such swaps

Example 1:

- **(9,0,1) swap** Here each month's floating payment is defined to be the average of the preceding nine consecutive months' average price fixings
- The labelling convention (9,0,1) refers to:
  - The number of months' average price fixings that are averaged, N=9.
  - The time shift before the present month before averaging starts. Here P=0 indicates that the average is computed up to the latest month for which a fixing is available.
  - The number of months for which the average applies, Q=1, meaning a new average is computed every month.

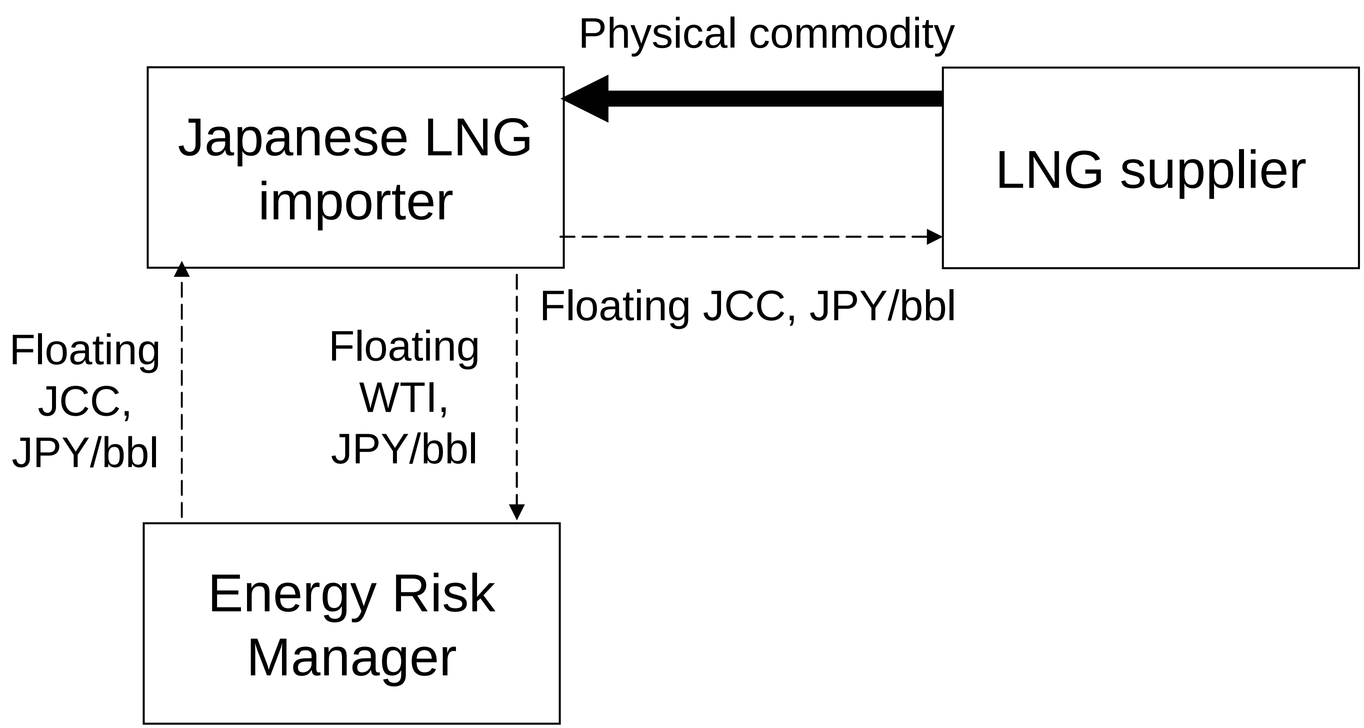
(9,0,1) swap calculation

Month in which settlement is due	Floating payment
January 2007	$\frac{1}{9}(P_{Apr06} + P_{May06} + \ldots + P_{Dec06})$
February 2007	$\frac{1}{9}(P_{May06} + P_{Jun06} + \ldots + P_{Jan07})$
…	…

(3,1,3) swap In this case the monthly floating payment is based upon 3 consecutive months' (averaged) prices, time lagged by 1 month, with the average applying for 3 months at a time.

Month in which settlement is due	**Floating payment**
January 2007	$\frac{1}{3}(P_{Sep06} + P_{Oct06} + P_{Nov06})$
February 2007	$\frac{1}{3}(P_{Sep06} + P_{Oct06} + P_{Nov06})$
March 2007	$\frac{1}{3}(P_{Sep06} + P_{Oct06} + P_{Nov06})$
April 2007	$\frac{1}{3}(P_{Dec06} + P_{Jan07} + P_{Feb07})$
May 2007	$\frac{1}{3}(P_{Dec06} + P_{Jan07} + P_{Feb07})$
June 2007	$\frac{1}{3}(P_{Dec06} + P_{Jan07} + P_{Feb07})$
July 2007	$\frac{1}{3}(P_{Mar07} + P_{Apr07} + P_{May07})$
…	…

Japanese LNG importer: Reference swap



The Analytics of Intra-Month Daily Spot Prices

- Time Line

$F_t =$ the price for a monthly block of power for the month $[t,\, t + 1/12]$

$f_s =$ price of daily power on day s, $s \in [t,\, t + 1/12]$

Accordingly, the time sequence is the following:

Date	Time Index t
Today	0
Beginning of spot month	t
End of spot month	$t + 1/12$

- Assume the stochastic price process:

Eq.	Stochastic Process	Time	Verbal Interpretation
(1)	$d \ln F_t = -\,0.5\, \Sigma_{Ft}^2\, dt + \Sigma_{Ft}\, dz_{Ft}$	$0 \le s \le t$	Futures prices follow GBM
	$\widetilde{f}_t = \widetilde{F}_t$	$s = t$	The spot price at date t is equal to the then-current futures price
(2)	$d \ln f_t = -\,0.5\, \sigma_{ft}^2\, dt + \sigma_{ft}\, dz_{ft}$	$t \le s \le t + 1/12$	Intra-month *spot* prices follow GBM

Note: $\widetilde{F}_t$ is the realized value of $\widetilde{F}$ at the end of the *prompt* month

- If the daily option payoff is $\max\{f_T - K,\, 0\}$, then under eqs. (1) – (2) the call-option value is given by:

$$c_t = \sum_{s=1}^{m_t} \exp\left\{ -\, r_t \left(t + \frac{s}{12\, m_t} \right) \right\} \left[F_t N \left(d_{t+s/12\, m_t} \right) - K N \left(d_{t+s/12\, m_t} - \Sigma_{t+s/12\, m_t} \sqrt{t + \frac{s}{12\, m_t}} \right) \right], \tag{3}$$

where

$$d_{t+s/12\, m_t} \equiv \frac{\log\left(F_t / K \right)}{\Sigma_{t+s/12\, m_t} \sqrt{t + s/12\, m_t}} + \frac{1}{2}\, \Sigma_{t+s/12\, m_t} \sqrt{t + s/12\, m_t}$$

$$\Sigma_{t+s/12\, m_t}^2 \left(t + \frac{s}{12\, m_t} \right) = \Sigma_{Ft}^2\, t + \sigma_{Ft}^2\, \frac{s}{12\, m_t}$$

Three-way options

Simple collar structures strictly limit the buyer's potential to enjoy upside benefit

Variations on this theme have evolved to offer some upside participation

The first package we'll consider is known variously as the **three-way option**, **three-way collar** or **enhanced collar**

Three-ways are related to collars, but the holder starts to benefit again from sufficiently large upside market movements

Three-ways take their name from the fact that they are packages of three underlying options instruments

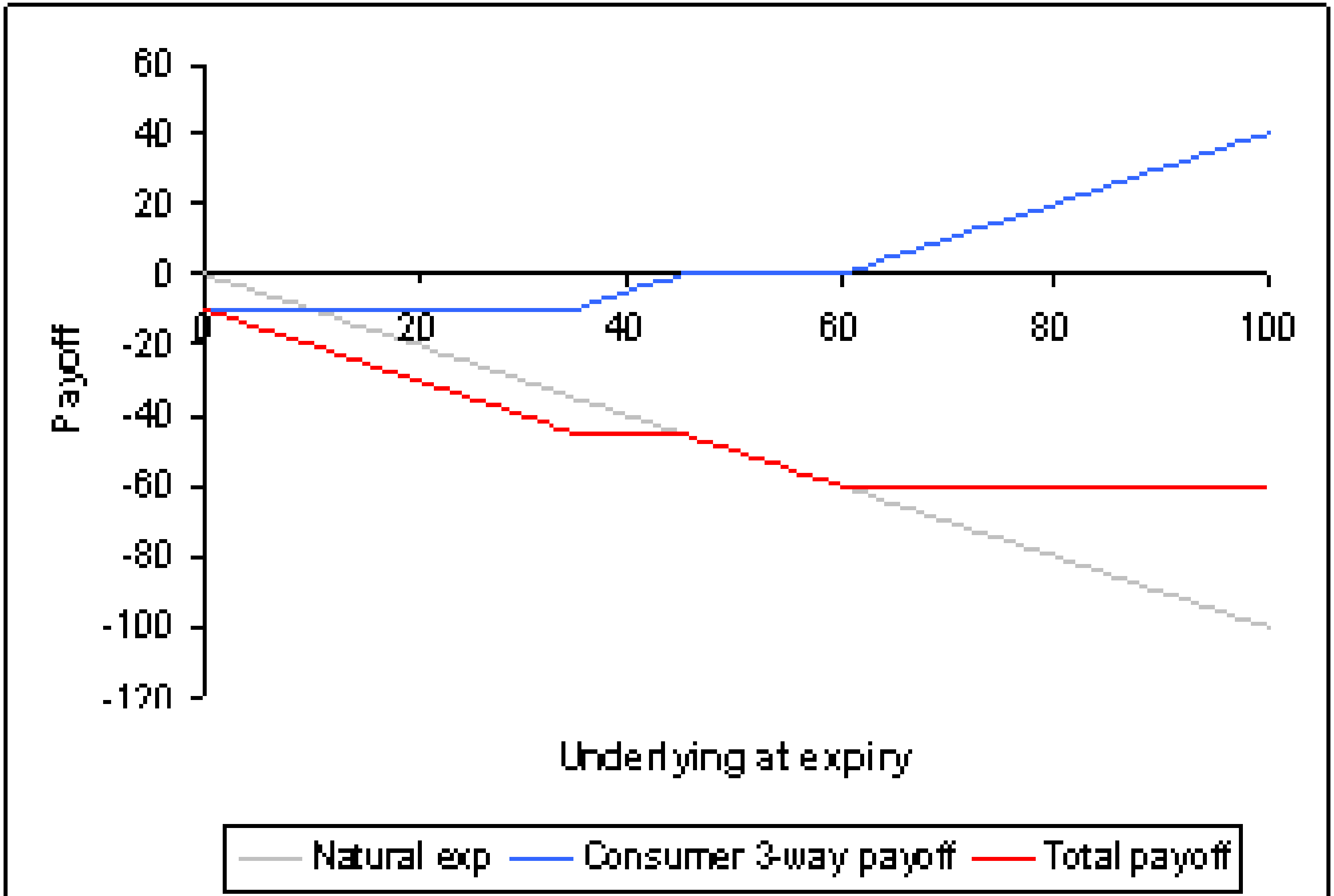
Consumer three-way

A **consumer three-way** can be constructed from a consumer collar (long a call, short a put of lower strike) together with a further long put at an even lower strike

Sufficiently large price movements to the consumer's upside (that is, decreasing prices) lead to a decreasing net exposure for the consumer

- A regular consumer collar ensures that for all prices below the put strike the consumer receives a fixed price
- This is because every dollar decrease in the underlying is balanced by dollar-for-dollar by the sold put
- Buying another put means that for sufficiently large price drops the "effect" of the first put is cancelled out

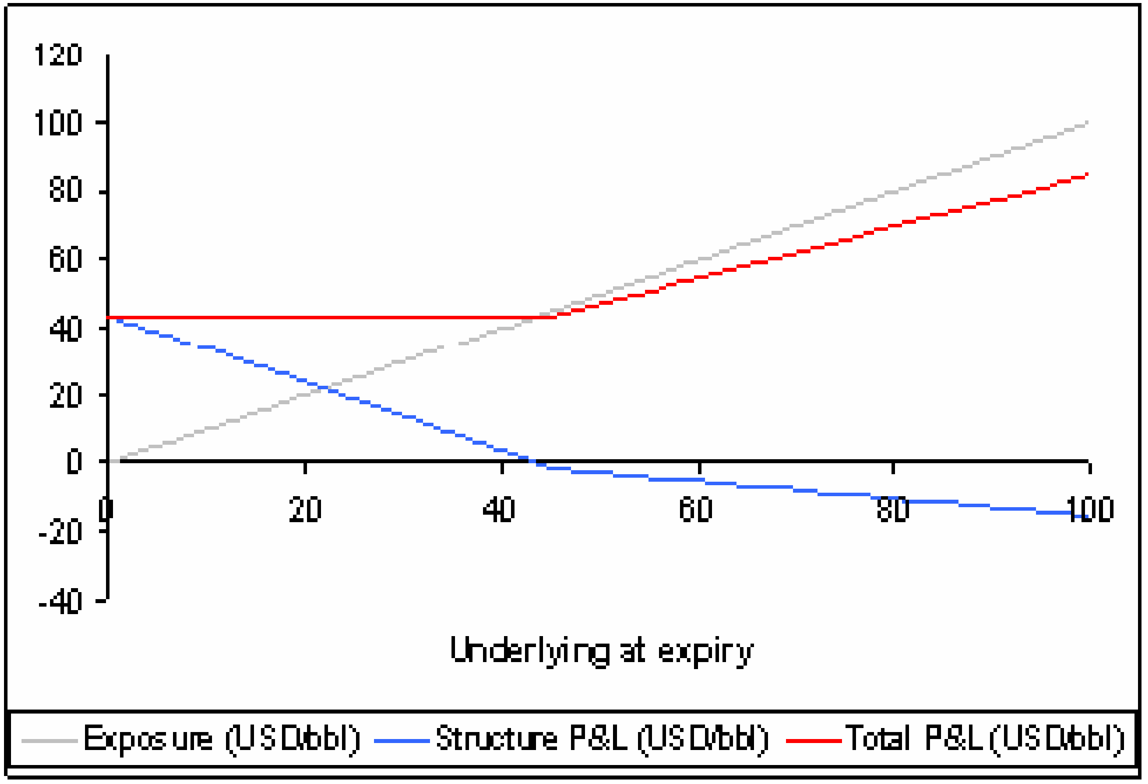
Consumer three-way payoff



Choosing the participation level

After considering the amount of upside participation they are prepared to offer the energy risk manager the producer decides to opt for a 25% participation level

They pay 1.50 USD/bbl for the package



The WTI Crude-Oil Price Environment — NYMEX, April 30, 2007

- Prices and vols are:

Month	Price ($/bbl)	Implied Volatility (%)
Feb-08	70.70	25.36
Mar-08	70.91	25.01
Apr-08	71.09	24.57
May-08	71.24	24.17
Jun-08	71.39	23.81
Jul-08	71.49	
Aug-08	71.55	
Sep-08	71.60	22.71
Oct-08	71.60	
Nov-08	71.63	
Dec-08	71.65	22.12
Jan-09	71.62	

- Correls:

Month 1	Month 2	Correl
Feb-08	Mar-08	0.999
Feb-08	Apr-08	0.999
Feb-08	May-08	0.998
Mar-08	Apr-08	0.999
Mar-08	May-08	0.999
⋮		
Feb-08	Jan-09	0.975

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Generic 1st 'CL'
CL Contract Series Graph

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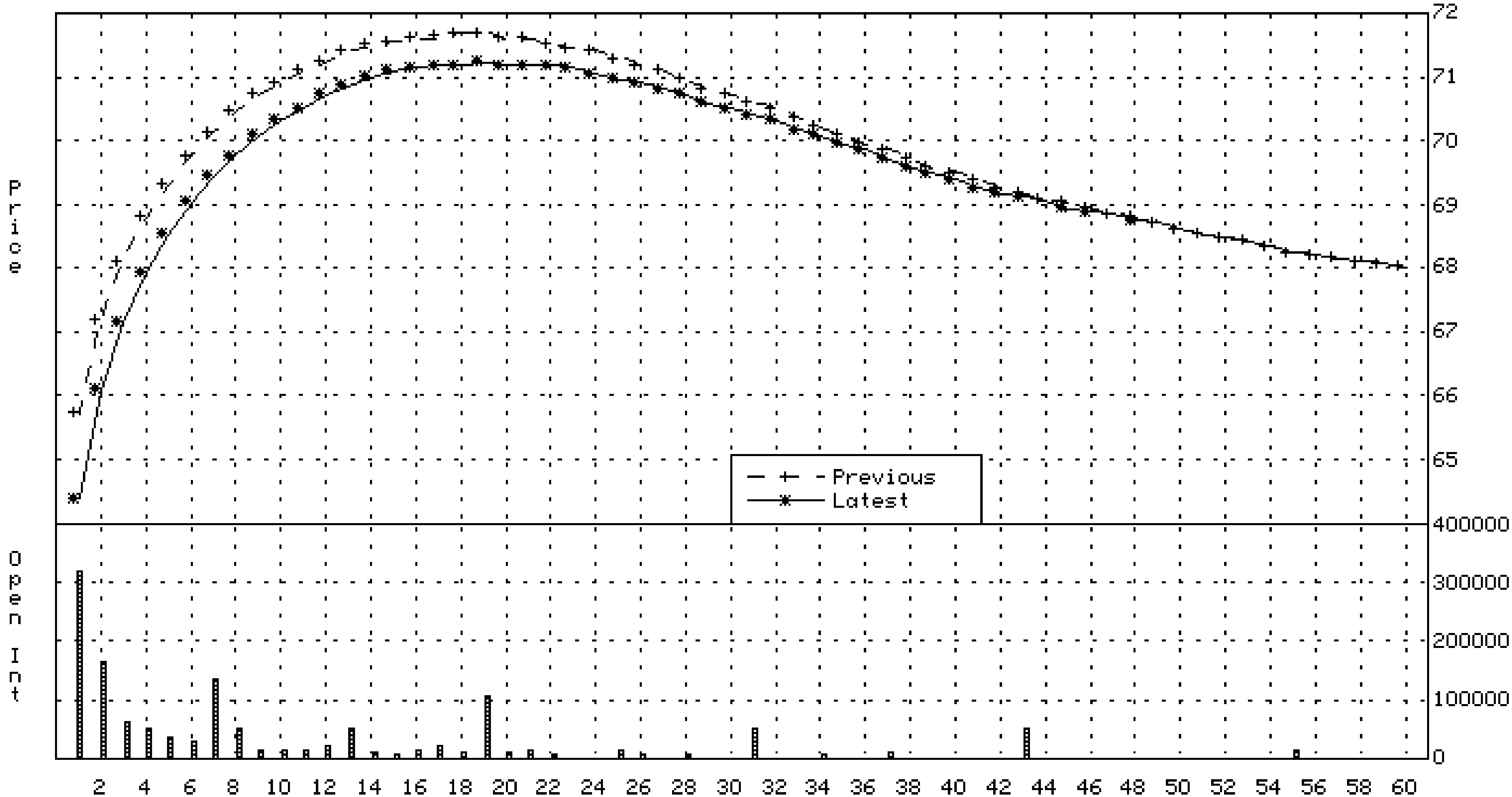
Vol/OpInt/Change 0



Average-Style Option I: $\max\{F_{\mathbf{Ave}} - K,\, 0\}$

- Interpretation: F_{Ave} is the *average value of F_{13} over calendar-year 2008*
- Computation of *Volatility:* Effective Vol is "blended volatility" of GBM until 12/31/07, then *average vol* over 2008. With $T_1 = [\text{date}\,(2007, 12, 31) - \text{date}\,(2006, 4, 30)]\,/365 = 0.6712$ and $T_{13} = 1.6712$,
$$\Sigma^2\, T_{13} = T_1\, \sigma_{13}^2 + (T_{13} - T_1)\, \sigma_A^2 \tag{1}$$
Using the Turnbull and Wakeman (1991) approximation for the computation of arithmetic-average volatility[3] with $t \equiv T_{13} - T_1 = 1:$
$$\sigma_A^2 = \frac{1}{t} \ln\left(\frac{2\left[\exp\{\sigma_{13}^2\, t\} - (1 + \sigma_{13}^2\, t)\right]}{\sigma_{13}^4\, t^2}\right) \tag{2}$$
- Expectation is: $E^*\left(F_{\text{Ave}}\right) = F = \$71.62$
- Applying $\sigma_{13} = 22\%$ to eqs. (1) and (2), Effective Vol is:

$$\begin{aligned} \sigma_A &= 12.73\% \\ 1.6712\, \Sigma^2 &= 0.6712 \cdot .22^2 + .1273^2 \\ \\ \Longrightarrow \qquad \Sigma &= 17.07\% \end{aligned}$$

[3] The original Turnbull and Wakeman (1991) approximation is stated in terms of the cost of carry $r - q$, which is equal to zero in the case of futures contracts. Thus, solving for the relevant first and second moments M_1 and M_2 required repeated use of L'Hospital's Rule.

Average-Style Option II: $\max\{S_{\mathbf{Ave}} - K, 0\}$

- Define S_t, $t = 2, \ldots, 13$, as the *spot* price at month t in 2008 ($S_2 = S_{\text{Feb. 08}}$, $S_3 = S_{\text{March 08}}$, $\ldots$, $S_{13} = S_{\text{Jan. 09}}$)
  Further,

$$\begin{aligned} T_2 &= 0.6712 + 1/12 = 0.7546 \\ T_{13} &= 1.6712 \end{aligned}$$

- Whereas the precise definition is

$$S_{\text{Ave}} \equiv \frac{1}{12} \sum_{t=2}^{13} S_t,$$

  let us *Approximate* that by

$$S_{\text{Ave}} \cong \frac{1}{2}(S_2 + S_{13})$$

  with current expected value

$$E^*\left[\frac{1}{2}(S_2 + S_{13})\right] = \frac{1}{2}(F_2 + F_{13}) = \$71.16$$

  and annualized Variance

$$\begin{aligned} T_{13}\,\text{Var}(\ln S_{\text{Ave}}) &\cong \frac{1}{4}\left(T_2\sigma_2^2 + T_{13}\sigma_{13}^2 + 2\rho_{2,13}T_2\sigma_2\sigma_{13}\right) \\ \text{Var}(\ln S_{\text{Ave}}) &\cong \frac{1}{4}\left(\frac{T_2}{T_{13}}\sigma_2^2 + \sigma_{13}^2 + 2\rho_{2,13}\frac{T_2}{T_{13}}\sigma_2\sigma_{13}\right) \end{aligned}$$

- With $\sigma_2 = 25.36\%$, $\sigma_{13} = 22\%$ and $\rho_{2,13} = 0.975$,

$$\sqrt{\text{Var}(\ln S_{\text{Ave}})} \cong 17.79\%$$

Average-Style Option III:

Swaption (Option on *Swap*) $\max\left\{\frac{1}{12}\sum_{t=2}^{13} F_{t,T_1} - K,\, 0\right\}$

- Define F_{t,T_1} as the set of forward prices for 2008 to be observed *as of* T_1 = Jan. 2008: $F_{2,T_1} = F_{\text{Feb. 08},T_1}$, $F_{3,T_1} = F_{\text{March 08},T_1}, \ldots,$ $F_{13,T_1} = F_{\text{Jan. 09},T_1}$

- Whereas the exact definition of the date T_1 swap price V_{T_1} is[4]

$$V_{T_1} \equiv \frac{\sum_t e^{-rt} F_{t,T_1}}{\sum_t e^{-rt}} = \sum_t w_t\, F_{t,T_1},$$

  let us use *two* approximations to obtain

$$V_{T_1} \cong \frac{1}{12}\sum_t F_{t,T_1} \cong \frac{1}{2}\left(F_{2,T_1} + F_{13,T_1}\right)$$

  with current expected value

$$E^*\left[\frac{1}{2}\left(F_{2,T_1} + F_{13,T_1}\right)\right] = \frac{1}{2}\left(F_1 + F_{13}\right) = \$71.16$$

  and annualized Variance

$$\begin{aligned} T_1 \operatorname{Var}(\ln V_{T_1}) &\cong \frac{1}{4}\left(T_1\sigma_2^2 + T_1\sigma_{13}^2 + 2\rho_{2,13}T_1\sigma_2\sigma_{13}\right) \\ \operatorname{Var}(\ln V_{T_1}) &\cong \frac{1}{4}\left(\sigma_2^2 + \sigma_{13}^2 + 2\rho_{2,13}\sigma_2\sigma_{13}\right) \end{aligned}$$

- With $\sigma_2 = 25.36\%$, $\sigma_{13} = 22\%$ and $\rho_{2,13} = 0.975$,

$$\sqrt{\operatorname{Var}(\ln V_{T_1})} \cong 23.53\%,$$

  but with a time-to-maturity equal to $T_1 = 0.6712 < T_{13} = 1.6712$

- Note well the distinction in Call Values between Average-Style Option II (C_{II}) and Average-Style Option III (C_{III}) :

$$\begin{aligned} C_{\text{II}}\left(K = F = 71.16,\, T = 1.6712,\, r = 5\%,\, \sigma = 17.79\%\right) &= \$5.992 \\ C_{\text{III}}\left(K = F = 71.16,\, T = 0.6712,\, r = 5\%,\, \sigma = 23.53\%\right) &= \$5.284 \end{aligned}$$

[4] The swap price V_{T_1} is a present-value weighted average (giving greater weight to the earlier time periods) of the futures prices over the relevant time interval.

SUMMARY

- The Average-style Options constitute a powerful structural vehicle:
  1. They *span* the time period of concern
  2. Such options are available at lower cost
- Three types of such options exist:[5]
  1. Average on the Forward Contract: $\max\left\{F_{\text{Ave}} - K,\, 0\right\}$
  2. Average on the Spot: $\max\left\{S_{\text{Ave}} - K,\, 0\right\}$
  3. Swaption (Option on a Swap): $\max\left\{\frac{1}{12}\sum_{t=2}^{13} F_{t,\,T_1} - K,\, 0\right\}$
- Valuation for C_{II} and C_{III} were obtained as *approximation;* valuations can be improved, in particular, by explicitly considering the Term Structures of Volatility (TSOV) and of Correlations (TSOC)
- In terms of cost, with $V(\cdot)$ representing the *valuation* operator, we obtain the double inequality

$$V\left(\max\left\{S_{13} - K,\, 0\right\}\right) \geq V\left(\frac{1}{12}\sum_{t=2}^{13} \max\left\{S_t - K,\, 0\right\}\right) \geq V\left(\max\left\{\frac{1}{12}\sum_{t=2}^{13} S_t - K,\, 0\right\}\right)$$

Intuition:

- First Inequality: Variance is non-decreasing with maturity[6]
- Second Inequality:

$$\begin{aligned} \text{Strip of Twelve Spot Options} &\geq \text{Price of Average-Style Option} \\ \text{Portfolio of Options} &\geq \text{An Option on a } \textit{Portfolio} \end{aligned}$$

In a Portfolio of Options, each option can be separately exercised; an option on a portfolio can be exercised once, or not at all

[5]There is a *fourth,* namely, Average on the Rate, with payoff $\max\left\{S_T - S_{\text{Ave}},\, 0\right\}$, but that type of option is more applicable in *equity* than in *energy-commodity* markets.

[6]This ignores minor price-level differences between the different futures-contracts $F_2,\, F_3,\, \ldots,\, F_{13}$.

Valuation of Spread Options

- Payoff: $\max\{S_2 - S_1,\, 0\}$, where

  $S_2 - S_1 =$ spread between the two prices at option expiration

- Valuation: With current futures prices F_2 and F_1,

$$e^{-rT}\left[F_2 N(d) - F_1 N\left(d - \sigma\sqrt{T}\right)\right],$$

  where

$$d \equiv \frac{\log(F_2/F_1)}{\sigma\sqrt{T}} + \tfrac{1}{2}\sigma\sqrt{T}$$
$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2}$$

  Note:

  - The similarity to the Black futures option model: The previously-constant strike price K has been replaced with the random value F_1, with the adjusted volatility σ set equal to $\sqrt{\sigma_1^2 + \sigma_2^2 - 2\rho\sigma_1\sigma_2}$
  - The dependence of option values on the *correlation coefficient* ρ. An increase in ρ reduces option value: Positively correlated assets will tend to increase in value simultaneously, reducing the value of this "relative-value" option

- Estimation: The relevant correlation is

$$\mathrm{Corr}\left(\ln\frac{S_{1,t+1}}{S_{1t}},\ \ln\frac{S_{2,t+1}}{S_{2t}}\right)$$

Valuation of Co-Generation Option

Today's Date:		11-Jun-98
Initial Date for Exercise		15-Jul-98
Option Maturity (Yrs.):		2.421917808
Quantity		210
#hours in a day		16
Heat Rate		11
Operation and Maintenance Co	$	1.00
Input :	**Gas**	
Total Value :	**$9,024,610**	
DCF Value :	**$507,857**	

Valuation of Co-Generation Option

Today's Date:	11-Jun-98
Initial Date for Exercise	15-Jul-98
Option Maturity (Yrs.):	2.421917808
Quantity	210
#hours in a day	16
Heat Rate	1.734468622
Operation and Maintenance Co	$ 1.00
Input :	**Oil**
Total Value :	**$19,899,156**
DCF Value :	**$9,891,708**

Valuation of Co-Generation Option

Today's Date:	11-Jun-98
Initial Date for Exercise	15-Jul-98
Option Maturity (Yrs.):	2.42
Quantity	279
Strike Price	$ 1.397
#hours in a day	16
Heat Rate	10.5
150 Operation and Maintenance Cost	$ 1.00
Input :	**Coal**
Total Value :	**$39,167,986**
DCF Value :	**$39,016,678**

“Swing” Options

<u>Definition:</u>

- “Swing” (“Take-or-Pay,” “Variable-Volume” or “Load-Factor Flexiblity”) contracts provide for the purchase or sale of power during the contract period subject to two constraints:

$$\text{Min} \;\leq\; \Sigma_{t=T_0}^{T_1} c_t \;\leq\; \text{Max} \tag{3}$$
$$\text{min} \;\leq\; c_t \;\leq\; \text{max} \qquad \forall t \in [T_0,\, T_1] \tag{4}$$

  where c_t is the energy consumption at time (day or hour) t

- Penalties may be imposed for constraint violations
- Exercise of option is typically “non-ruthless”

<u>Examples:</u>

- Coal (take-or-pay)
- Natural Gas (take-or-pay)
- Electricity (take-or-pay)
- Interest rate variants (flexi)
- Garbage collection (put-or-pay)
- Storage facility

Valuation of "Swing" Options: Numerical Example #3 (Cont'd)

Consider a *put* option — the right but not the obligation to *sell* at a pre-determined price — of the "Swing" variety:

- The constraints are:

$$\begin{array}{lcl} 0 \leq & \sum_{t=T_0}^{T_1} c_t & \leq 4 \\ 1 \leq & c_t & \leq 2 \qquad \forall t \in [0,\ 1\text{ mo.},\ 2\text{ mo.},\ 3\text{ mo.}] \end{array}$$

- Note two upper bounds to "Swing" value:

  1. Consider a contract that permits the seller to increase power sales by quantity Q each month for the next three months, at a fixed price K. This is simply a *sum* of put options:

$$Q \sum_{t=1/12}^{3/12} \text{Put}_t = Q \sum_{t=1/12}^{3/12} e^{-r_t t} \left[KN\left(\sigma_t \sqrt{t} - d_t\right) - PN\left(-d_t\right) \right]$$

  2. $N = 2$ American-style options

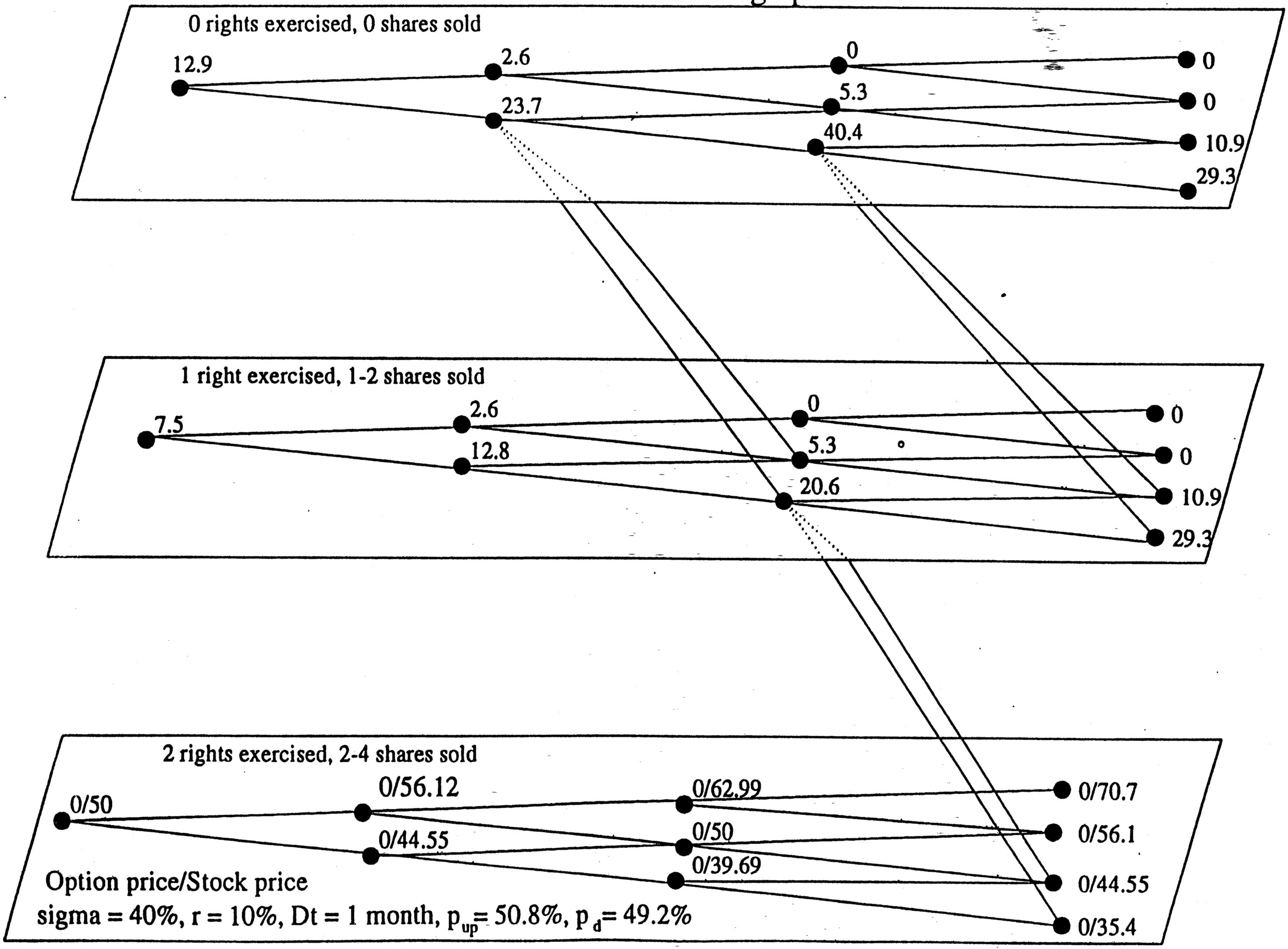
- Parameters are:[2]

Variable	Value
Asset Price, P	\$50
Stike Price, K	\$50
Volatility, σ	40%
Annualized interest rate, r	10%
Time interval, Δt	1 mo.
Binomial "up" Prob., p_u	0.508
Binomial "down" Prob., p_d	0.492

[2] The binomial probabilities are calculated as:

$$\begin{aligned} p_u &= \frac{e^{r\Delta t} - e^{-\sigma\sqrt{\Delta t}}}{e^{\sigma\sqrt{\Delta t}} - e^{-\sigma\sqrt{\Delta t}}} = 0.508 \\ p_d &= 1 - p_u = 0.492 \end{aligned}$$

Binomial forest for swing option



Chicago Mercantile Exchange

CME Environmental Products

Weather Contracts
United States

Monthly Contracts

	Ticker symbols		Clearing codes	
	HDD	CDD	HDD	CDD
Atlanta	H1	K1	H1	K1
Chicago	H2	K2	H2	K2
Cincinnati	H3	K3	H3	K3
New York	H4	K4	H4	K4
Dallas	H5	K5	H5	K5
Philadelphia	H6	K6	H6	K6
Portland	H7	K7	H7	K7
Tucson	H8	K8	H8	K8
Des Moines	H9	K9	H9	K9
Las Vegas*	H0	K0	H0	K0
Boston	HW	KW	HW	KW
Houston	HR	KR	HR	KR
Kansas City	HX	KX	HX	KX
Minneapolis	HQ	KQ	HQ	KQ
Sacramento	HS	KS	HS	KS
Salt Lake City	HU	KU	HU	KU
Detroit	HK	KK	HK	KK
Baltimore	HV	KV	HV	KV

** Number zero*

Seasonal Contracts

	Ticker symbols		Clearing codes	
	HDD	CDD	HDD	CDD
Atlanta	HS1	KS1	AH	AK
Chicago	HS2	KS2	HH	KH
Cincinnati	HS3	KS3	HT	KT
New York	HS4	KS4	HY	KY
Dallas	HS5	KS5	TH	TK
Philadelphia	HS6	KS6	FH	FK
Portland	HS7	KS7	RH	RK
Tucson	HS8	KS8	VH	VK
Des Moines	HS9	KS9	JH	JK
Las Vegas*	HS0	KS0	WH	WK
Boston*	A0	B0	A0	B0
Houston	A2	B2	A2	B2
Kansas City	A4	B4	A4	B4
Minneapolis	A5	B5	A5	B5
Sacramento	A9	B9	A9	B9
Salt Lake City	A7	B7	A7	B7
Detroit	A8	B8	A8	B8
Baltimore	A3	B3	A3	B3

**Number zero*

U.S. Contract Specifications

FUTURES

Contract Size: $20 times the Degree Day Index

Minimum Price Increment: 1 Degree Day Index point

Degree Day Index: HDD (winter), CDD (summer)

Degree Day Metric: Temperature measured in Fahrenheit

Tick Value: $20.00

Seasonal Contracts Traded:

Heating Season — Nov through Mar

Cooling Season — May through Sep

Monthly Contracts Traded:

Heating Degree Days (HDD)

Oct, Nov, Dec, Jan, Feb, Mar, Apr

Cooling Degree Days (CDD)

Apr, May, Jun, Jul, Aug, Sep, Oct

Trading Hours: Sun. – Thurs. 5:00 P.M. to 3:15 P.M. (CT) (LTD closing is 9:00 A.M.)

Trading Venue: CME® Globex®*

Currency: Contracts settled in U.S. dollars.

Trading Venue: Electronically traded only on CME Globex.

Termination of Trading: The first exchange business day that is at least two calendar days after the last calendar day of the contract month/season.

Settlement: Based on the relevant Degree Day Index on the first exchange business day at least two calendar days after the futures contract month/season.

**Electronic trading only. Times are Central Time zone.*

OPTIONS ON FUTURES

Contract Size: 1 CME weather futures contract

Minimum Price Increment:

1 Degree Day Index point (cabinet = .5 Degree Day Index)

Tick Value: 1 = $20.00

Seasonal Products Traded:

Heating Season — Nov through Mar

Cooling Season — May through Sep

Monthly Products Traded:

Heating Degree Days

Oct, Nov, Dec, Jan, Feb, Mar, Apr

Cooling Degree Days

Apr, May, Jun, Jul, Aug, Sep

Trading Hours: Mon. – Fri. 8:30 A.M. to 3:15 P.M. (CT) (LTD closing is 9:00 A.M.)

Trading Venue: CME Trading Floor (NASDAQ-100® Pit)

Termination of Trading: Same date and time as underlying futures

Strike Price Intervals:

	Min. Strike Price	Max. Strike Price	Interval
Monthly CDD	1	1500	1
Monthly HDD	1	3200	1
Seasonal CDD	1	7500	1
Seasonal HDD	1	15500	1

Exercise: European Style (Exercised on last trading day)

For more information: info@cme.com or (800) 331-3322 Market Data link: www.cme.com/weatheri CME London: +44 (0)20 7623 2550

Weather Derivatives

"Weather Derivatives" consist of Heating-Degree Day (HDD) and Cooling-Degree Day (CDD) swaps.

- For example, a one-month HDD *swap* might contain the following payoff:

$$\$50,000 \times \left(\sum_{t=1}^{22} \max\left\{65^{\circ} - T_t,\ 0\right\} - 600 \right) \gtrless 0,$$

  where

  T_t = is the *average* of the high-low temperature on day t of the 22-business-days month in question

  65° Fahrenheit $\cong 18^{\circ}$ Celsius

- An HDD *call option contract* could be structured as:

$$\$2,500 \max\left\{ \sum_{t=11/1/99}^{3/31/2000} \max\left\{65^{\circ} - T_t,\ 0\right\} - 5116,\ 0 \right\}$$

  If that call option had a "400 HDD limit ($1,000,000)," that translates into the "vertical call spread option"

$$\$2,500 \left(\max\left\{ \sum_{t=11/1/99}^{3/31/2000} \max\left\{65^{\circ} - T_t,\ 0\right\} - 5116,\ 0 \right\} - \max\left\{ \sum_{t=11/1/99}^{3/31/2000} \max\left\{65^{\circ} - T_t,\ 0\right\} - 5516,\ 0 \right\} \right)$$

  where the second call option has a strike price $K = 5116 + 400 = 5516$

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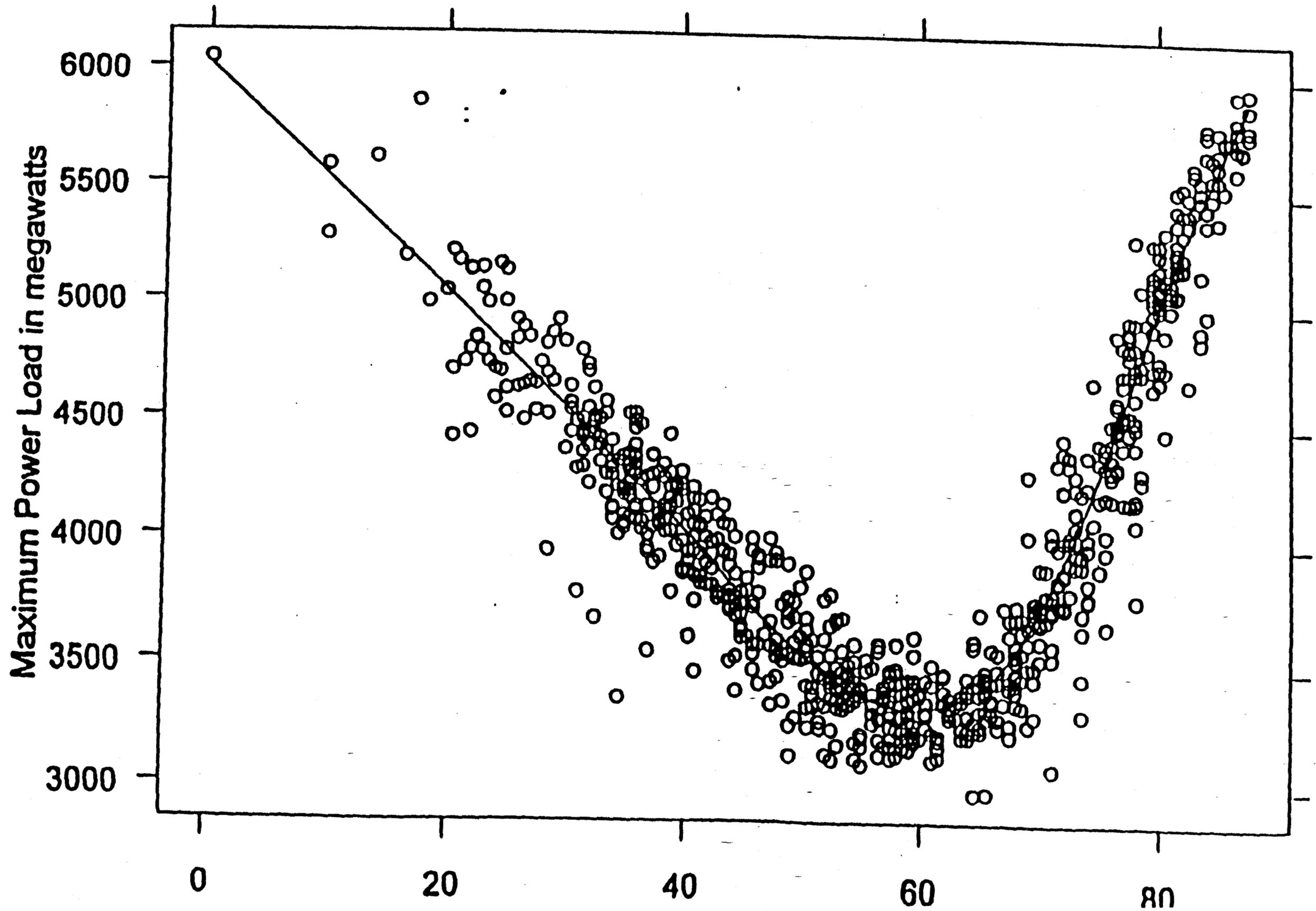
Weather Derivatives 101

- ***A Weather Derivative is a financial instrument who's value is determined by the outcome of the weather or climate.***
- ***Example: Heating Degree Day Call (Actually Traded)***
  - *Daily Index: Heating Degree Days = $\max(0, 65-T_{avg})$ (F)*
    - *Convention: Tavg = $[\text{round}(T_{max}) + \text{round}(T_{min})]/2$, no HDD rounding*
  - *Term Index: Total number of HDDs over the term*
  - *Term: Nov 1, 1999 - Mar 31, 2000*
  - *Location: Chicago O'Hare, WBAN: 94846*
  - *Index Strike: 5116 HDDs*
  - *Tick Size: \$2500/HDD (400 HDD limit (\$1,000,000))*
  - *CALL Payoff: For every degree day above 5116, the owner call receives \$2500.*
  - *Price: \$ 250,000*

Maximum Power Load vs Average Daily Temperature in Baltimore
Jannuary 1993 - December 1995



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Baltimore

Increased interest in commodity-linked products: the investors point of view

- spectacular returns in the last few years
- diversification
  - historically commodity returns are weakly correlated with equity or fixed income products and can be used as a separate asset class
  - protection against inflation caused by economic growth
  - commodities are correlated with non-economic drivers: weather, environmental issues, supply constraints, etc.

Examples: Commodity-linked bonds

- At redemption, holder is paid par if the GSCI has fallen. If the the GSCI price has risen, holder receives par (1 + a percentage gain in the GSCI)

- At redemption, holder receives

  85% of par + par * (2 * percentage rise in gold price)

  For example, if gold grows from $400 to $440 then the holder of a $1000 par bond gets $1000(.85) + $1000 * 2(.1) = $1050

Examples: Commodity-linked bonds

- At redemption, holder receives par. In addition, holder receives semi-annual coupon. Those payments are .82 (percentage gain in the NYMEX WTI). Say the NYMEX WTI goes from \$50/bbl to \$55/bbl, coupon payment on a \$1000 par bond would be .82 (.1) (1000) or \$82. Next coupon payment would be determined off a new base price of \$55.

Basket Products

- 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
- Challenges:
  - Finding distribution of basket prices
  - How to construct the volatility structure of the basket from the volatility structures of the individual components?

Commodity-contingent interest rate/equity products

- Commodity-contingent interest rate swap
  – floating leg - LIBOR
  – “fixed” leg - fixed rate multiplied by the number of days (expressed as a fraction of the payment period) during which crude or other commodity prices are above a certain level
- Commodity-contingent interest rate swaption (typically, Bermudan style)
- Bermudan-style commodity-contingent guaranteed minimum coupon knock-out option
  – Pays coupon dependent on the commodity price levels at the payment time
  – Disappears after the total coupon reaches a specified level
  – If at the end of the deal the total value of paid coupons is less than the specified value the last coupon pays the difference

SUMMARY

- For Commercial users, Energy Derivatives are not "exotic for exotic sake":
  - They have a natural *raison d'être*
  - They address specific risk exposures in an efficient manner

- Non-Commercial Investors use Structured Products to obtain Energy-Price Exposure