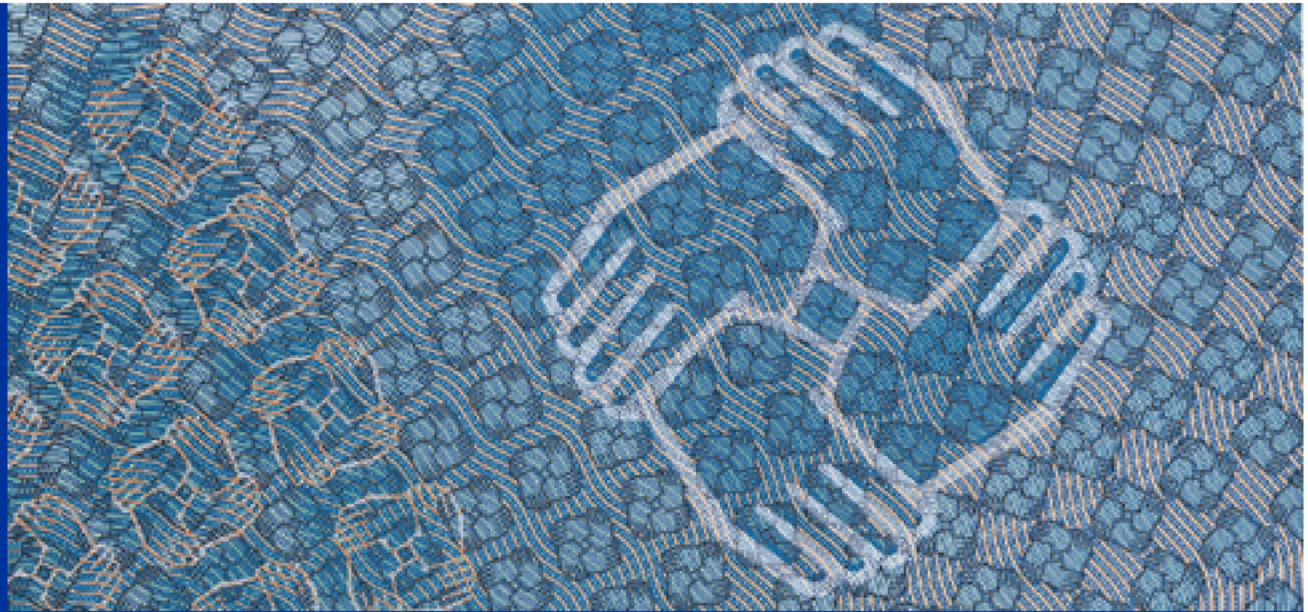

Applied Fixed Income Risk Modeling

Successes and…Learning Experiences

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Northfield's 18th Annual Research Conference
July 2005

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Risk Management at OFI

- Fixed Income Risk Management and Analytics group
  - Responsible for fixed income risk management at OppenheimerFunds – both retail and institutional.
  - Responsible for conducting fund complex-level risk management analyses and reporting all funds' risks to:
    - Senior management
    - OppenheimerFunds boards
- As such, we have three sets of audiences:
  - The fund managers and their analysts
  - Senior management and the boards
  - Sales, marketing, product management, Request-for-Proposal, and other departments

Risk System Goals

- An *ex-ante* portfolio (or trade) evaluation system.
- Not an *ex-post* portfolio decomposition/reporting system.
- Use to structure efficient, active portfolios
- Relate risk factors to portfolio returns and use this relationship to reveal risks in active portfolios
- Also:
  - Counterparty risk analyses
  - Senior Management-level fund complex analyses

Risk System Goals

- Structure efficient, active portfolios along dimensions of outperformance
  - Prove consistency of portfolio manager's risk/reward beliefs
    - Quantifying intended tilts
    - Evaluating risk impact of potential trades
    - Hedging tool
  - Assisting in active benchmarks construction
  - Risk Budgeting
- Reveal and manage risks in active portfolios
  - Reveal unintentional marginal risks
  - Predict portfolio and benchmark risks
  - Provide quantitative insights into past performance

Risk System Goals

- Main risk measures include
  - Prediction of portfolio and benchmark variances
  - Active risk (tracking error)
  - Value-at-Risk
  - Marginal tracking error
  - Incremental tracking error
  - Component tracking error

What's a fixed income risk manager to do?

- We own or have bought over the years: domestics, foreigns, treasuries, high yield, [very] emerging markets debt, local EM, USD EM, swaps, swaptions, cross-currency structured notes, local EM CDS, futures, CDX indices, ABS, CAT bonds, currency forwards and options, and sometimes funky structured notes.

Fixed income risk models 2002

- Available choices in 2002 – Inhouse model, Wilshire, Lehman Point, CMS BondEdge, Citigroup Yield Book Tracking Error
- In a nutshell:
- *None but one* of the above models captured the risks of *most* fixed income securities well!

Fixed income risk models 2002

- Inhouse model – historical, simple covariance matrix (linear). Not a "black-box."
- Wilshire – factor-based. Citi indices needs, some FI non-linearity concerns, support staff size vs peers. Good software design for access and downloads.
- Lehman – lacked its current capabilities, non-PCA. Different "customer paradigm" than Yield Book.
- CMS BondEdge – lacked full risk modeling capabilities, esp MBS. Good software engineering.
- Citigroup Yield Book – PCA-based with Monte Carlo approach capturing non-linearity.

OppenheimerFunds The Right Way to Invest

Inhouse approach was:

In general,

$$s_p^2 = w_1^2 s_{11}^2 + 2w_1 w_2 s_{12} + w_2^2 s_{22}^2 \ldots$$

$$w_i = \text{weights of portfolio holdings}$$

$$s_{\text{ij}} = \text{return covariance matrix member}$$

$$s_p^2 = \mathbf{X}^{\mathbf{T}} \Sigma \mathbf{X}$$

Example:

1. Gather index yields and calculate spread beta to UST
2. Construct covariance matrix of spread Δy's
3. Calculate weights and durations
4. Aggregate to predicted return price volatility via $\frac{\Delta P}{P} \approx -MD\Delta y$ where

$$s^2\left(\frac{\Delta P}{P}\right) \approx (MD)^2 s^2(\Delta y)$$

Regression/factor approach

In general,

$$r_i = a_i + b_{i1} f_1 + \ldots + b_{ik} f_k + e_i$$

$$r_i = \text{excess return of holding } i$$

$$f_k = \text{return of factor } j$$

$$b_{ik} = r_i \text{ sensitivity to factor } k$$

$$e_i = \text{residual return } i$$

Example: Wilshire Axiom

1. Regress excess return against shifts in YC

Excess Return =	factor return$_1$ to parallel shift (β_1)	x	sensitivity to parallel shift (eff. dur.)	+	factor return$_2$ to steepening shift (β_2)	x	sensitivity to steepening shift	+	factor return$_3$ to curve shift (β_3)	x	sensitivity to curve shift	+ residual return

2. Regress residual return against shifts in spreads (i.e. sector, quality, prepayment, etc)
3. Covariance matrix constructed from historical factor returns
4. Aggregate to predicted return volatility

Simulation Approach

Example: Yield Book

1. **Identify** risk factors for each security grouping
2. **Represent** the risk factors by their principal components
3. **Construct** covariance matrix of the principal components
4. **Sample** from the distribution to obtain changes in the risk factors (risk factor PC moves)
5. **Translate** principal component moves to individual bond returns
   - Interpolation on pre-calculated scenario analysis results for returns due to yield curve moves
   - Risk duration based calculations for risk factors such as volatilities and spreads.
6. **Aggregate** returns of all securities to obtain portfolio return distribution.

Approaches Comparison Recap

Simple covariance-based:

$$\frac{\Delta P}{P} \approx -\frac{1}{P}\frac{dP}{dy}\Delta y$$

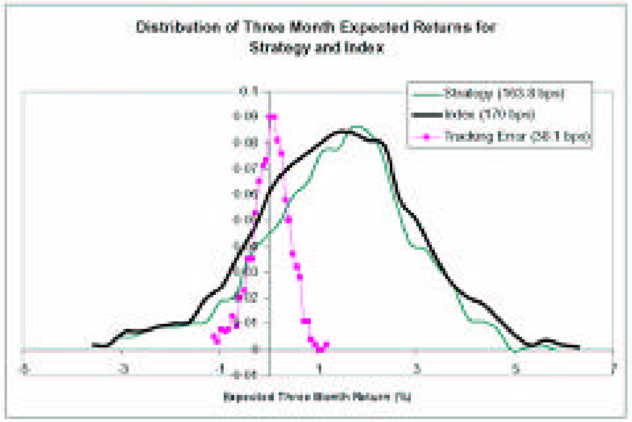
Factor-based:

$$\text{excess return} = b_1\left(\frac{dP}{dy}\right)_{parallel} + b_2\left(\frac{dP}{dy}\right)_{steepening} + b_3\left(\frac{dP}{dy}\right)_{curve} + b_4\left(\frac{dP}{dy}\right)_{\substack{sector\\spread}} + \ldots$$

Simulation-based:

1. Repeated draws from ΔPC multivariate normal distribution
2. Run MC scenario analysis using set of ΔPC from above
3. Aggregate to obtain price distribution ➔

Sample, Translate, and Aggregate



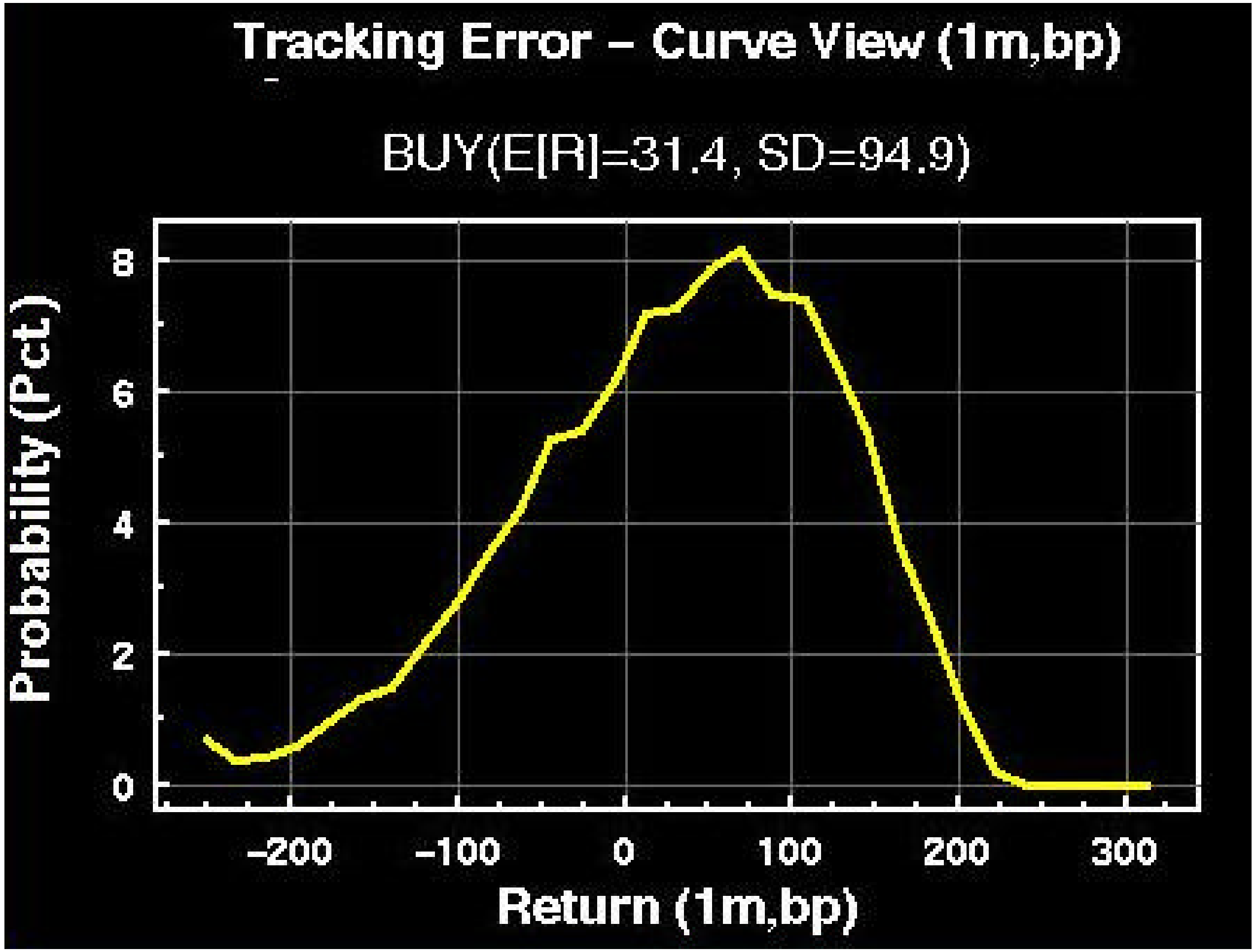
Fixed income risk models 2002

- We chose Yield Book ("Tracking Error") because:
- Monte Carlo approach provided best estimate of fixed income securities' returns
  - we buy lots of non-linear stuff!
  - "forward-looking" via scenario analysis
- Portfolios priced using security-specific models
  - Do not impose a linear relationship – hence analyze securities with non-normal return distributions.
  - Securities without sufficient price history can also be analyzed.

Fixed income risk models 2002

- Pricing, hedging, and risk analysis of all securities can be done with the same models (eliminating inconsistencies between assumptions).
- Extensive and clean data sets (Citi indices)
- Yield Book has a long track record (since 1991)
- Used internally at Citi by trading and sales (robust analytics – tried and tested)

Example of returns non-linearity: Citi Mortgage Index



Distribution of 10,000 paths using Monte Carlo simulation over a one-month horizon

Simulation Approach

Example: Yield Book

1. Identify risk factors for each asset class (security type or grouping)
2. Perform PCA on covariance matrices of each security type
3. Build correlation matrix between PC's (i.e., simulate the correlated occurrences of approximately 800 market variables)
4. Sample from distribution in 3) to obtain ΔPC (e.g. $2s$)
5. Transform change in PC to bond space (i.e., map PC factors to market risk factors; two examples below)

<u>Yield Curve</u>:

a. Determine that a $2s$ ΔPC equates to an 80 *bp* move in the 10-year tsy rate.

b. Perform horizon scenario analysis (via Monte Carlo simulation) to obtain individual bond returns (i.e. estimate the returns for each bond for an 80 *bp* move in the 10-year tsy rate).

<u>Spreads</u>:

a. Determine that a $2s$ move in the spread PC corresponds to a 100 *bp* change in the spread for a short maturity, AA, industrial, US corporate bond.

b. Perform horizon scenario analysis for *each such bond* to obtain individual bond spread returns (i.e., estimate the bond's return for a 100 *bp* change for a short maturity, AA, industrial, US corporate bond).

Simulation Approach

Example: Yield Book (contd.)

6. Assessment of the distribution of portfolio returns - P&Ls due to interest-rate and volatility shocks are obtained via Yield Book's scenario analytics engine
7. Aggregate returns of all securities to construct portfolio price distribution

Also:

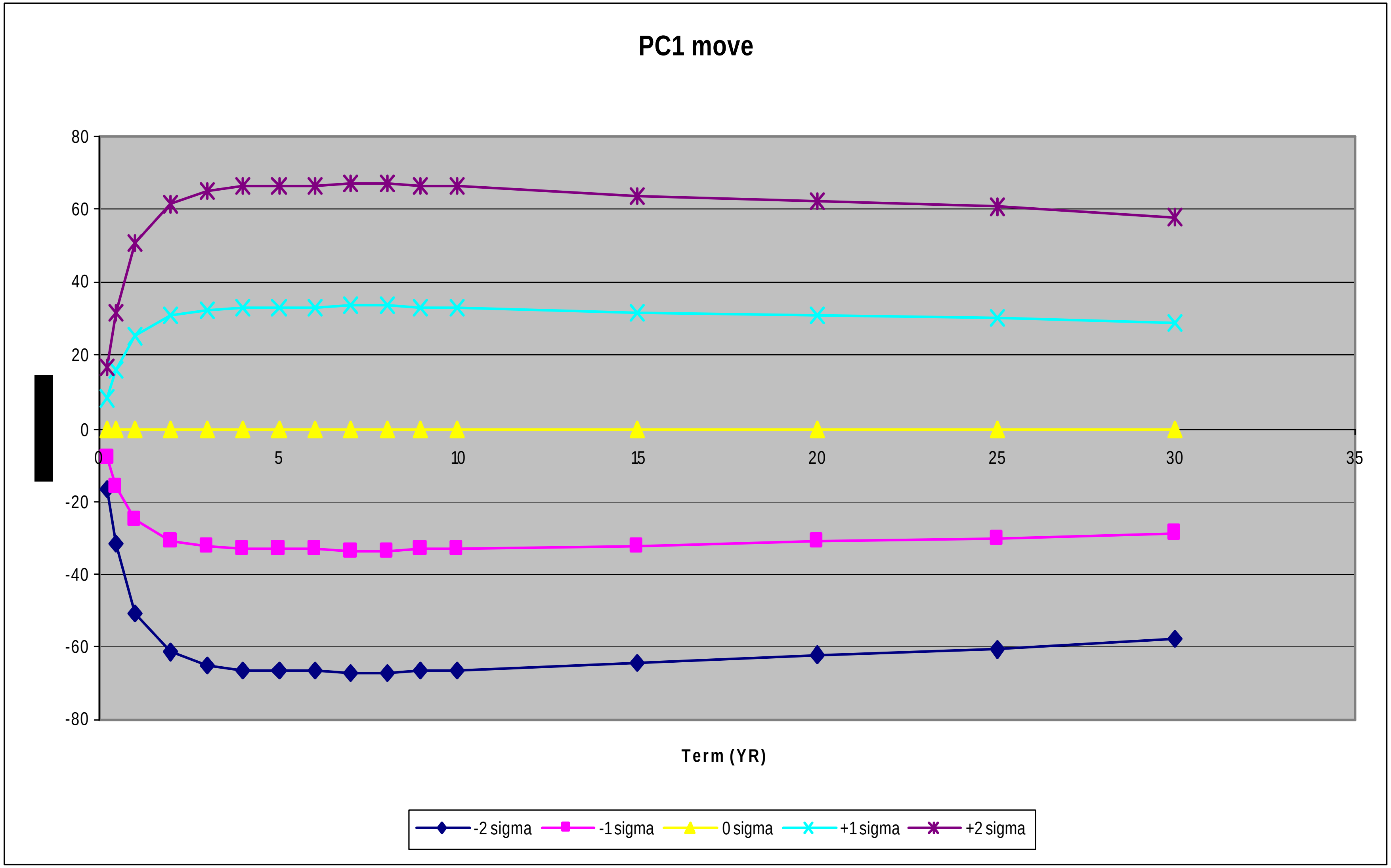
- The Yield Book datasets provide options to use either three-year or two-year of monthly data points for the PC correlation matrix.
- The covariance is estimated from Citigroup's historical fixed-income dataset.

Curve Risk PCs

Correlations Between Yield Curve Principal Components												
	US 1	US 2	US 3	EMU 1	EMU 2	EMU 3	UK 1	UK 2	UK 3	YEN 1	YEN 2	YEN 3
US 1	1	0	0	0.89	0.03	-0.18	0.87	0.03	-0.25	-0.11	0.03	0.03
US 2	0	1	0	0	0.64	-0.11	0.06	0.65	0.15	-0.02	0.41	-0.27
US 3	0	0	1	0.12	0.24	0.22	0.09	0.33	0.36	0.24	0.21	0.21
EMU 1	0.89	0	0.12	1	0	0	0.92	0	0.04	-0.11	0.09	0.14
EMU 2	0.03	0.64	0.24	0	1	0	0.14	0.71	-0.02	0.13	0.3	-0.11
EMU 3	-0.18	-0.11	0.22	0	0	1	0.12	-0.18	0.6	-0.03	0.02	0.17
UK 1	0.87	0.06	0.09	0.92	0.14	0.12	1	0	0	-0.11	0.13	0.19
UK 2	0.03	0.65	0.33	0	0.71	-0.18	0	1	0	0.07	0.6	-0.11
UK 3	-0.25	0.15	0.36	0.04	-0.02	0.6	0	0	1	0.14	0.1	0.04
YEN 1	-0.11	-0.02	0.24	-0.11	0.13	-0.03	-0.11	0.07	0.14	1	0	0
YEN 2	0.03	0.41	0.21	0.09	0.3	0.02	0.13	0.6	0.1	0	1	0
YEN 3	0.03	-0.27	0.21	0.14	-0.11	0.17	0.19	-0.11	0.04	0	0	1
Red: High Correlation (magnitude of correlation > 0.5)												
Green: Low Correlation (magnitude of correlation greater than 0.2, less than 0.5)												
Light Blue: Very low correlation (magnitude of correlation less than 0.2)												

Curve Risk PCs

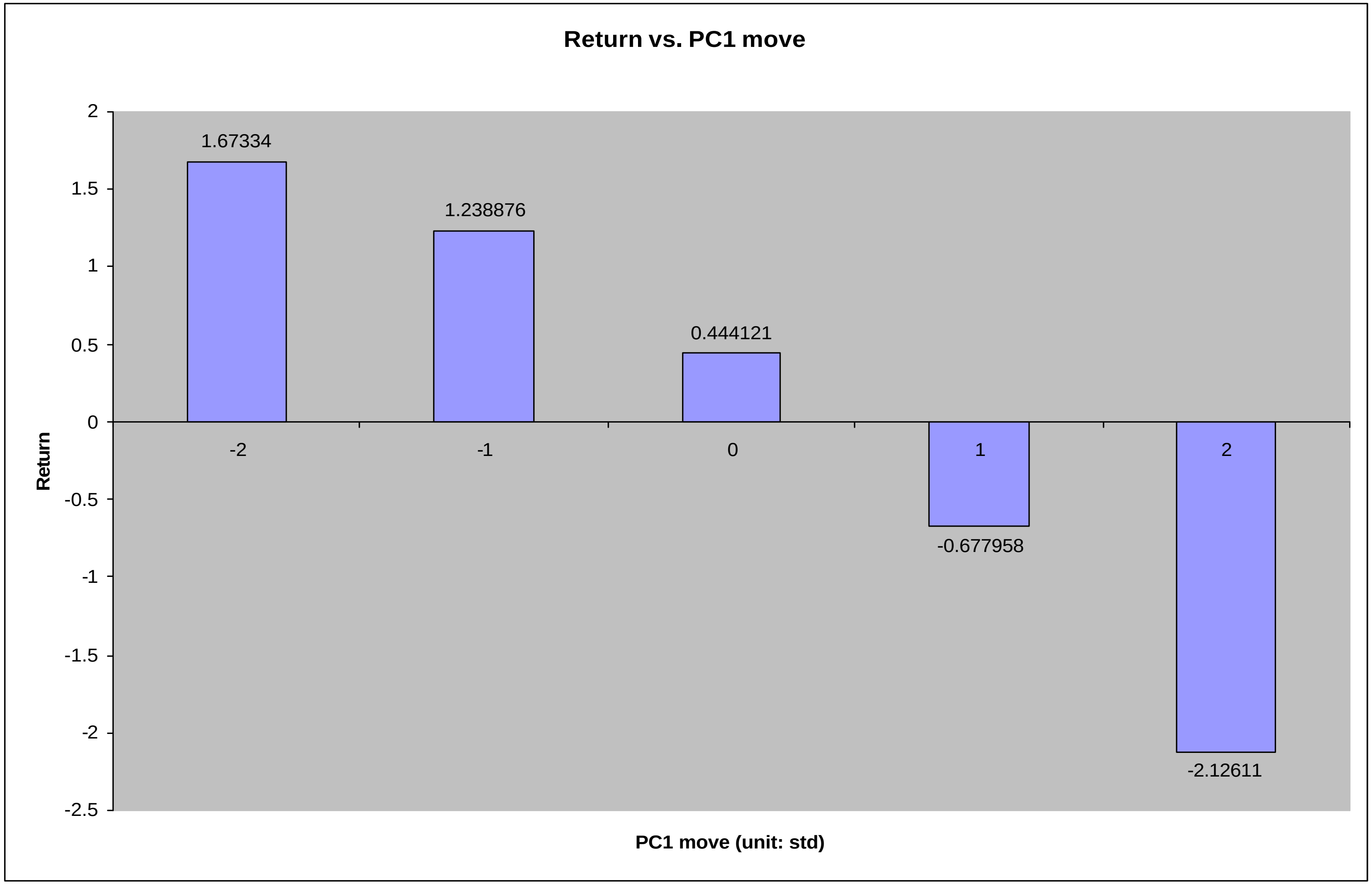
Principal Component #1 of the UST curve movements



Yield Curve risk factors

Curve Data for Each Market																		
Country	Curve	Maturity																
		3m	6m	1Y	2Y	3Y	4Y	5Y	6Y	7Y	8Y	9Y	10Y	12Y	15Y	20Y	25Y	30Y
US	On The Run	x	x	x	x	x	x	x		x			x			x		x
	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Swap	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x
	Agency			x	x	x	x	x	x	x	x	x	x		x			x
EMU	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Swap	x	x	x	x	x	x	x	x	x			x		x	x	x	x
Japan	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x		
	Swap	x	x	x	x	x	x	x	x	x	x	x	x					
UK	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Swap	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Canada	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Swap	x	x	x	x	x	x	x	x	x	x	x	x					
Denmark	Model	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	
	Swap	x	x	x	x	x	x	x	x	x	x	x	x					
Switzerland	Model	x	x	x	x	x	x	x	x	x	x	x	x		x			
	Swap	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Sweden	Model	x	x	x	x	x	x	x	x	x	x	x	x		x			
	Swap	x	x	x	x	x	x	x	x	x	x	x	x					
Australia	Model	x	x	x	x	x	x	x		x			x					
	Swap	x	x	x	x	x	x	x		x			x					
Poland	Swap*	x	x	x	x	x	x	x		x	x	x	x					
S. Africa	Swap*	x	x	x	x	x	x	x	x	x	x	x	x		x	x		
Czech	Swap*	x	x	x	x	x	x	x		x			x					
Norway	Model	x	x	x	x	x	x	x	x									
New Zealand	Swap*	x	x	x	x	x	x	x		x			x		x			
Hong Kong	Swap*	x	x	x	x	x	x	x		x			x		x			
South Korea	Swap*	x	x	x	x	x	x	x		x			x		x			
Thailand	Model	x		x	x	x	x	x		x			x	x				
Singapore	Model	x		x	x			x		x			x		x			
Hungary	Model	x	x	x		x		x					x		x			

Returns impacts on a bond for five specified standard deviation movements of PC #1



Sample output

						Risk factors perturbations (values in bp/month)						
	number of issues	weight in % of par amt	weight in % of mktval	effective duration	total volatility contribution	total curve contribution to volatility	1st curve PC contribution to volatility	2nd curve PC contribution to volatility	3rd curve PC contribution to volatility	spread contribution to volatility	currency contribution to volatility	volatility contribution to volatility
PORT_NAME	Nsec	%Par	%MV	EDur	VOLTR (bp/mo)	VOLCrv (bp/mo)	VOLPC1 (bp/mo)	VOLPC2 (bp/mo)	VOLPC3 (bp/mo)	VOLSprd (bp/mo)	VOLCurr (bp/mo)	VOL(VOL) (bp/mo)
High yield fund	404	100	100	3.75	261.8	112.1	110.1	19.9	8.0	321.6	2.1	1.2
High yield index	1023	100	100	4.38	452.4	150.3	145.7	33.9	4.9	509.6	0	0.7
Tracking error		0	0	-0.63	237.7	41.5	35.7	17.2	12.8	236.6	2.1	1
HY Fund (bynow)	404	100	100	3.75	261.8	112.0	110.0	19.7	7.6	321.6	0	0.8
HYLDMKT &AL INDEX	1023	100	100	4.38	452.4	150.3	145.7	33.9	4.9	509.6	0	0.7
Difference:		0	0	-0.63	237.6	41.4	35.7	17.1	12.5	236.6	0	0.1

Total Return Volatility

9.1% annual total volatility or 261.8 bps/mo TR standard deviation per month

15.7% annual total volatility or 452.4 bps/mo TR standard deviation per month

Difference or Tracking Error

8.2% annual tracking error volatility

A TE of 0.5% annualized implies that the fund and benchmark returns
will differ by an average of 50 bps per year

A TE of 8.2% implies that the fund and benchmark returns
will differ by an average of 820 bps per year or 237.7 bps per month

Currency Volatility

0.1% annual currency volatility or 2.1 bps per month for the f.

0% annual currency volatility for the benchmark
all securities in the benchmark are USD denominated

0.1% annual or 2.1 bps/mo currency tracking error volatility

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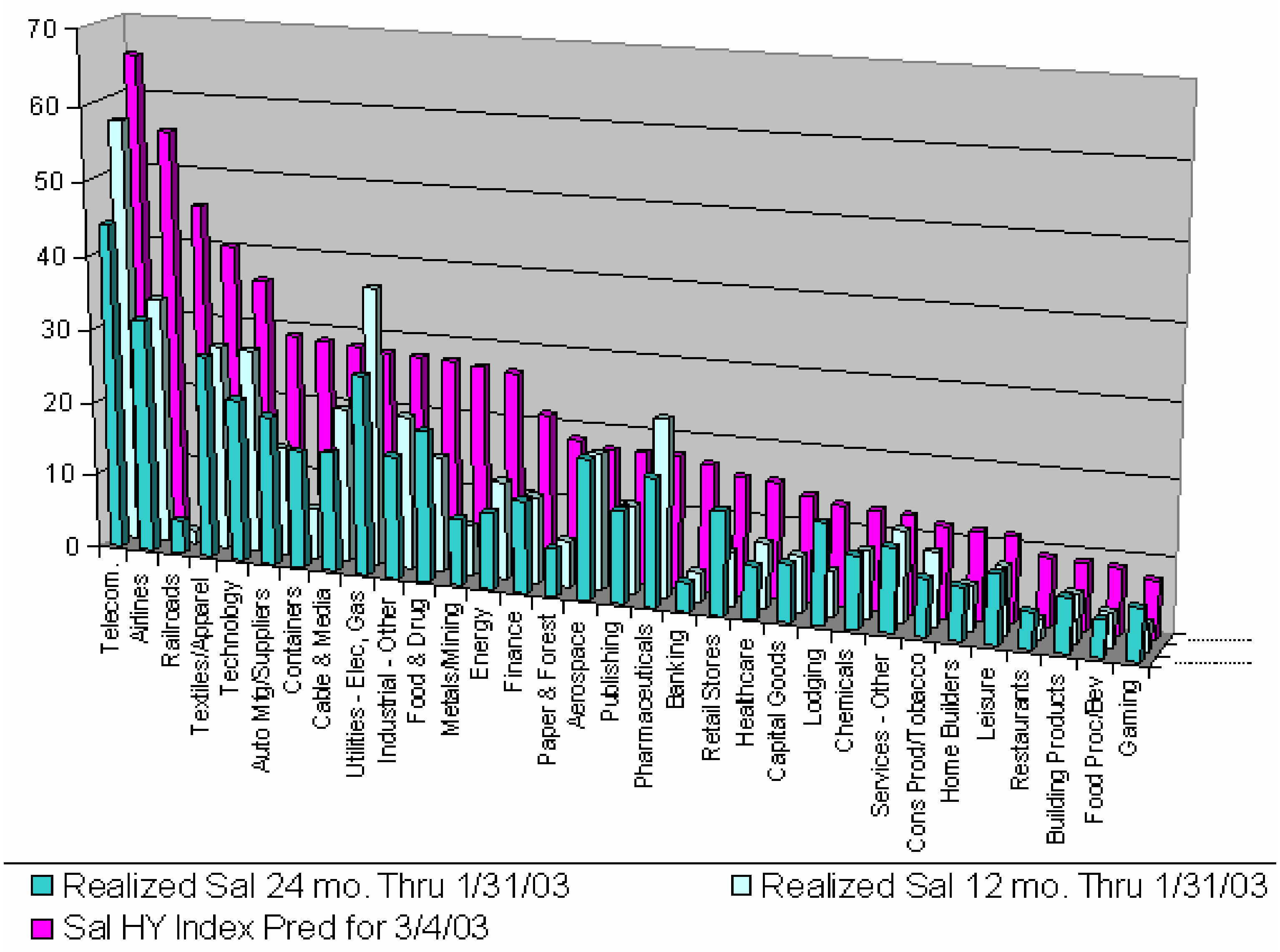
High Yield bonds testing and corrections

Citi HY index predictions (by industry) were found to be more volatile than realized volatility:



High Yield bonds testing and corrections

In the YB TE Module, Spread Return, ***in general***, is estimated based on spread duration:

(Spread Return) = - P_0 * D * D**(Spread)**

D: Spread Duration of the bond

D(Spread): Simulated OAS change of the bond

P_0: Initial Bond Price

The issue-level **spread move** is approximated by a weighted sum of two relevant sector-level moves.

The first sector is based on rating,maturity and industry sector; the second sector is based on industry sub-sector:

$$\Delta S = a \Delta S_1 + b \Delta S_2$$

ΔS: Simulated issue-level spread change

ΔS_1: Simulated spread move of rating, maturity and industry sector;

ΔS_2: Simulated spread move of industry sub-sector;

a,b: Pre-determined coefficients based on regression; *coefficients are updated at the beginning of each month.*

High Yield bonds testing and corrections

- However, the high yield market is very fragmented and tough to quantify!
  - Pricing is less consistent
  - this market is poorly described by aggregate credit curves
  - industry sub-sectors contain only 10 to 20 bonds
  - company-related idiosyncratic factors
  - at the same time, companies also driven by sector-specific events
- YB model uses a different approach for spread change calculation:

$$\Delta S = \frac{\sigma}{\sigma_s} \Delta S_s$$

Where:

ΔS: Simulated issue-level spread change

ΔSs: Simulated spread move of the aggregated high yield industry sub-sector

σ: Issue-level historical volatility of OAS *level*

σs: (Sub)sector-level historical volatility of OAS *level*

The bond's return due to spread change remains as for a corporate bond:

(Spread Return) = - P_0 * D * D**(Spread)**

High Yield bonds testing and corrections

- Use of **OAS *level* volatility** to calculate the issue-level spread change:
  - Missing or unchanged data: flat OAS time-series due to illiquid high-yield bonds
  - But, during spread tightening periods – may be too high
    - This is what our research results revealed
- YB changed the OAS level volatility to instead use OAS change volatility.

$$\Delta S = \frac{\boldsymbol{s}}{\boldsymbol{s}_{s}} \Delta S_{s}$$

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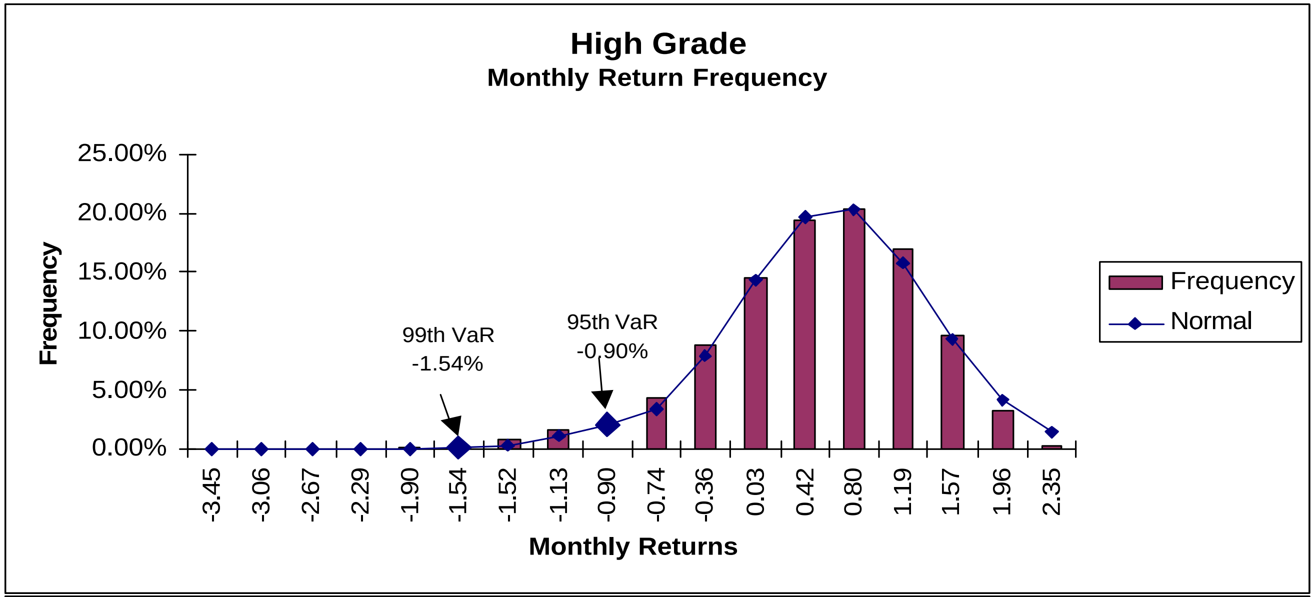
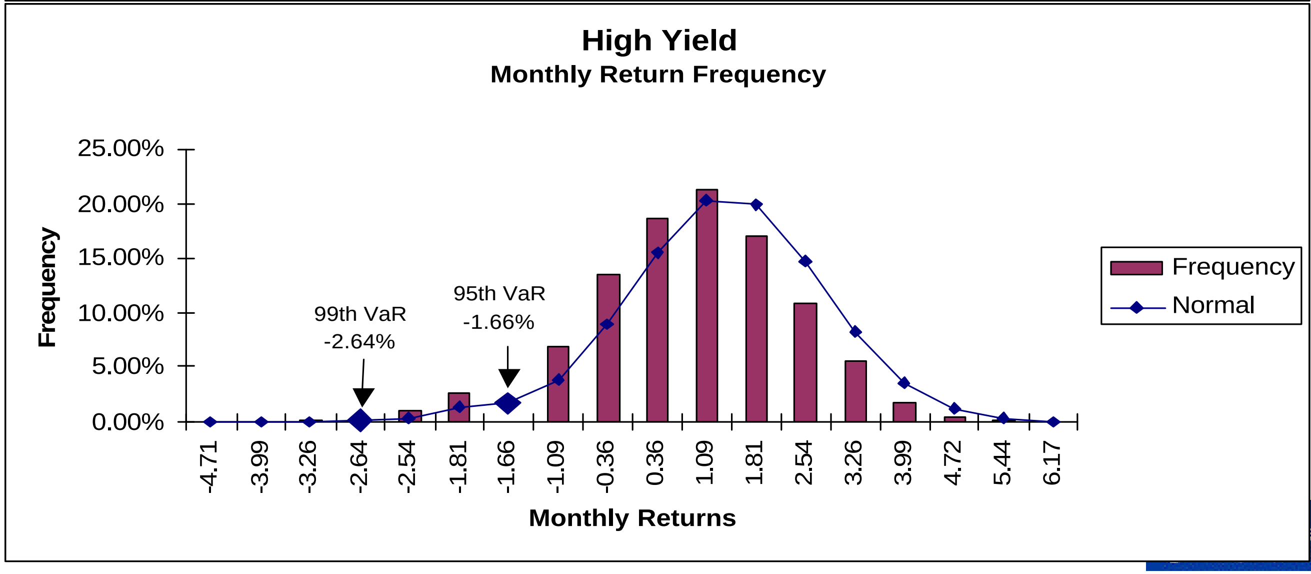
High Yield bonds testing and corrections

Subsequent testing of predictive versus empiricals, after changes, revealed:

- Much better volatility and tracking error results between portfolios and benchmarks:
  - Fund volatilities match empirical return volatilities much better.
  - Tracking error of funds to high yield market benchmarks is much closer to expectations (and, in general, about 25% of the funds' volatilities).
- But it is still the case that:
  - The benchmark predictions are still somewhat higher than empiricals.
    - Expected since total issue-level spread volatility is not decomposed into systematic and non-systematic components.
  - The risk calculations reflect that remaining inconsistency by indicating betas lower than our expectations.
- We also know that:
  - Selected industries volatilities predictions are much closer to empiricals (utilities and pharmaceutical) than others (telecomm and airlines). The more volatile industries do not map as well.
  - Also, high yield volatilities have gone from 150 bps (annualized) to over 350 bps during the past three+ years. So, such significantly moving historical data will throw off the predictions.
  - We are focusing on selected industries.

Value-at-Risk





Risk Budgeting Measures

- Risk budgeting measures are numbers that quantify risk exposures attributable to a specific sector. These include:
  - Incremental tracking error
  - Marginal tracking error
  - Component tracking error

Incremental TE

- Definition:

  Incremental TE = TE(all holdings) – TE(holdings in a sector eliminated)

Incremental TE captures the change of total risk exposure when you sell out an entire sector in your portfolio.

Marginal TE

- Definition:

  Marginal TE = $\frac{\Delta(\text{Tracking Error})}{\Delta(\text{Market "Weight" of a Sector})}$

Marginal TE captures the change of total risk exposure when you increase your bet on a sector by small amount

Component TE

- Definition:

  Component TE = $$\frac{COV(w_i R_i - u_i Q_i, r)}{\sqrt{COV(r,r)}}$$

  r : total return difference (portfolio vs. benchmark)

  w_i (u_i) : market weight of a sector in portfolio (benchmark)

  R_i (Q_i) : return of a sector in portfolio (benchmark)

- Component TE is an <u>additive risk measure</u> because it sums up to the total risk exposure.

Hedging via Risk Budgeting
Component Tracking Error

THE YIELD BOOK

Component Tracking Error
(TE is based on percent return difference)

Portfolio ID: foptim1
Description: foptim1 v. FUND061n

Compounding Frequency : Semi-annual
Base currency : USD

PORTNAME	NIss	%Par	%Mkt	%Edur	EDur	SPRDDUR	YTM	OAS	VOL(Tot)	VOL(Curve)	VOL(Sprd)	VOL(ccy)	VOL(Vol)
TOTALS													
foptim1	52	100.0	100.0	100.0	0.00	4.727	6.31	223	100.000	3.106	94.713	0.264	0.149
FUND061n	45	100.0	100.0	100.0	5.49	4.727	6.31	223	100.000	63.868	27.257	9.247	-0.910
Difference:		0.0	0.0	0.0	-5.49	0.000	0.00	0	100.000	92.206	0.000	7.794	0.000
DEV MARKETS													
foptim1	11	*****	5.5	*****	-98.01	2.494	4.86	117	31.862	38.817	0.163	-7.288	0.000
FUND061n	4	5.6	5.5	1.2	2.52	2.494	4.86	117	2.050	1.495	0.097	0.407	0.000
Difference:		*****	0.0	*****	******	0.000	0.00	0	100.000	92.206	0.000	7.794	0.000
o DEV - US													
foptim1	2	27.9	6.8	1.9	1.44	1.439	4.13	69	-0.537	-0.559	0.022	0.000	0.000
FUND061n	2	6.7	6.8	0.9	1.44	1.439	4.13	69	1.329	1.239	0.089	0.000	0.000
Difference:		21.3	0.0	1.0	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000	0.000
o DEV - GERM	ANY												
foptim1	1	3.3	0.9	0.5	3.87	3.766	4.22	135	0.279	-0.182	0.002	0.293	0.000
FUND061n	1	0.8	0.9	0.3	3.87	3.766	4.22	135	1.070	0.195	0.001	0.823	0.000
Difference:		2.5	0.0	0.3	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000	0.000
EMG US$													
foptim1	36	357.8	85.9	201.0	5.99	5.122	6.45	233	66.497	-35.410	94.549	5.609	0.149
FUND061n	36	85.6	85.9	96.8	5.99	5.122	6.45	233	96.218	61.834	27.160	7.647	-0.910
Difference:		272.1	0.0	104.2	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000	0.000
o EMUS$ - ARG	ENTINA												
foptim1	2	20.1	3.9	2.6	3.38	3.361	6.13	200	2.095	-0.887	2.980	0.000	0.000
FUND061n	2	4.8	3.9	1.2	3.38	3.361	6.13	200	2.806	1.610	1.196	0.000	0.000
Difference:		15.3	0.0	1.3	0.00	0.000	0.00	0	0.000	0.000	0.000	0.000	0.000

Hedging via Risk Budgeting

Tracking Error

THE YIELD BOOK

Tracking Error Report

Portfolio ID: foptim1
Description: foptim1 v. FUND061

Compounding Frequency : Semi-annual
Base currency : USD

Portfolio Name	No Iss	PctMkt Base	Eff DUR	Sprd DUR	Eff CVX	OAS	Total Vol	Curve Vol	Level Vol	Slope Vol	Shape Vol	Sprd Vol	Curr Vol
TOTALS													
foptim1	52	100.0	0.00	4.73	0.35	223	103	15	14.8	2.4	3.6	101	0.7
FUND061	45	100.0	5.49	4.73	0.61	223	188	151	148.9	21.7	12.7	101	25.1
Difference:		0.0	-5.49	0.00	-0.27	0	178	165	163.5	23.9	9.3	0	25.1
DEV MARKETS													
foptim1	11	5.5	-97.99	2.49	-4.79	117	3051	2844	2809.3	430.0	154.2	6	419.8
FUND061	4	5.5	2.52	2.49	0.09	117	86	65	63.0	10.8	11.3	6	24.0
Difference:		0.0	******	0.00	-4.88	0	3126	2906	2872.1	420.0	164.0	0	441.3
o DEV - US													
foptim1	2	6.8	1.44	1.44	0.04	69		43	41.6	7.4	9.8	4	0.0
FUND061	2	6.8	1.44	1.44	0.04	69		43	41.6	7.4	9.8	4	0.0
Difference:		0.0	0.00	0.00	0.00	0		0	0.0	0.0	0.0	0	0.0
o DEV - GERMANY													
foptim1	1	0.9	3.87	3.77	0.21	135		65	64.3	3.8	10.0	1	300.4
FUND061	1	0.9	3.87	3.77	0.21	135		65	64.3	3.8	10.0	1	300.4
Difference:		0.0	0.00	0.00	0.00	0		0	0.0	0.0	0.0	0	0.0
EMG US$													
foptim1	36	85.9	5.99	5.12	0.70	233	203	163	160.6	24.8	13.6	112	22.5
FUND061	36	85.9	5.99	5.12	0.70	233	203	163	160.6	24.8	13.6	112	22.5
Difference:		0.0	0.00	0.00	0.00	0	0	0	0.0	0.0	0.0	0	0.0
o EMUS$ - ARGENTINA													
foptim1	2	3.9	3.38	3.36	0.18	200		95	94.7	3.2	10.3	85	0.0
FUND061	2	3.9	3.38	3.36	0.18	200		95	94.7	3.2	10.3	85	0.0
Difference:		0.0	0.00	0.00	0.00	0		0	0.0	0.0	0.0	0	0.0

Handling missing capabilities today

- EM CDS (buy or sell protection)
  - Underlying bond in CDS (credit risk impact)
  - Interest rate swap used for PV01-neutrality.
  - Cash offset (for buying protection → “unfunded” mkt val; i.e., int rt swap + cash bond + cash = 0 MV)
- Swaptions or options
  - Capture delta impact via underlying security or proxy
    - Use swaps as swaptions proxies
    - Notional value adjusted by delta
    - Recalibrate deltas weekly (for weekly runs)
- External tracking error combination
  - Use YB volatility outputs and combine with external calculations
  - Calculate local emerging markets tracking error using Bloomberg data

Municipals

- "Shoe-horn" into Yield Book
- Issues that needed to be overcome:
  - Muni security type defines muni curve use at present.
  - Lack of muni curves (can load own…but one-at-a-time)
  - No facility for pre-refunding (high yield bond becomes a virtual treasury bond)
  - Need to incorporate inverse floaters (leveraged munis)
  - Specifications for various sinker retirement provisions (e.g., optional double sinker versus mandatory sinker
  - Tend to be called on first call date (change specs in YB)
  - Specifications of inverse floaters
    - Index (BMA not in YB)
    - Price/performance approximation
  - Testing in risk model as corporate bonds….

Other analyses

- Fund complex risks (aggregate all funds)
  - For senior management and boards
  - Betas to market (S&P/Citi BIG/MSCI World)
  - Compare funds' volatilities to market
  - VaR analyses
- Counterparty analyses
  - Estimate VaR of counterparties
    - Aggregate as one portfolio
    - Combine fixed income and equities
  - Credit risk
    - use right side of the distribution (our gain is our loss!)
    - Incorporate joint probabilities-of-default across counterparties

Future expectations

- Use of historical distributions for simulation
- Additional emerging market countries
- Stressing correlation matrix
- Derivatives coverage – options on futures, swaptions, etc.
- VaR – need to formalize parameters and outputs including better fat tails estimation
- Longer horizon periods desired (3 months to 1 year)
- Portfolio optimization using tracking error constraints