RESERVE BANK OF INDIA

Centre for Advanced Financial Research and Learning (CAFRAL)

Seminar on Hedging Oil Requirements of Indian Oil Marketing Companies (OMCs)

Using Structured Derivative Contracts to Hedge Oil-Price Exposure

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Mumbai, Oct. 10, 2014

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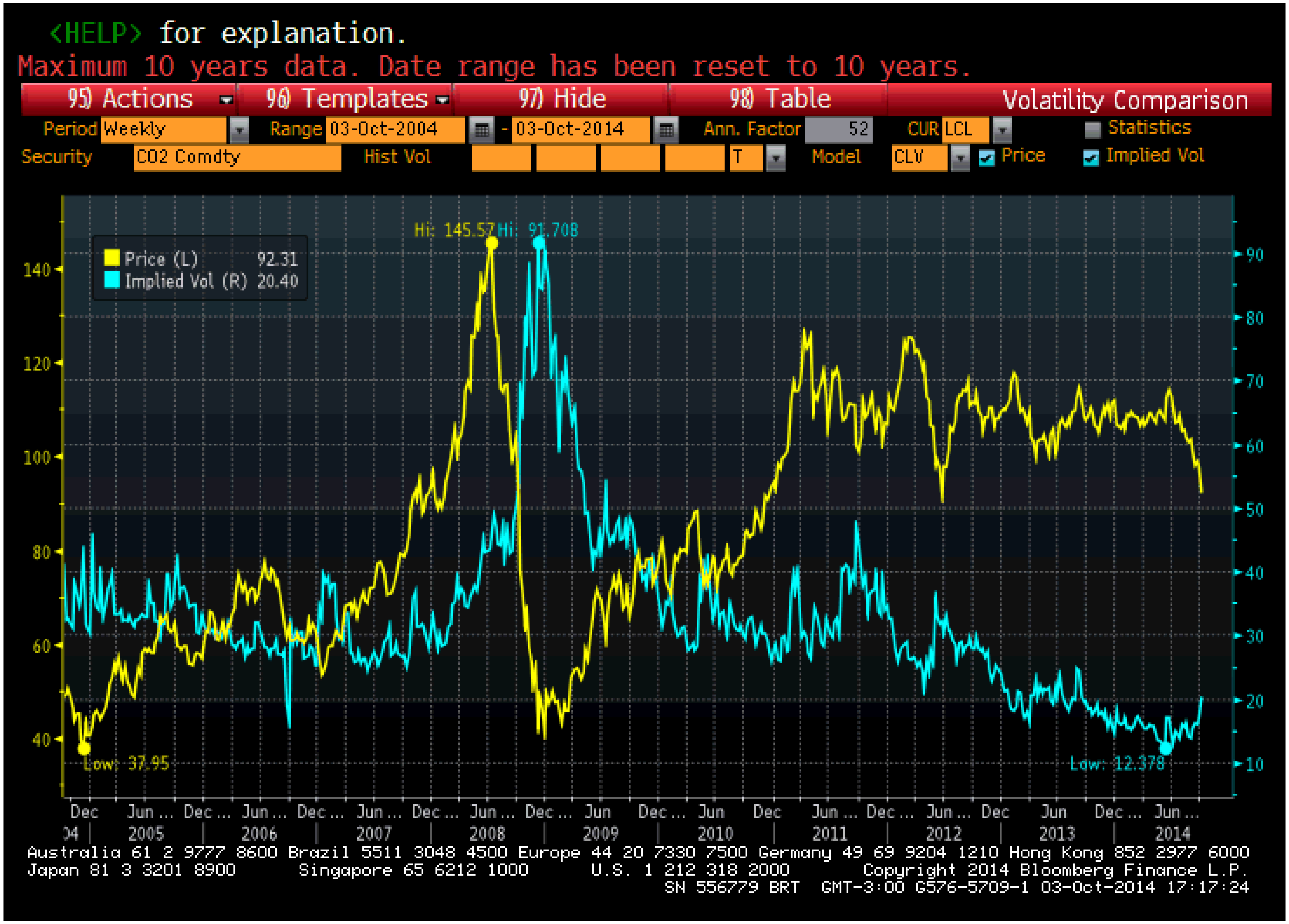
EHUD I. RONN — BIO

- Professor of Finance, University of Texas at Austin, 1988 – . Co-Director, Center for Energy Management and Innovation
- Director of Energy Risk Analytics at Guzman Energy, 2012 –
- 1997 – 2009: Director of the Center for Energy Finance Education and Research at the McCombs School of Business
- Ph.D. Finance, Stanford University
- Publications: Articles on investments, interest rate-sensitive instruments and energy derivatives in the academic and practitioner literature; edited **Real Options and Energy Management: Using Options Methodology to Enhance Capital Budgeting Decisions,** published in 2002 by Risk Books, London
- Additional Academic Affiliations: Member or visiting faculty at the business schools of the University of California, Berkeley, University of Chicago, European Business School, Nanyang Technological University, Dartmouth College and Fordham University
- Industry Experience:
  - Vice President, Trading Research Group, Merrill Lynch & Co., valuation and hedging of interest rate securities, 1991 – 1993
  - Practice Area Manager, Commodity Market Modeling, Morgan Stanley & Co., Jan. 2010 – Feb. 2011
- In Nov. 2004, one of fifty individuals selected by *Energy Risk* Magazine to the "Energy Risk Hall of Fame"

OVERVIEW

- Making Informed Hedging Decisions: What Are Oil Markets Telling Us?
  - Oil Prices and Option-Based Implied Volatilities — The Past 10 Yrs.
  - The Level and Slope of Oil-Price Futures: Brent (North Sea) vs. Cushing (WTI)
  - Demand- and Supply-Side Oil Price Shocks: Corr(Oil Prices, Oil Vols), Corr(Oil Prices, Equity Prices)
  - Is the greater Risk in Upside or Downside oil-price movements? Volatility "Smile" in the Oil Markets
- Enterprise-Wide Risk Management
  - Specifying an Objective Function for Optimal Enterprise Energy-Price Risk Management
  - Explicitly Incorporating Options in the Hedge Portfolio
- Structuring Derivative Products in Energy Markets
  - Hedging Using Linear Instruments
  - Hedging with Option Collars
  - Average-Style Options in Commodities: Case Study of a Major European Airline
  - Annual-Average Options as an Efficient Risk-Management Tool



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Maximum 10 years data. Date range has been reset to 10 years.
95) Actions
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97) Hide
98) Table
Volatility Comparison
Period Weekly
Range 03-Oct-2004 - 03-Oct-2014
Ann. Factor 52
CUR LCL
Statistics
Security CO2 Comdty
Hist Vol
T
Model CLV
Price
Implied Vol
Price (L) 92.31
Implied Vol (R) 20.40
Hi: 145.57
Hi: 91.708
Low: 37.95
Low: 12.378
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Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
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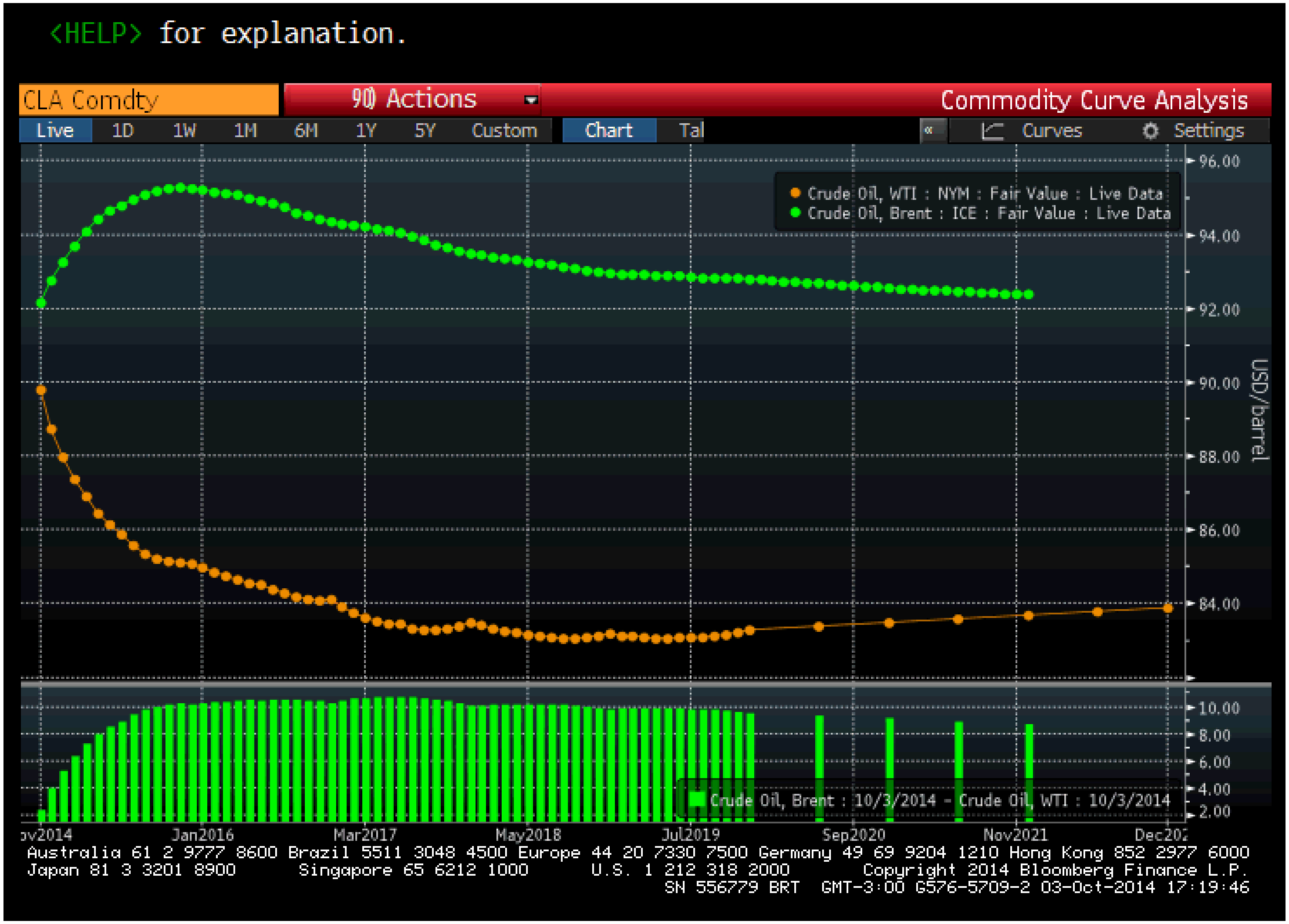
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Curves
Settings
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Crude Oil, Brent : ICE : Fair Value : Live Data
96.00
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88.00
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84.00
USD/barrel
10.00
8.00
6.00
4.00
2.00
Crude Oil, Brent : 10/3/2014 - Crude Oil, WTI : 10/3/2014
Jan2016
Mar2017
May2018
Jul2019
Sep2020
Nov2021
Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
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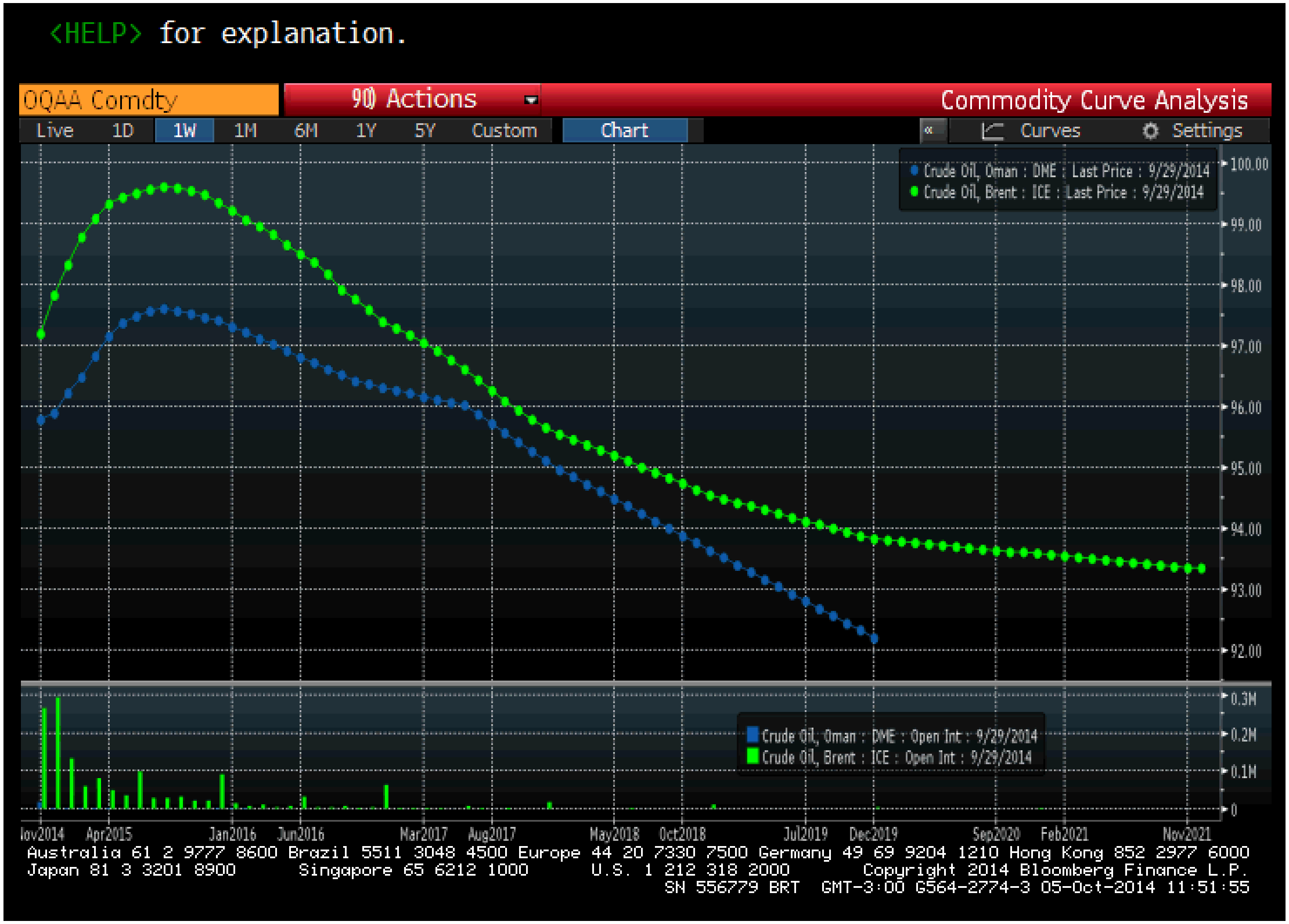
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OQAA Comdty
90) Actions
Commodity Curve Analysis
Live 1D 1W 1M 6M 1Y 5Y Custom
Chart
Curves
Settings
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Crude Oil, Brent : ICE : Last Price : 9/29/2014
100.00
99.00
98.00
97.00
96.00
95.00
94.00
93.00
92.00
Crude Oil, Oman : DME : Open Int : 9/29/2014
Crude Oil, Brent : ICE : Open Int : 9/29/2014
0.3M
0.2M
0.1M
0
Apr2015 Jan2016 Jun2016 Mar2017 Aug2017 May2018 Oct2018 Jul2019 Dec2019 Sep2020 Feb2021 Nov2021
Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2014 Bloomberg Finance L.P.
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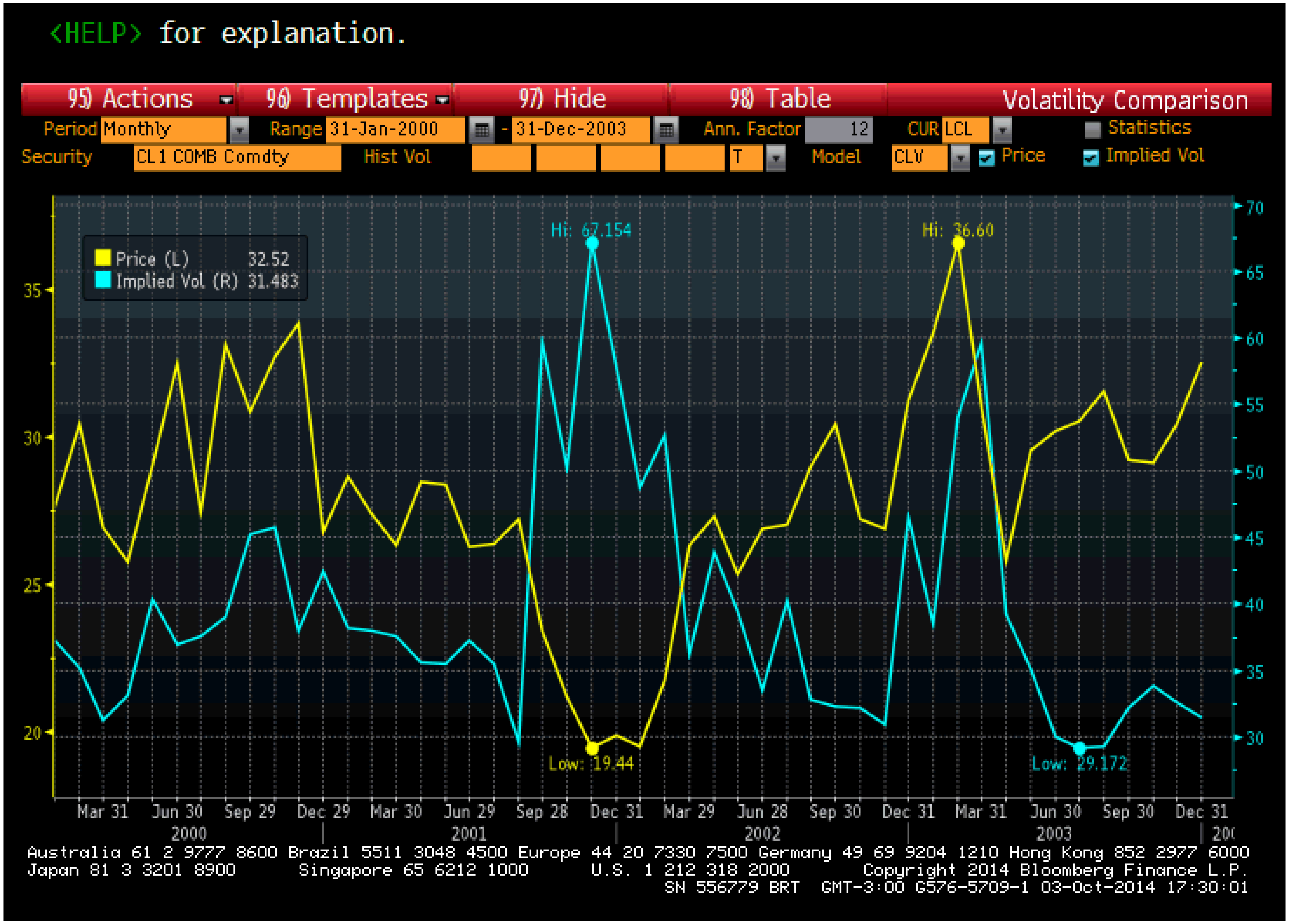
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95) Actions
96) Templates
97) Hide
98) Table
Volatility Comparison
Period Monthly
Range 31-Jan-2000 - 31-Dec-2003
Ann. Factor 12
CUR LCL
Statistics
Security CL1 COMB Comdty
Hist Vol
T
Model CLV
Price
Implied Vol
Price (L) 32.52
Implied Vol (R) 31.483
Hi: 67.154
Hi: 36.60
Low: 19.44
Low: 29.172
Mar 31 Jun 30 Sep 29 Dec 29 Mar 30 Jun 29 Sep 28 Dec 31 Mar 29 Jun 28 Sep 30 Dec 31 Mar 31 Jun 30 Sep 30 Dec 31
2000 2001 2002 2003
Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2014 Bloomberg Finance L.P.
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Comparative Analytics Menu
Generic 1st 'CL' Future Comdty
SGP
Message
<HELP> for explanation.
1<Go> to View Spread, 11<Go> to Save as Index, 12<Go> to View Regression
Buy CL1 COMB Comdt - Sell SPX Index 96) Actions 97) Edit Spread Analysis
Data Field Last Price Data Field Last Price 10/01/2007 - 08/18/2014 Regression Corr. 60
Mult. 1.0 Constant 0.0 Mult. 1.0 Constant 0.0 Normalize by Factor 100.0 Calc. Percent Local CCY
1D 3D 1M 6M YTD 1Y 5Y Max Daily
Security/Study
Event
Track Annotate News Zoom
Correlation(SPX Index,PR005,60,0) (CL1 COMB) 0.0637
0.80
0.60
0.40
0.20
0.0637
0.00
-0.20
-0.40
-0.60
2007
2008
2009
2010
2011
2012
2013
2014
Where's the Yuan vs its Trading Bands? See it in >>>
ECWB <GO>

Integrating Oil-Futures and Equity Markets: A CAPM-Based Expected Spot Price of Oil

- Combining the CAPM with oil futures markets,

$$\begin{aligned} \mu_i &= \beta_i \left(\mu_M - r\right) = \frac{\rho_i \sigma_i}{\sigma_M} \left(\mu_M - r\right) \\ &= \rho_i \sigma_i \frac{\mu_M - r}{\sigma_M} \equiv \rho_{it} \sigma_{it} \lambda_t, \end{aligned} \tag{1}$$

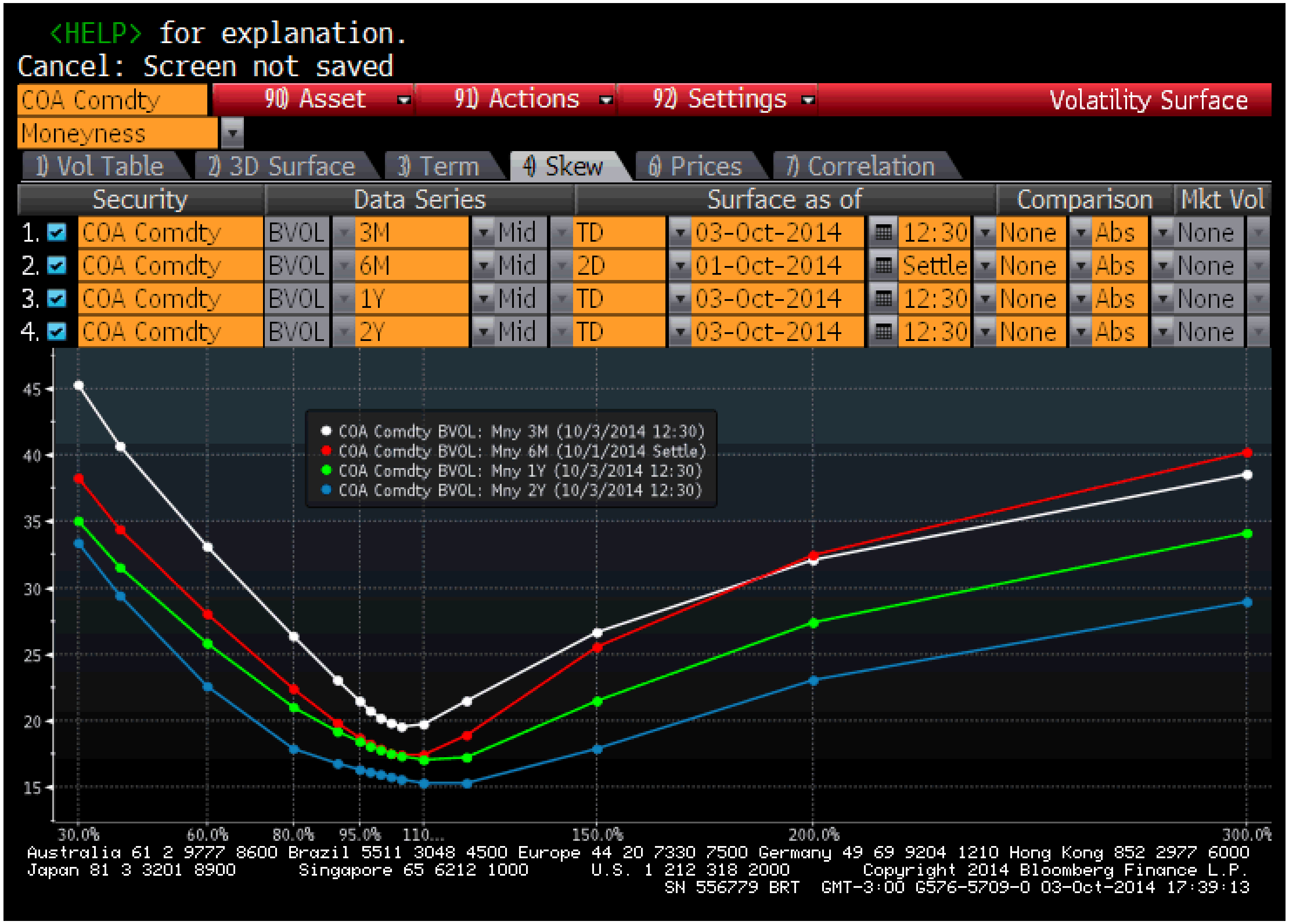
  where λ_t is the Sharpe Ratio at date t

- With respect to futures contract of maturity i,

$$\begin{aligned} E\left(F_{iT}\right) &\equiv F_{i0} \exp\left\{\mu_{iT} T\right\} \\ &= F_{i0} \exp\left\{\rho_{it} \sigma_{it} \lambda_t \, T\right\} \\ \Longrightarrow \quad \frac{1}{T} \ln\left[\frac{E\left(F_{iT}\right)}{F_{i0}}\right] &= \rho_{it} \sigma_{it} \lambda_t \end{aligned} \tag{2}$$

$$\begin{matrix} \text{Annualized Expected} \\ \text{Futures Price Change} \end{matrix} \equiv \rho_{it} \begin{pmatrix} \text{Current CL}_i \\ \text{Implied Vol} \end{pmatrix} \begin{pmatrix} \text{Current Stock Market} \\ \text{Sharpe Ratio} \end{pmatrix}$$

- Implication: When $\rho_{it} < 0$ — say, because of a geopolitical crisis — the resulting $F_{i0} > E\left(F_{iT}\right)$ reflects the intuitive notion of a risk premium attributable to concerns over oil supplies reaching consumer markets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COA Comdty
90) Asset
91) Actions
92) Settings
Volatility Surface
Moneyness
1) Vol Table
2) 3D Surface
3) Term
4) Skew
6) Prices
7) Correlation
Security
Data Series
Surface as of
Comparison
Mkt Vol
1. COA Comdty BVOL 3M Mid TD 03-Oct-2014 12:30 None Abs None
2. COA Comdty BVOL 6M Mid 2D 01-Oct-2014 Settle None Abs None
3. COA Comdty BVOL 1Y Mid TD 03-Oct-2014 12:30 None Abs None
4. COA Comdty BVOL 2Y Mid TD 03-Oct-2014 12:30 None Abs None
COA Comdty BVOL: Mny 3M (10/3/2014 12:30)
COA Comdty BVOL: Mny 6M (10/1/2014 Settle)
COA Comdty BVOL: Mny 1Y (10/3/2014 12:30)
COA Comdty BVOL: Mny 2Y (10/3/2014 12:30)
45
40
35
30
25
20
15
30.0%
60.0%
80.0%
95.0%
110...
150.0%
200.0%
300.0%
Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2014 Bloomberg Finance L.P.
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Calibrating Merton (1976) during the "Arab Spring of 2011"

Merton (1976) Jump-Diffusion Model: For each maturity T, including $T = 2$ mos., the parameters of the jump process are:

$\overline{k}$ = Average amplitude of the jump process

δ^2 = Variance of the jump process amplitude

σ^2 = Variance of the diffusion process

Date	Event	Country	Value of $\widehat{k}_2$
Dec. 18, 2010	Self-immolation	Tunisia	−25.6%
Jan. 25, 2011	Protests in Tahrir Square	Egypt	−29.6%
Feb. 11, 2011	President Mubarak resigns	Egypt	−2.76%
Feb. 14, 2011	First contagion to Persian Gulf	Bahrain	−.26%
Feb. 19, 2011	Resignation of prime minister	Kuwait	9.44%
March 2, 2011			55.7%
March 11, 2011	Economic concessions by king	Saudi Arabia	43.2%
April 5, 2011			−5.3%

Source for Timeline: Article on the "Arab Spring," `http://en.wikipedia.org/wiki/Arab_Spring`

SUMMARY

The Economic and Informational Role of Derivatives

- Brealey, Myers and Allen, **Principles of Corporate Finance:**

  > "If [financial markets are] efficient, prices impound all available information. Therefore, if we can only learn to read the entrails, security prices can tell us a lot about the future."

  Efficient capital markets — including specifically the markets for crude-oil futures and options — can be informationally-revealing

- The Challenge, as always, is to *Interpret* them. Using models developed in financial economics, such as the CAPM and Merton Jump-Diffusion, we can estimate Parameters of Interest, including

  – Expected Spot Prices and

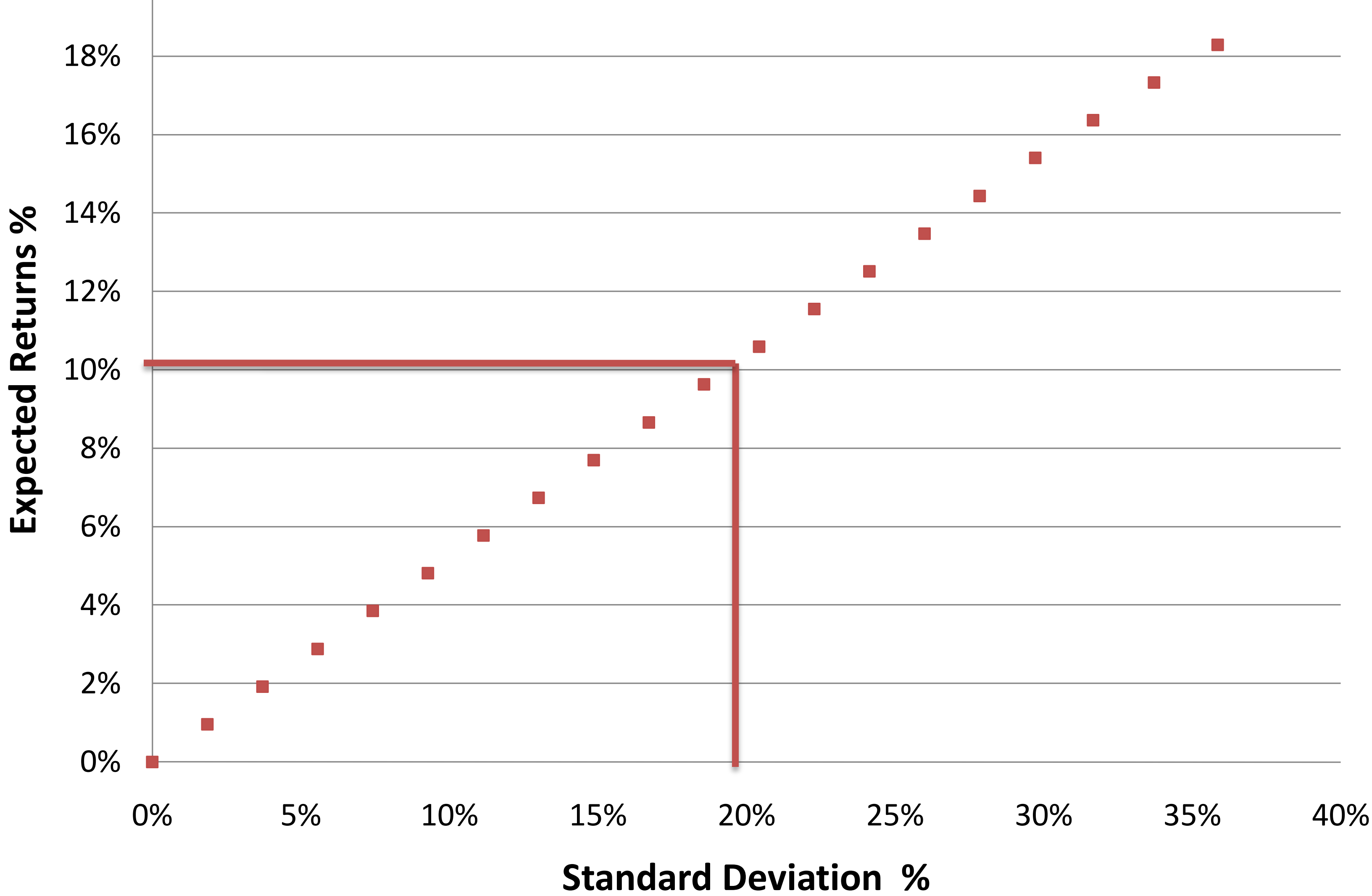
  – Markets' Directional Spike/Crash Concern

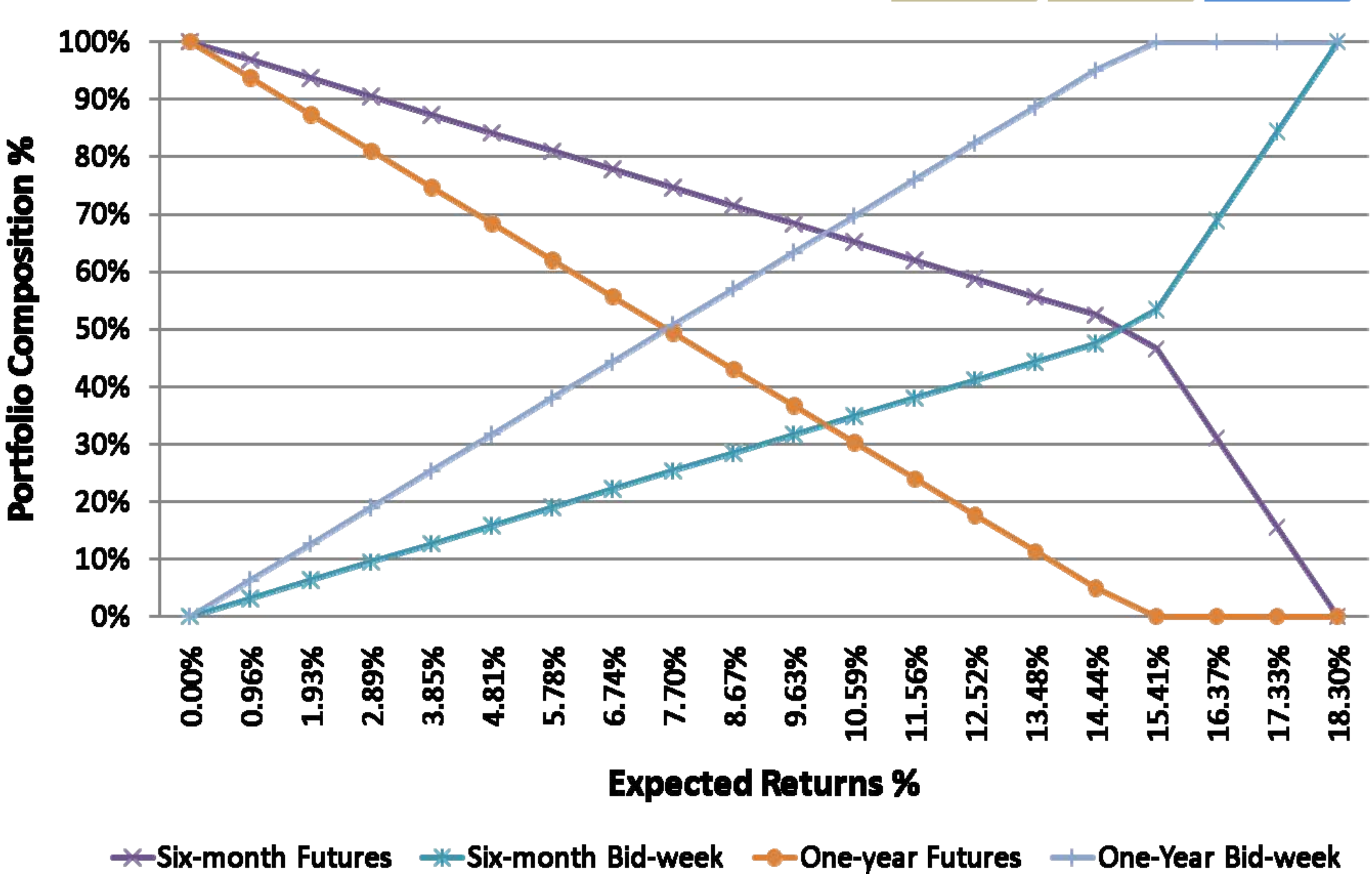
Energy-Price Risk-Management: Motivation and Practical Implications

- Five Reasons for Energy-Price Risk Management:
  1. Understanding Risks You Are “Paid” to Take
  2. Stabilize Financial Results and Cash Flow
     - Lower Cost of Capital
     - Provide Management with “Clarity of Environment”
  3. Insure against Tail Risks
     - Protect Stakeholders against Material Hedgeable Risks
     - Can Be Source of Competitive Advantage
  4. Allow Firms to Better Plan for Their Future Capital Needs/Reduce Need to Access Capital Markets
  5. Decrease Firm’s Expected Tax Payments
- These specific objectives are not easy to model explicitly. Fortunately, in applying these rationales to the corporation, they can be shown to be equivalent to:
  1. Using mean-variance efficiency for hedging with *futures contracts*
  2. Using downside risk-aversion to motivate optimal hedging strategies involving *options*

Application I: Mean-Variance Efficiency

- Mean-Variance Efficiency, from stock-investment Portfolio Theory: Trade-Off between Higher Mean ("Return") and Lower Variance ("Risk")
- Generate a risk-return profile for oil sales using:
  - Historical and implied market data
  - Modern portfolio theory
- Hedge Instruments: Futures Contracts
- Decision Tools:
  - Efficient Frontier: Choosing the Desired Trade-off between Risk and Return
  - Portfolio Composition


18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0%
5%
10%
15%
20%
25%
30%
35%
40%
Expected Returns %
Standard Deviation %



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Portfolio Composition %
0.00%
0.96%
1.93%
2.89%
3.85%
4.81%
5.78%
6.74%
7.70%
8.67%
9.63%
10.59%
11.56%
12.52%
13.48%
14.44%
15.41%
16.37%
17.33%
18.30%
Expected Returns %
Six-month Futures
Six-month Bid-week
One-year Futures
One-Year Bid-week

Application II: Mean-Value at Risk

- Objectives:
  - Extend the discussion to Incorporating *Options* in the Hedge Portfolio
  - Corporation seeks to maximize expected earnings while simultaneously minimizing downside without affecting upside capture

- Optimization of Hedge Portfolio: Company adjusts Optimal Hedge per Desired Risk Level
  - "High" Risk: Preference for higher expected cash flows induces a firm to avoid hedging
  - "Moderate" Risk: Use of options permits downside risk protection together with maintenance of upside capture
  - "Low" Risk: Downside risk minimization becomes increasingly important motive, leading to transition from options to futures

Implementing *Corporate*-Level Price Risk Management Policy Using Futures or Options

- For a Corporation short or long price exposure, define the objective function as:[2]

$$E\left(\widetilde{E}\right) + \alpha\, E_{\text{Lower Percentile}} \tag{5}$$

- Properties of optimal solution:
  - The greater is α, the more concerned is the decision-maker with the *lower* side of the earnings distribution $\Longrightarrow$ the more hedging he/she will undertake.
  - Varying α from 0 (risk-neutrality) to ∞ (in practice, α of 1 or 2 will suffice) will provide the entire range of earnings-distribution alternatives

- Main Result. There exits a *systematic pattern to optimal hedging:* As α, the degree of risk aversion, increases from zero to positive values, the company's optimal hedge proceeds from
  - *No-hedging,* to
  - *Acquiring call options* (up to 100% of expected quantity), to
  - *Replacing call options with futures contracts*

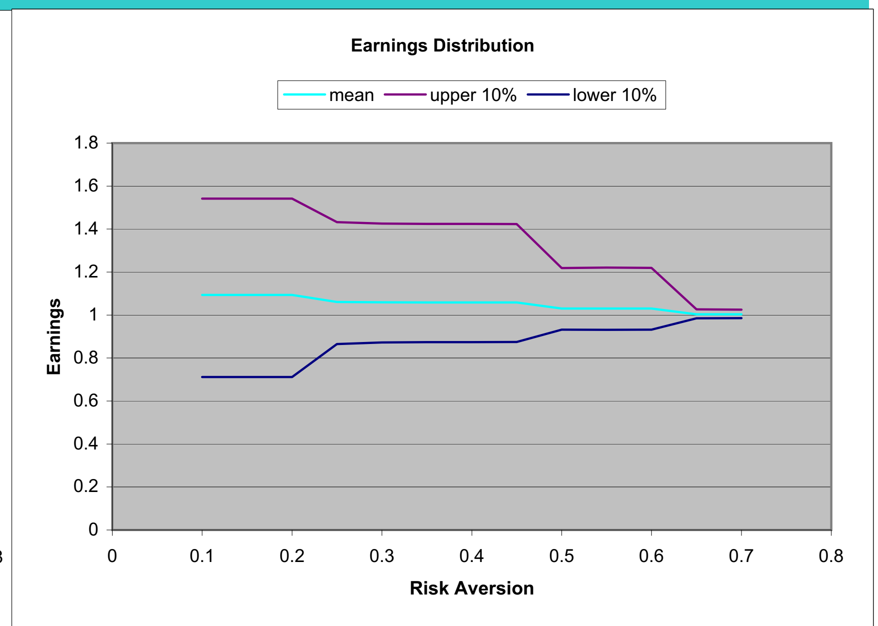
- Managerial Decision is taken upon consideration of the Expected Earnings $E\left(\widetilde{E}\right)$ and the lower percentile $E_{\text{Lower Percentile}}$

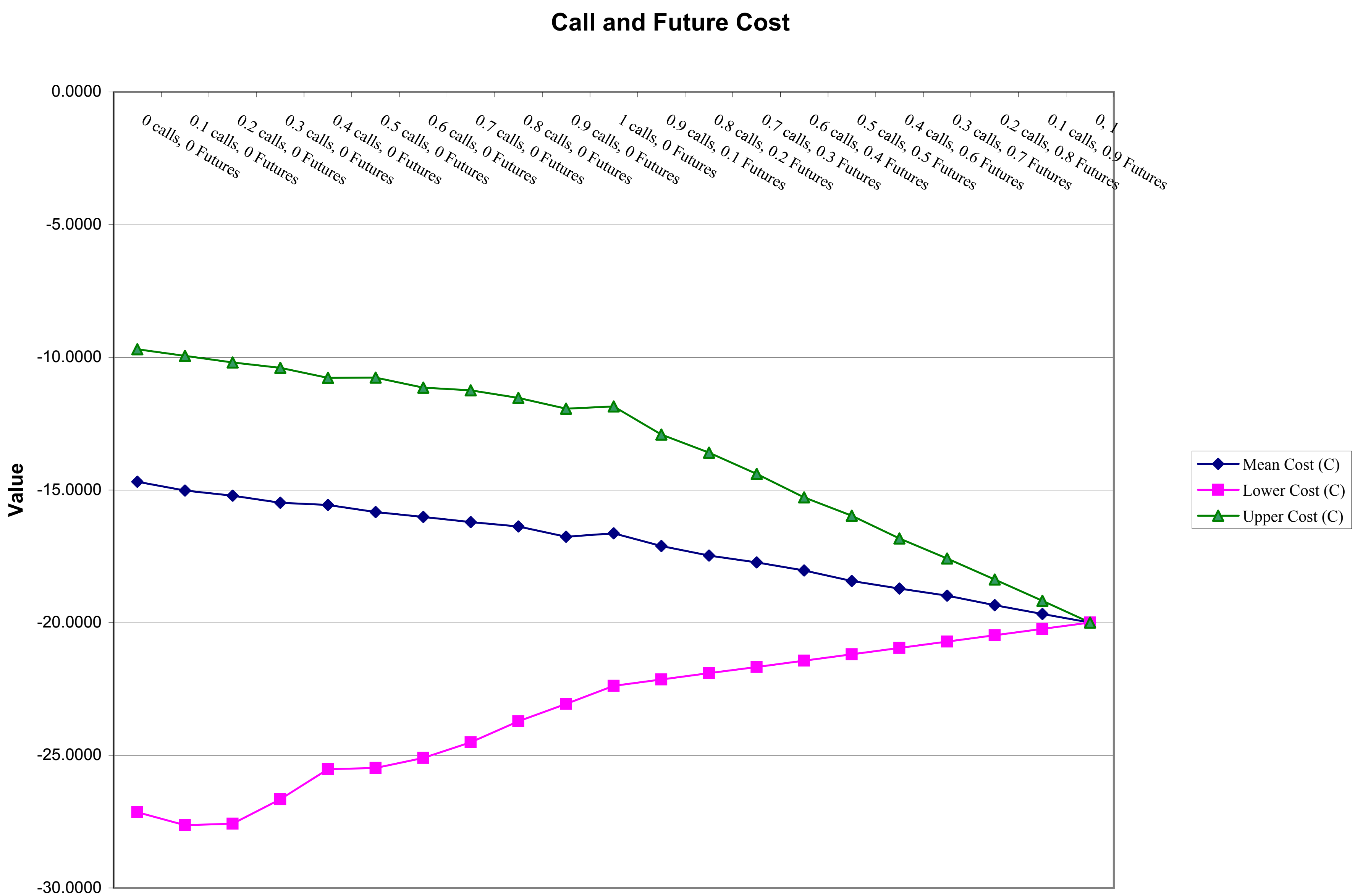
[2]An alternative intuitive objective function, which gives rise to the same optimal solution, is *Downside-Risk Minimization,* based on the semi-variance criterion $E\left(\widetilde{E}\right) - \alpha\sqrt{E\left(\max\left\{\left[E\left(\widetilde{E}\right) - \widetilde{E}\right], 0\right\}\right)^2}$.

Position in commodity	long				
Option's strike	1				
Market price of risk	0.3				
F_0	1				
Futures' drift	0.09				
Futures' volatility	0.3				
Expected quantity	1				
Quantity's volatility	0.01				
Correlation matrix	1	0			
	0	1			
Objective function	mean -	VatRisk			
Risk aversion range	0.1	0.7	0.05	0	13
Number of paths in MC	30,000				
Rik free rate	0.1				
Time to maturity	1				
Number of time periods	1				
Hedging funds	-1				
Maximization algorithm	2				
Horizontal axis	Risk Aversion				

Calculate | Replot | Create Report

100%





Call and Future Cost
Value
0.0000
-5.0000
-10.0000
-15.0000
-20.0000
-25.0000
-30.0000
0 calls, 0 Futures
0.1 calls, 0 Futures
0.2 calls, 0 Futures
0.3 calls, 0 Futures
0.4 calls, 0 Futures
0.5 calls, 0 Futures
0.6 calls, 0 Futures
0.7 calls, 0 Futures
0.8 calls, 0 Futures
0.9 calls, 0 Futures
1 calls, 0 Futures
0.9 calls, 0.1 Futures
0.8 calls, 0.2 Futures
0.7 calls, 0.3 Futures
0.6 calls, 0.4 Futures
0.5 calls, 0.5 Futures
0.4 calls, 0.6 Futures
0.3 calls, 0.7 Futures
0.2 calls, 0.8 Futures
0.1 calls, 0.9 Futures
0, 1
Mean Cost (C)
Lower Cost (C)
Upper Cost (C)

SUMMARY

- Per Smith and Stulz (1985), Froot, Scharfstein and Stein (1993) and Grinblatt and Titman (2001), the motivation for corporate risk-management includes:
  - Reducing the costs of financial distress
  - Allowing firms to better plan for their future capital needs/reduce their need to access external capital markets
  - Improving the quality of managerial decisions by removing impact of externally-determined input/output prices
  - Improving the design of management compensation contracts/allowing firms to evaluate top executives more accurately
  - Decreasing the firm's expected tax payments
- While these criteria are difficult to model, they may be shown to correspond to corporate risk-aversion, which *can* be modeled to produce a decision framework
- Specifying an explicit risk-averse corporate objective function — e.g., mean-variance or mean-value at risk — admit specific optimal solutions and give rise to structuring an optimal derivative contracts

Structuring Derivative Products in Energy Markets

For many market participants, the name of the game is:

Structuring — Valuation — Hedging

These represent critically important profitable market-making opportunities

- Structuring: Address client's needs (e.g., low-cost options) by providing appropriate products
- Valuation: "Reverse engineer" the structure using prices of observable futures/forwards and options

  Given these prices, we can value conventional and "exotic" energy options
- Hedging: At all times, ask: Have we "spanned" the OTC product with available futures/forwards and options?

Examples: Structured Energy Derivative Products

1. Forward/Futures contracts
2. Exchange of futures for physicals ("EFP")
3. Swaps
4. Conventional American and European call and put options
   (a) Monthly options
   (b) Daily options
5. Option Collars: Combination of long call with exercise price K_H, short a put with K_L, such the customer will pay the random index $\tilde{I}$ subject to the condition:

$$\text{Net Cost to Customer} = \begin{cases} K_H & \text{if } \tilde{I} \geq K_H \\ \tilde{I} & \text{if } K_L \leq \tilde{I} \leq K_H \\ K_L & \text{if } \tilde{I} \leq K_L \end{cases}$$

6. Average options[2]
7. Spread options

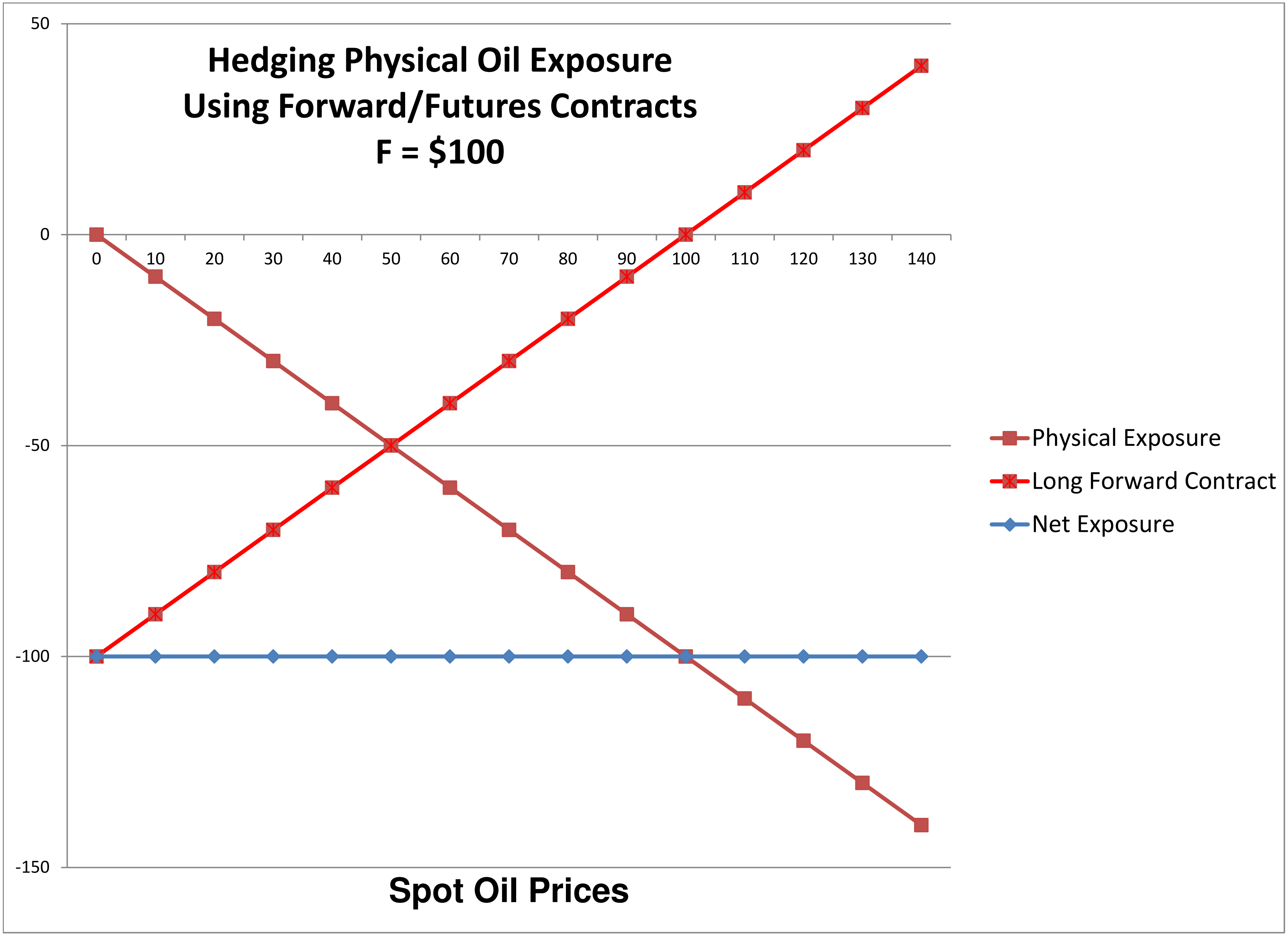
Product	Type of Spread
Transportation	Locational
Basis	Locational
Spark	Natural gas – electricity
Crack	Crude oil – Crude products
Frac	Natural gas – natural gas liquids

8. "Swing" options, with/without "ruthless" exercise
9. Weather derivatives

[2]Motivation for Average Options:

(a) Average prices more accurately reflect commercial-users' true exposure

(b) Such options are cheaper then European-style options (vol of the *average price* is lower than vol of the *spot price*)


Hedging Physical Oil Exposure
Using Forward/Futures Contracts
F = $100
50
0
-50
-100
-150
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Physical Exposure
Long Forward Contract
Net Exposure
Spot Oil Prices

Example of Structured Energy Derivative Products: Option Collars

For a client *short* the physical product,[3] the Option Collar is:

- Short the physical spot
- Long call with exercise price K_H
- Short a put with exercise price K_L, such the customer will pay the random index $\widetilde{I}$ subject to the condition:

$$\text{Net Cost to Customer} = \begin{cases} K_H & \text{if } \widetilde{I} \geq K_H \\ \widetilde{I} & \text{if } K_L \leq \widetilde{I} \leq K_H \\ K_L & \text{if } \widetilde{I} \leq K_L \end{cases}$$

- For a costless collar (aka "zero-cost collar"),

$$c\left(K_H\right) = p\left(K_L\right)$$

- Note implications for costless collar as $K_H \rightarrow K_L$

[3]For a client *long* the physical product, the Option Collar constitutes a combination of long physical, long a put with exercise price K_L, short a call with K_H.

Numerical Example — Option Collar

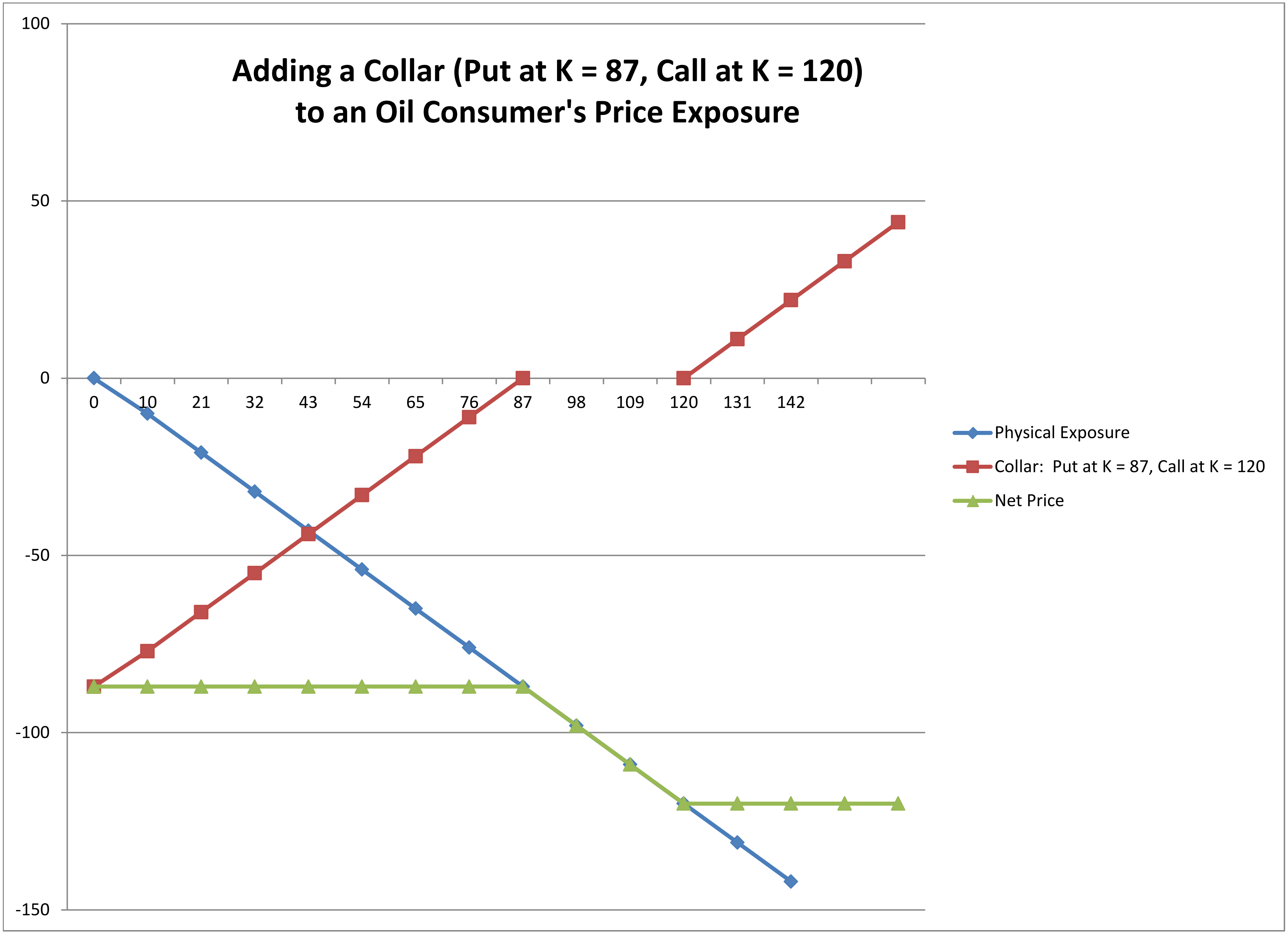
- *Definition:* A costless collar is one in which the long call option with exercise price K_H has value equal to and offset by the short put option position with exercise price $K_L < K_H$
- Assume:
  - $F = \$100$, $T = 1$, $\sigma = 40\%$, $r = 6\%$, $K_H = \$120$, i.e., 20% in-the-money
  - The volatility of 40% is constant for all options expiring one year from today — i.e., for both calls and puts, and for all exercise prices.[4]
- *Question:*
  1. Find K_L such that the collar is costless.
  2. Describe the net cost of the commodity one year hence to the purchaser of this costless collar.
- *Solution:*
  1. For the given parameters, we have

$$\begin{aligned} c\,(F = 100,\, T = 1,\, \sigma = 40\%,\, r = 6\%,\, K_H = 120) &= 8.65 \\ p\,(F = 100,\, T = 1,\, \sigma = 40\%,\, r = 6\%,\, K_L = 87) &= 8.66 \cong 8.65 \end{aligned}$$

  2. If the terminal value of the asset is I_T, the

$$\text{Net Cost to Customer} = \begin{cases} 120 & \text{if } I_T \geq 120 \\ I_T & \text{if } 87 \leq I_T \leq 120 \\ 87 & \text{if } I_T \leq 87 \end{cases}$$

[4] This numerical example abstracts from the existence of a volatility *skew* in which vols vary by option *strike price.*



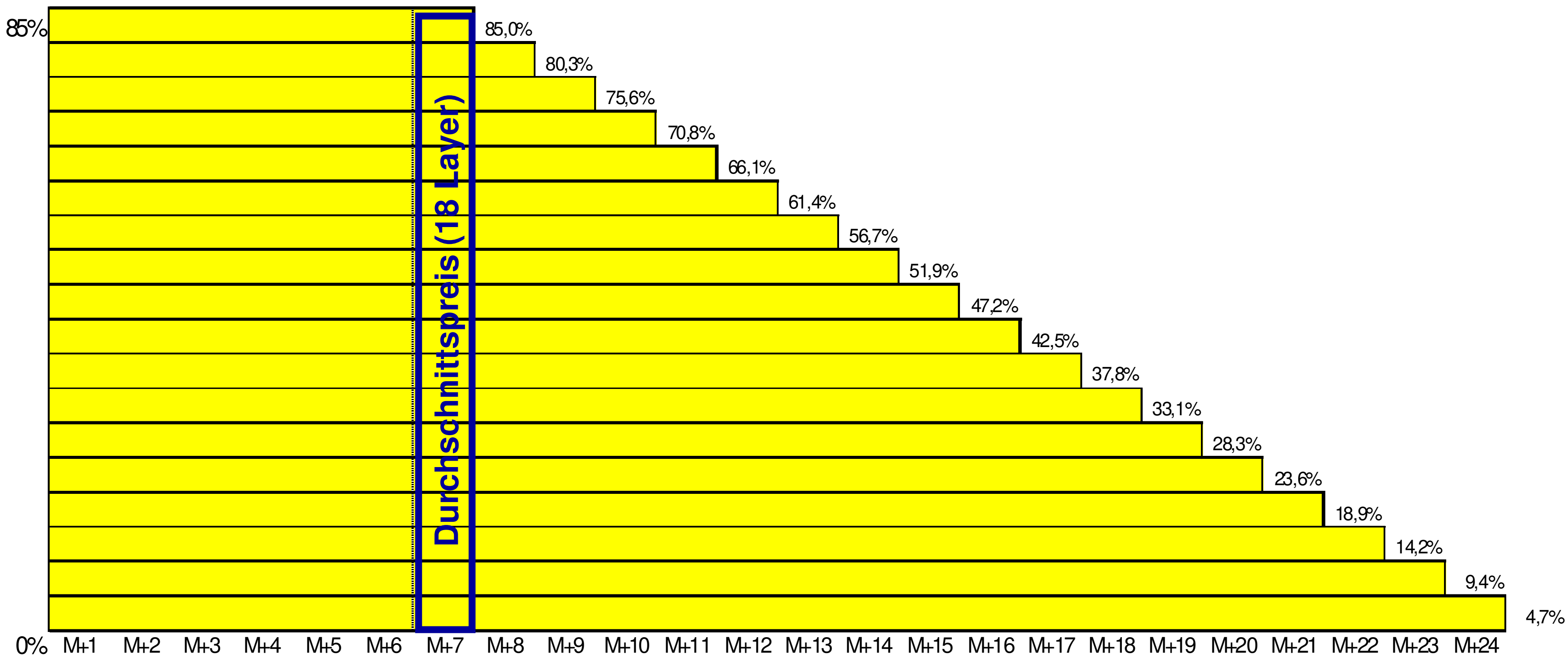
Adding a Collar (Put at K = 87, Call at K = 120)
to an Oil Consumer's Price Exposure
100
50
0
-50
-100
-150
0
10
21
32
43
54
65
76
87
98
109
120
131
142
Physical Exposure
Collar: Put at K = 87, Call at K = 120
Net Price

Jet-Fuel Hedging Optimization by European Airline

1. Two principles:
   (a) Gradual hedging of 4.7% each month from month $M-24$ to $M-7$. Instruments used include Swaps, Calls, Premium Collar and Four-Way
   (b) Evaluation by Plotting Sensitivity of Periodic Price (e.g., Apr. – Dec. price cond'l on realized average price)

Layer building process based on a guideline

- Monthly hedging of 4,7% of the expected demand for M+7 upt to M + 24 in crude oil
- Degree of coverage aimed for: 85 % for specific business model only



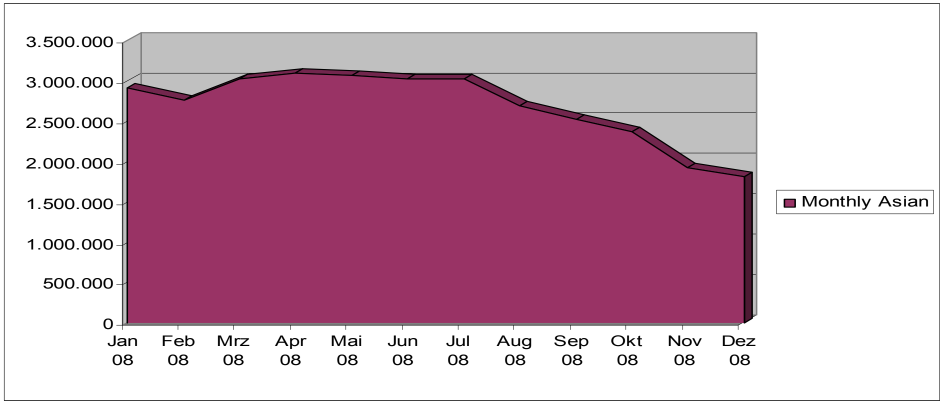
Graphik: Sicherungskonzept Treibstoff

Hedging Portfolio for 2008 – Collar Structure

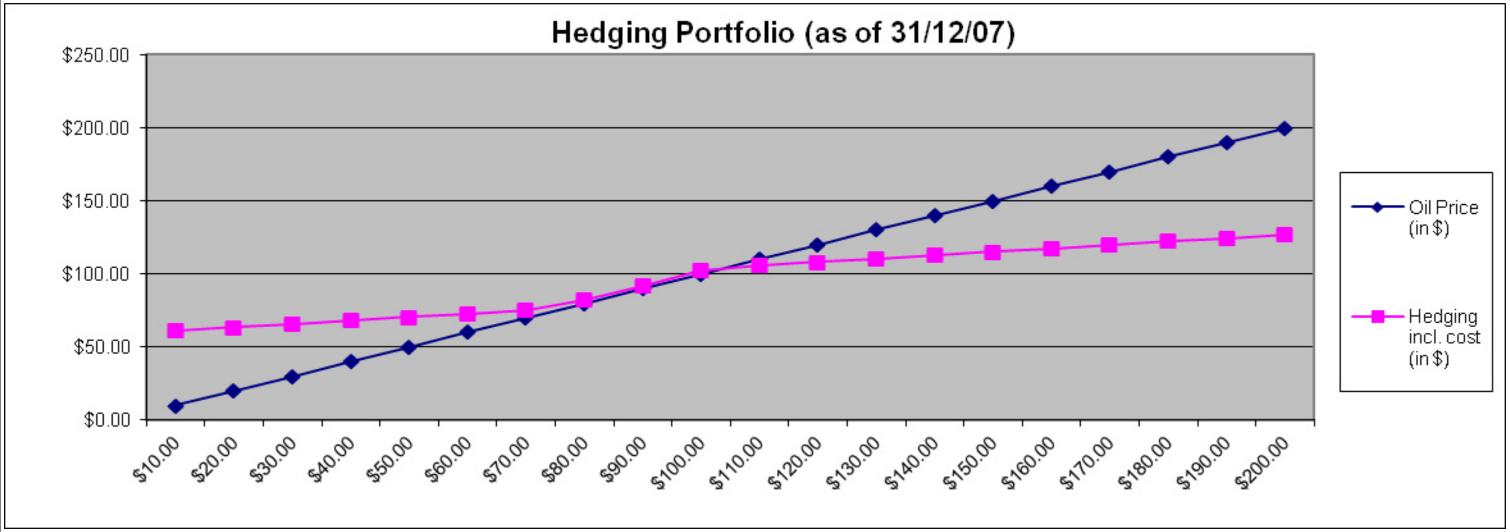
Assumptions:

- **Transaction date for all options: 12/31/2007**
- **Pricing of the Options using future prices and volatilities as of 31/12/2007**
- **Risk free rate of 3%**
- Portfolio of Collars
  -> long call (110% strike price)
  -> short put (80% strike price)
- Usage of monthly Asian Options
- Constant monthly consumption of 3.500.000 barrels of oil

Hedging Volume



Portfolio Position "S-Curve":



Hedging Cost per barrel
$ 2,09

Total Hedging Cost 2008
$ 67.192.529

Excel Calculation

Proposing an *Annual* Average-Style Option

- *Actual Hedge Instrument:* A strip of collars using Last-Month Averaged Options (LMAO) on the Brent futures contract, whereby the realized futures prices are averaged over their last month[2]
- *Proposed Hedge Instrument:* One annual-averaged price option
  - Disadvantage: Whereas a strip of Monthly-Averaged Options permits 12 distinct exercise dates, the Annual-Average is a one-time exercise (similar to the distinction between a cap and a swaption)
  - Advantage: Averaging will induce lower cost; Protection against annual-average price intact

[2] In practice, Brent futures contracts mature mid-month, requiring a blending of two contracts to obtain the monthly averaged price.

The Financial Environment, 12/31/07

Datum	Fraction of ATM	Value
Futures Price	100%	\$92.37
Call Strike Price	110%	\$101.76
Put Strike Price	80%	\$74.01

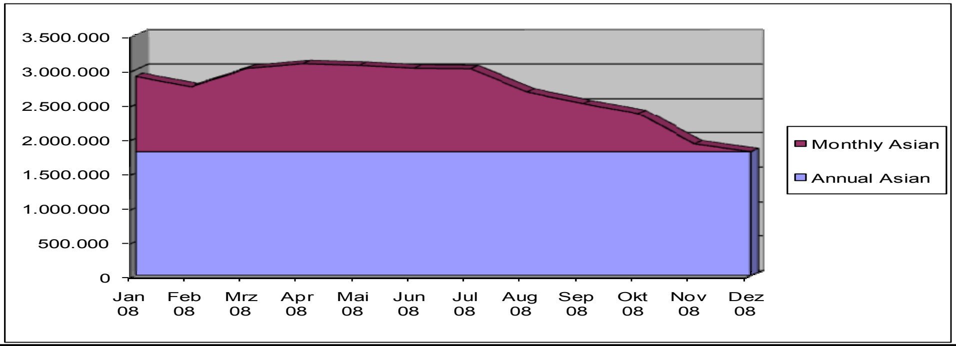
Range of Vanilla Vols	
(Jan. 2008 to Dec. 2008)	32.7% to 21.6%
Annual Arithmetic Volatility	14.07%

Hedging Portfolio – Min Annual Options (110/80)

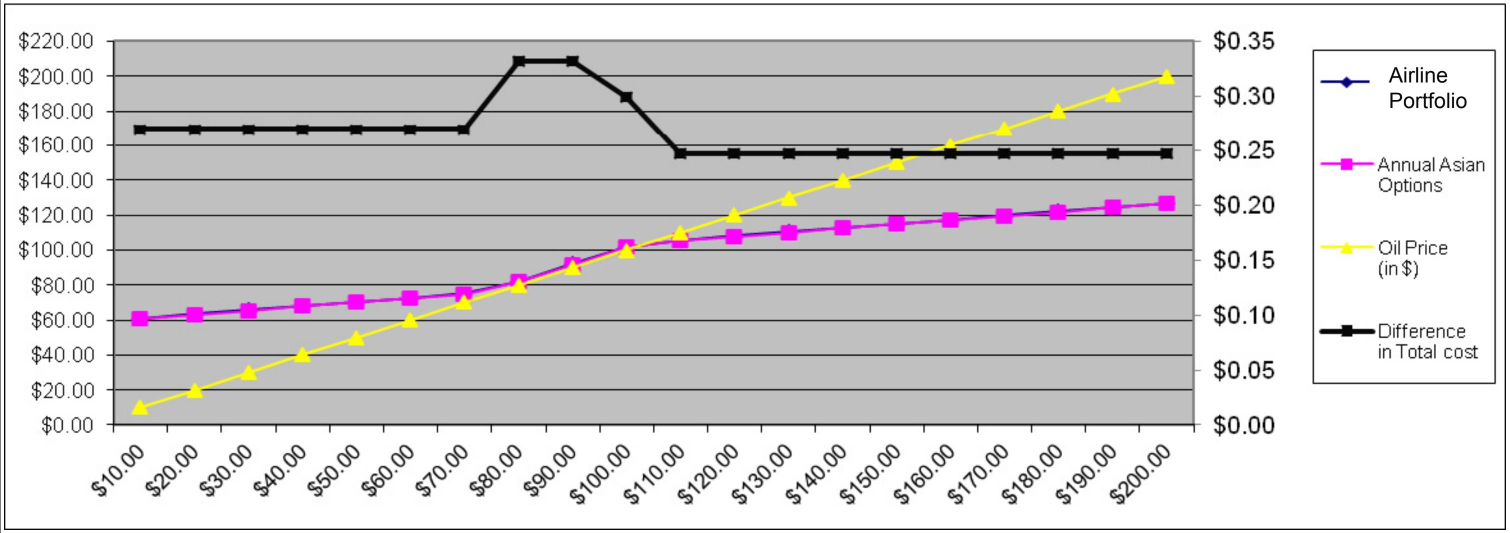
Assumptions:

- Usage of **annual** Asian Options (1.807.000 barrel oil each month equally to hedged position of Dec 08)
  -> long call (110% Strike, $101,67)
  -> short put (80% Strike, $ 73,94)
- Usage of **monthly** Asian Options (difference between hedged position for Dec 08 and individual monthly hedge volume)
  -> long call (110% Strike)
  -> short put (80% Strike)

Hedging Volume



Portfolio Position "S-Curve":



Hedging Cost per barrel
$ 1,76

Total Hedging Cost 2008
$56.529.850

Cost Savings per year:
$10.662.678

Excel calculation

Commodity Futures Information (Brent Crude Oil Market Data as of Mar 11, 2013)

	May'13	Jun'13	Jul'13	Aug'13	Sep'13	Oct'13	Nov'13	Dec'13	Jan'14	Feb'14	Mar'14	Apr'14
Futures Price	109.58	108.97	108.37	107.78	107.11	106.49	105.96	105.44	104.96	104.49	104.03	103.58
Implied Volatility	18.05%	19.68%	19.95%	20.41%	20.47%	20.81%	21.06%	20.98%	21.04%	20.81%	20.78%	20.64%

Option Pricing

Option Pricing Parameters

	May'13	Jun'13	Jul'13	Aug'13	Sep'13	Oct'13	Nov'13	Dec'13	Jan'14	Feb'14	Mar'14	Apr'14
Last Month Avg Calls	3.461	4.286	4.832	5.313	5.594	5.927	6.251	6.446	6.676	6.782	6.941	7.040
Std European Calls	4.183	4.885	5.326	5.748	5.981	6.283	6.582	6.752	6.964	7.050	7.194	7.280

Correlation Matrix Implied Volatilities	Price ($)	Implied Volatility
Annual-Average Style Option (Calls)	4.99	11.79%

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Option Comparison

	Annual-Average Option	Strip of Last-Month Average Option	Strip of Standard European Options
Price of 1000 Barrels ($)	4.99	5.8	6.19
Relative to Annual-Average Style	100%	116.07%	123.88%
Savings of 1000 Barrels (in $M)		0.8	1.19

SUMMARY

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

- As hedge instruments, Annual-Average Options have the triple merit:
  1. They more accurately reflect commercial-users' true exposure
  2. Given corporate planning horizons, they appear to Span an Optimal Length of Time
  3. Their Averaging Property Reduces their Cost

APPENDICES

A Analytics of Managing Long or Short Energy Price- and Quantity-Exposure at the Corporate Level

B Consumer Three-Way Payoff

Optimizing a Hedging Strategy by Energy End-Users

Two Optimization Methodologies for Energy Consumer and Producer End-Users:

1. Mean-Variance: Optimal Use of Futures Contracts
2. Mean-Value-at-Risk: Optimal Use of Futures *and* Options

Intuition and Analytics of Mean-Variance Optimization: Modeling the Commodity Producer's Hedging Optimization

1. Intuition:

   (a) Model the expected rate of return for a producer hedging with short position in futures contracts

   (b) Create a *tension* between expected rate of return and std. dev.: The less risk the producer is willing to take, the lower the expected rate of return on their portfolio of physicals-futures. This creates an intuitively-plausible tradeoff, in that the hedge portfolio is neither 0 nor 100% of expected output

2. Analytics:

   (a) Model the notion of a "Commodity Market Price of Risk," a risk premium measure which corresponds to the Sharpe Ratio in equities

   (b) Consider a producer facing a two-period $t = 0.5$ and $t = 1$ optimization, with expected output Q_t:

$$V = \sum_{t=1/12}^{1} \frac{Q_t F_{0t}}{(1+r)^t} \tag{1}$$

where

$V =$ Value of Cash Flows to be Received at six-mos. and 1-yr.

$Q_t =$ Fixed Quantity at time t, $t = 0.5$, 1

$F_{0t} =$ Current (time 0) futures price for contract maturing at time t, $t = 1/2$, 1

$r =$ Discount rate

(c) Let $\widetilde{V}$ stand for uncertain value under incomplete hedging. Since the producer is long energy, the hedge uses n_t *short* futures contracts $(0 \leq n_t \leq Q_t)$:[1]

$$\widetilde{V} = \sum_{t=1/12}^{1} \frac{Q_t \widetilde{F}_t + n_t \left(F_{0t} - \widetilde{F}_t\right)}{(1+r)^t} \tag{2}$$

(d) We can now compute the expected value and its variance:

$$E\left(\Delta\widetilde{V}\right) = \lambda \left[\frac{(Q_{0.5} - n_{0.5})\, F_{0,\,0.5}}{(1+r)^{0.5}}\, 0.5\, \sigma_{0.5} + \frac{(Q_1 - n_1)\, F_{01}}{1+r}\, \sigma_1 \right] \tag{3}$$

where

$\lambda =$ Market Price of Risk for this commodity

$\sigma_t =$ Annualized implied volatility for date t

Based on past experimentation (to obtain plausible portfolio values[2]), we use values of λ in the range $[0.3,\ 0.8]$.

$\mathrm{Var}\left(\Delta\widetilde{V}\right)$ is given by:

$$\begin{aligned} \mathrm{Var}\,(\Delta V) = & \left[\frac{(Q_{0.5} - n_{0.5})\, F_{0,\,0.5}}{(1+r)^{0.5}} \right]^2 0.5\, \sigma_{0.5}^2 + \left[\frac{(Q_1 - n_1)\, F_{0,\,1}}{(1+r)} \right]^2 \sigma_1^2 \\ & + 2 \left[\frac{(Q_{0.5} - n_{0.5})\, F_{0,\,0.5}}{(1+r)^{0.5}}\, \frac{(Q_1 - n_1)\, F_{0,\,1}}{(1+r)} \right] \rho_{0.5,\,1} \sqrt{0.5}\, \sigma_{0.5} \sigma_1 \end{aligned} \tag{4}$$

(e) To proceed to the optimization, we state things in terms of *rates of return:*

$$E\left(\frac{\Delta\widetilde{V}}{V}\right) = \frac{1}{V}\, E\,(V) \tag{5}$$

$$\text{Std. Dev.}\left(\frac{\Delta\widetilde{V}}{V}\right) = \frac{1}{V}\ \text{Std. Dev.}\left(\Delta\widetilde{V}\right) \tag{6}$$

Formally, the optimization surface is obtained by solving the optimization problem

$$\begin{aligned} \min_{\{n_{0.5},\ n_1\}} \quad & \text{Std. Dev.}\left(\frac{\Delta\widetilde{V}}{V}\right) \\ \text{subject to} \quad & E\left(\frac{\Delta\widetilde{V}}{V}\right) = c, \end{aligned} \tag{7}$$

which "sketches out" the optimization frontier as c varies

[1]Any expression with a tilde ("$\sim$") is random as of time-0.
[2]We seek portfolios that provide lattitude for both hedging and non-hedging.

Definition of Earnings for Corporations Short or Long Price Exposure

- Definition of Earnings (for a Corporation *Short* Prices):

$$\widetilde{E} = -\widetilde{P}\widetilde{Q} + n_F\left(\widetilde{P} - F\right) + n_C \max\left\{0,\ \widetilde{P} - K\right\} - n_C\left(1+r\right)^T C\left(K\right) \tag{3}$$

where

Notation	Definition
$E\left(\widetilde{P}\right)$	Current expectation of average price for month T
$E\left(\widetilde{Q}\right)$	Current expectation of total quantity consumed in month T
$\sigma_Q,\ \sigma_P$	Proportional volatility for $\widetilde{Q}$ and $\widetilde{P}$
$\rho_{P,Q}$	Correlation coefficient between $\ln P$ and $\ln Q$
F	Forward price for month T
$C\left(K\right)$	Call option with given strike price K
T	Time to expiration
r	Riskfree rate of interest

- For a corporation *long* prices, the analogous earnings statement is

$$\widetilde{E} = \widetilde{P}\widetilde{Q} - n_F\left(\widetilde{P} - F\right) + n_{\text{Put}} \max\left\{0,\ K - \widetilde{P}\right\} - n_{\text{Put}}\left(1+r\right)^T \text{Put}\left(K\right) \tag{4}$$

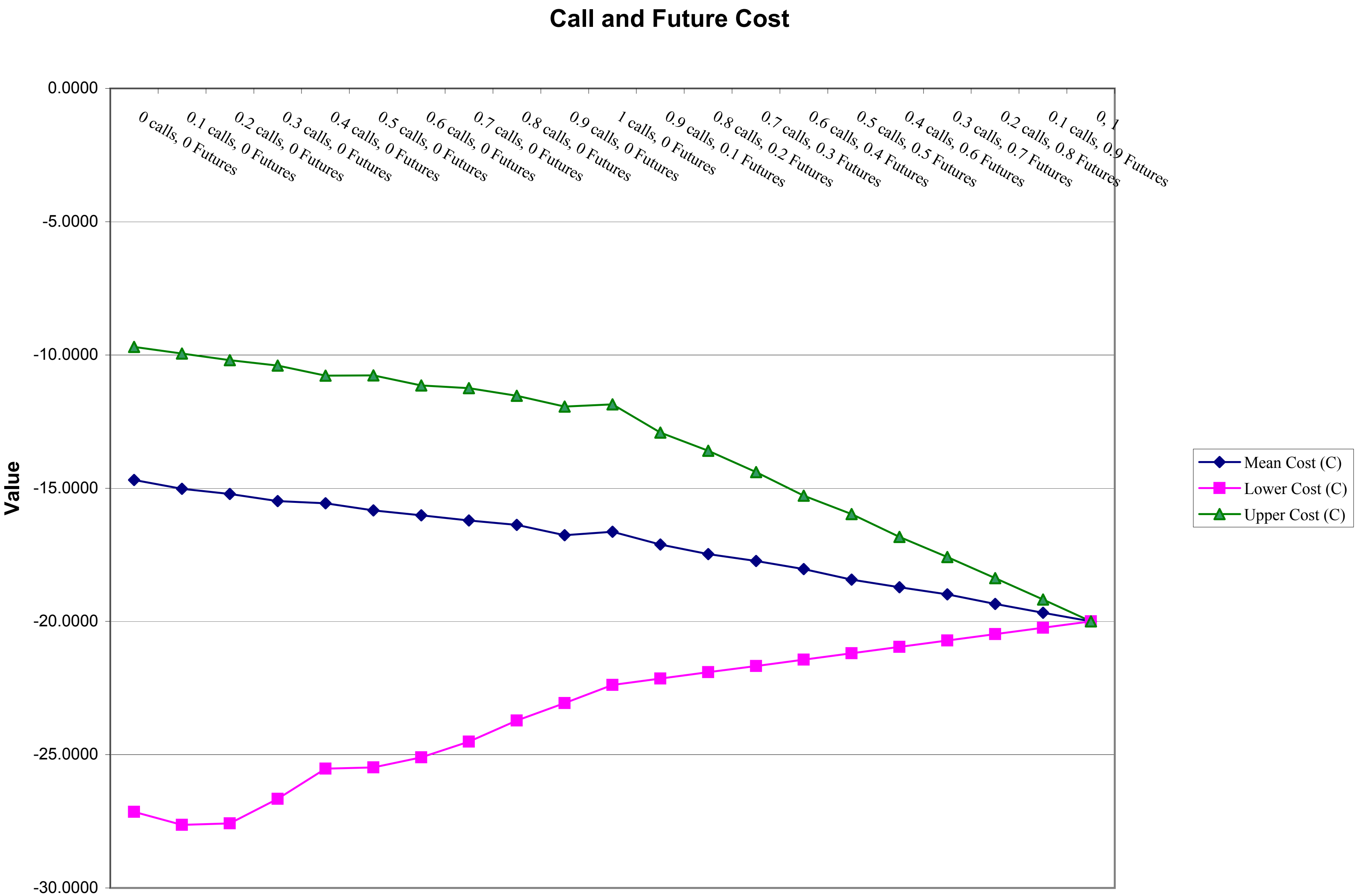
Implementing *Corporate*-Level Price Risk Management Policy Using Futures or Options

- For a Corporation short or long price exposure, define the objective function as:[2]

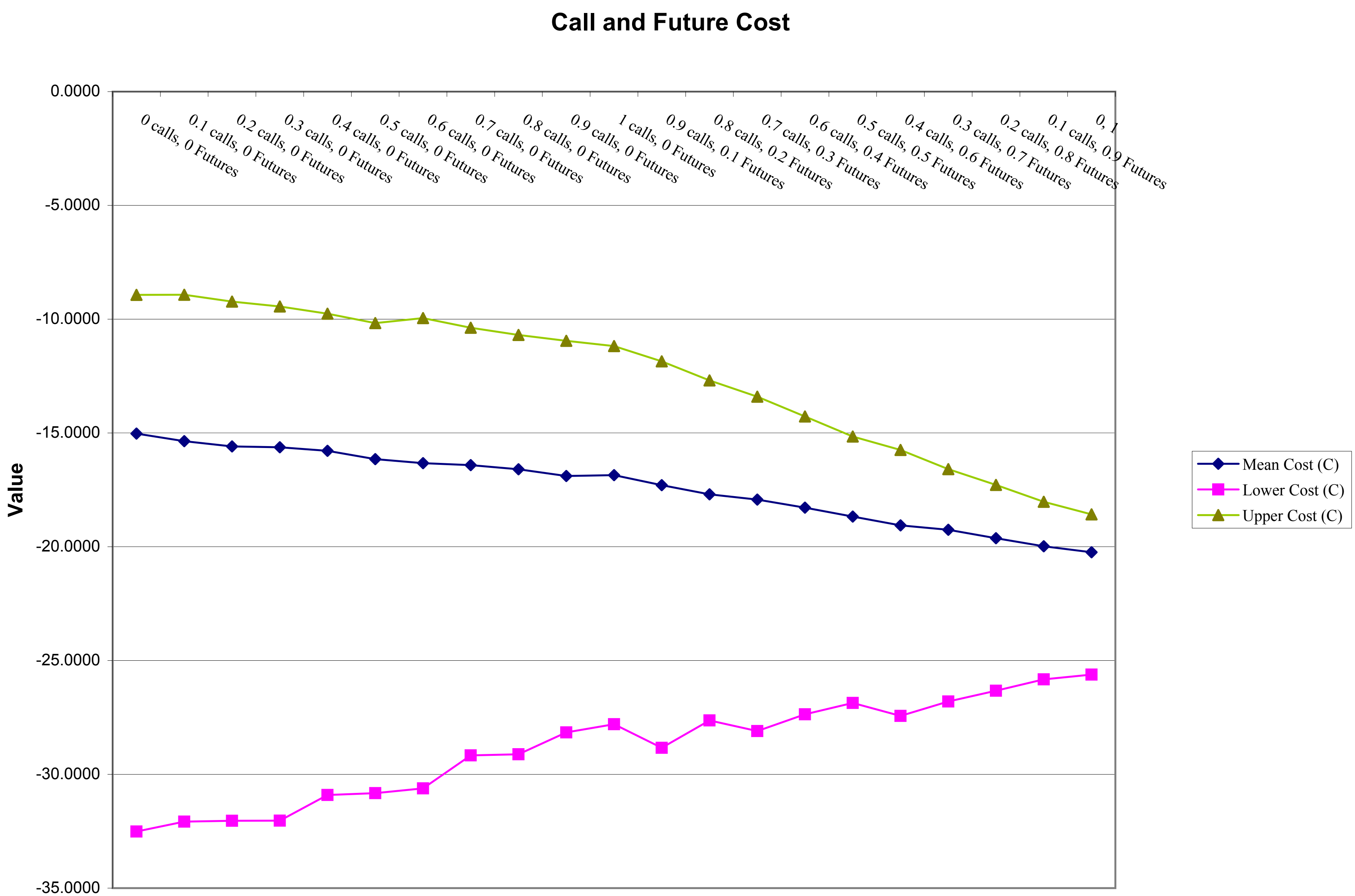
$$E\left(\widetilde{E}\right) + \alpha\, E_{\text{Lower Percentile}} \tag{5}$$

- Properties of optimal solution:
  - The greater is α, the more concerned is the decision-maker with the *lower* side of the earnings distribution $\Longrightarrow$ the more hedging he/she will undertake.
  - Varying α from 0 (risk-neutrality) to ∞ (in practice, α of 1 or 2 will suffice) will provide the entire range of earnings-distribution alternatives
- Main Result. There exits a *systematic pattern to optimal hedging:* As α, the degree of risk aversion, increases from zero to positive values, the company's optimal hedge proceeds from
  - *No-hedging,* to
  - *Acquiring call options* (up to 100% of expected quantity), to
  - *Replacing call options with futures contracts*
- Managerial Decision is taken upon consideration of the Expected Earnings $E\left(\widetilde{E}\right)$ and the lower percentile $E_{\text{Lower Percentile}}$

[2]An alternative intuitive objective function, which gives rise to the same optimal solution, is *Downside-Risk Minimization,* based on the semi-variance criterion $E\left(\widetilde{E}\right) - \alpha\sqrt{E\left(\max\left\{\left[E\left(\widetilde{E}\right) - \widetilde{E}\,\right],\, 0\right\}\right)^2}$.



Call and Future Cost
0.0000
-5.0000
-10.0000
-15.0000
-20.0000
-25.0000
-30.0000
Value
0 calls, 0 Futures
0.1 calls, 0 Futures
0.2 calls, 0 Futures
0.3 calls, 0 Futures
0.4 calls, 0 Futures
0.5 calls, 0 Futures
0.6 calls, 0 Futures
0.7 calls, 0 Futures
0.8 calls, 0 Futures
0.9 calls, 0 Futures
1 calls, 0 Futures
0.9 calls, 0.1 Futures
0.8 calls, 0.2 Futures
0.7 calls, 0.3 Futures
0.6 calls, 0.4 Futures
0.5 calls, 0.5 Futures
0.4 calls, 0.6 Futures
0.3 calls, 0.7 Futures
0.2 calls, 0.8 Futures
0.1 calls, 0.9 Futures
0, 1
Mean Cost (C)
Lower Cost (C)
Upper Cost (C)


Call and Future Cost
Value
0.0000
-5.0000
-10.0000
-15.0000
-20.0000
-25.0000
-30.0000
-35.0000
0 calls, 0 Futures
0.1 calls, 0 Futures
0.2 calls, 0 Futures
0.3 calls, 0 Futures
0.4 calls, 0 Futures
0.5 calls, 0 Futures
0.6 calls, 0 Futures
0.7 calls, 0 Futures
0.8 calls, 0 Futures
0.9 calls, 0 Futures
1 calls, 0 Futures
0.9 calls, 0.1 Futures
0.8 calls, 0.2 Futures
0.7 calls, 0.3 Futures
0.6 calls, 0.4 Futures
0.5 calls, 0.5 Futures
0.4 calls, 0.6 Futures
0.3 calls, 0.7 Futures
0.2 calls, 0.8 Futures
0.1 calls, 0.9 Futures
0, 1
Mean Cost (C)
Lower Cost (C)
Upper Cost (C)

Consumer Three-Way Payoff

Consumer three-way payoff