Applied Fixed Income Risk Modeling
Successes and…Learning Experiences

Navin Sharma
VP, Director of Fixed Income Risk Management and Analytics
OppenheimerFunds, Inc.
Northfield’s 18th Annual Research Conference
July 2005
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.
Inhouse approach was:

In general,

\[ \sigma_p^2 = w_1^2 \sigma_{11}^2 + 2w_1w_2 \sigma_{12} + w_2^2 \sigma_{22}^2 \ldots \]

\[ w_i = \text{weights of portfolio holdings} \]

\[ \sigma_{ij} = \text{return covariance matrix member} \]

\[ \sigma_p^2 = X^T \Sigma X \]

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

\[ \sigma^2 \left( \frac{\Delta P}{P} \right) = (MD)^2 \sigma^2 (\Delta y) \]
Regression/factor approach

In general,

\[ r_i = a_i + b_{i1} f_1 + \ldots + b_{ik} f_k + \varepsilon_i \]

\( r_i \) = excess return of holding \( i \)

\( f_k \) = return of factor \( j \)

\( b_{ik} \) = \( r_i \) sensitivity to factor \( k \)

\( \varepsilon_i \) = residual return \( i \)

Example: Wilshire Axiom

1. Regress excess return against shifts in YC

   \[
   \text{Excess Return} = \text{factor return}_{\text{to parallel}} \cdot 1 + \text{factor return}_{\text{to parallel}} \cdot \beta_1 + \text{factor return}_{\text{to steepening}} \cdot 1 + \text{factor return}_{\text{to steepening}} \cdot \beta_2 + \text{factor return}_{\text{to curve}} \cdot 1 + \text{factor return}_{\text{to curve}} \cdot \beta_3 + \text{residual return} 
   \]

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:

excess return = \( \beta_1 \left( \frac{dP}{dy} \right)_{\text{parallel}} + \beta_2 \left( \frac{dP}{dy} \right)_{\text{steepening}} + \beta_3 \left( \frac{dP}{dy} \right)_{\text{curve}} + \beta_4 \left( \frac{dP}{dy} \right)_{\text{sector spread}} + \ldots \)

Simulation-based:

1. Repeated draws from \( \Delta PC \) multivariate normal distribution
2. Run MC scenario analysis using set of \( \Delta PC \) from above
3. Aggregate to obtain price distribution ➔
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 $\Delta PC$ (e.g. $2\sigma$)
5. Transform change in PC to bond space (i.e., map PC factors to market risk factors; two examples below)

Yield Curve:
   a. Determine that a $2\sigma$ $\Delta PC$ 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).

Spreads:
   a. Determine that a $2\sigma$ 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

<table>
<thead>
<tr>
<th></th>
<th>US 1</th>
<th>US 2</th>
<th>US 3</th>
<th>EMU 1</th>
<th>EMU 2</th>
<th>EMU 3</th>
<th>UK 1</th>
<th>UK 2</th>
<th>UK 3</th>
<th>YEN 1</th>
<th>YEN 2</th>
<th>YEN 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.89</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.87</td>
<td>0.03</td>
<td>-0.25</td>
<td>-0.11</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>US 2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.64</td>
<td>-0.11</td>
<td>0.06</td>
<td>0.65</td>
<td>0.15</td>
<td>-0.02</td>
<td>0.41</td>
<td>-0.27</td>
</tr>
<tr>
<td>US 3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.12</td>
<td>0.24</td>
<td>0.22</td>
<td>0.09</td>
<td>0.33</td>
<td>0.36</td>
<td>0.24</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>EMU 1</td>
<td>0.89</td>
<td>0</td>
<td>0.12</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0.92</td>
<td>0</td>
<td>0.04</td>
<td>-0.11</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>EMU 2</td>
<td>0.03</td>
<td>0.64</td>
<td>0.24</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.14</td>
<td>0.71</td>
<td>-0.02</td>
<td>0.13</td>
<td>0.3</td>
<td>-0.11</td>
</tr>
<tr>
<td>EMU 3</td>
<td>-0.18</td>
<td>-0.11</td>
<td>0.22</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.12</td>
<td>-0.18</td>
<td>0.6</td>
<td>-0.03</td>
<td>0.02</td>
<td>0.17</td>
</tr>
<tr>
<td>UK 1</td>
<td>0.87</td>
<td>0.06</td>
<td>0.09</td>
<td>0.92</td>
<td>0.14</td>
<td>0.12</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>-0.11</td>
<td>0.13</td>
<td>0.19</td>
</tr>
<tr>
<td>UK 2</td>
<td>0.03</td>
<td>0.65</td>
<td>0.33</td>
<td>0</td>
<td>0.71</td>
<td>-0.18</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.07</td>
<td>0.6</td>
<td>-0.11</td>
</tr>
<tr>
<td>UK 3</td>
<td>-0.25</td>
<td>0.15</td>
<td>0.36</td>
<td>0.04</td>
<td>-0.02</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.14</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>YEN 1</td>
<td>-0.11</td>
<td>-0.02</td>
<td>0.24</td>
<td>-0.11</td>
<td>0.13</td>
<td>-0.03</td>
<td>-0.11</td>
<td>0.07</td>
<td>0.14</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>YEN 2</td>
<td>0.03</td>
<td>0.41</td>
<td>0.21</td>
<td>0.09</td>
<td>0.3</td>
<td>0.02</td>
<td>0.13</td>
<td>0.6</td>
<td>0.1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>YEN 3</td>
<td>0.03</td>
<td>-0.27</td>
<td>0.21</td>
<td>0.14</td>
<td>-0.11</td>
<td>0.17</td>
<td>0.19</td>
<td>-0.11</td>
<td>0.04</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- **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)
Curves Risk PCs

Principal Component #1 of the UST curve movements
## Yield Curve risk factors

### Curve Data for Each Market

<table>
<thead>
<tr>
<th>Country</th>
<th>Curve</th>
<th>Maturity</th>
<th>3m</th>
<th>6m</th>
<th>1Y</th>
<th>2Y</th>
<th>3Y</th>
<th>4Y</th>
<th>5Y</th>
<th>6Y</th>
<th>7Y</th>
<th>8Y</th>
<th>9Y</th>
<th>10Y</th>
<th>15Y</th>
<th>20Y</th>
<th>25Y</th>
<th>30Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>On The Run</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMU</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Swap</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. Africa</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Czech</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Zealand</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td>Swap*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Returns impacts on a bond for five specified standard deviation movements of PC #1

Return vs. PC1 move

-2 -1 0 1 2

PC1 move (unit: std)

-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2

Return

1.67334 1.23876 0.444121 -0.677958 -2.12611

Returns impacts on a bond for five specified standard deviation movements of PC #1.
## Risk factors perturbations (values in bp/month)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Number of factors</th>
<th>New</th>
<th>VAR</th>
<th>MAD</th>
<th>Median</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
<th>Value at Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>HY yield fund</td>
<td>404</td>
<td>100</td>
<td>100</td>
<td>3.76</td>
<td>261.3</td>
<td>117.5</td>
<td>101.1</td>
<td>19.9</td>
<td>8.0</td>
<td>521.8</td>
<td>21</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking error</td>
<td>3.3</td>
<td>3</td>
<td>237.7</td>
<td>315</td>
<td>90.4</td>
<td>45.7</td>
<td>33.3</td>
<td>4.8</td>
<td>598.8</td>
<td>6.6</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HY yield (index)</td>
<td>404</td>
<td>100</td>
<td>100</td>
<td>3.76</td>
<td>261.3</td>
<td>112.0</td>
<td>10.9</td>
<td>19.7</td>
<td>7.6</td>
<td>321.6</td>
<td>0.0</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HY yield (GAL INDEX)</td>
<td>1023</td>
<td>100</td>
<td>100</td>
<td>3.58</td>
<td>452.4</td>
<td>130.3</td>
<td>45.7</td>
<td>33.3</td>
<td>4.9</td>
<td>500.6</td>
<td>0.0</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>3.3</td>
<td>3</td>
<td>237.7</td>
<td>315</td>
<td>90.4</td>
<td>45.7</td>
<td>33.3</td>
<td>4.8</td>
<td>598.8</td>
<td>6.6</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total Return Volatility

- 0.5% annual total volatility of 261.8 bps
- 0.5% annual total volatility of 452.4 bps

### Currency Volatility

- 0.5% annual currency volatility of 2.1 bps

### Difference of Tracking Error

- 0.2% annual tracking error volatility

### Additional Information

- ATE of 0.5% or more implies that the fund and benchmark returns will differ by an average of 0.5% per year
- ATE of 0.2% implies that the fund and benchmark returns will differ by an average of 0.2% per year
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, \textit{in general}, is estimated based on spread duration:

\[(\text{Spread Return}) = - P_0 \ast D \ast \Delta(\text{Spread})\]

D: Spread Duration of the bond

\[\Delta(\text{Spread}): \text{Simulated OAS change of the bond}\]

\[P_0: \text{Initial Bond Price}\]

The issue-level \textbf{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:

\[
\Delta S = a \Delta S_1 + b \Delta S_2
\]

\[\Delta S: \text{Simulated issue-level spread change}\]

\[\Delta S_1: \text{Simulated spread move of rating, maturity and industry sector;}\]

\[\Delta S_2: \text{Simulated spread move of industry sub-sector;}\]

a, b: Pre-determined coefficients based on regression; \textit{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:

\(\Delta S\): Simulated issue-level spread change

\(\Delta S_s\): Simulated spread move of the aggregated high yield industry sub-sector

\(\sigma\): Issue-level historical volatility of OAS level

\(\sigma_s\): (Sub)sector-level historical volatility of OAS level

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

\((\text{Spread Return}) = -P_0 \times D \times \Delta(\text{Spread})\)
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.

\[
\Delta S = \frac{\sigma}{\sigma_s} \Delta S_s
\]
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

High Grade

Monthly Return Frequency

99th VaR -1.54%
95th VaR -0.90%

High Yield

Monthly Return Frequency

99th VaR -2.64%
95th VaR -1.66%
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:**
  
  \[
  \text{Component TE} = \frac{COV(w_i R_i - u_i Q_i, r)}{\sqrt{COV(r, r)}}
  \]

  - \( r \): 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 additive risk measure** because it sums up to the total risk exposure.
# Hedging via Risk Budgeting

**Component Tracking Error**

(TE is based on percent return difference)

<table>
<thead>
<tr>
<th>PORTNAME</th>
<th>Niss</th>
<th>%Par</th>
<th>%Mkt</th>
<th>%Eur</th>
<th>EDur</th>
<th>SPDUR</th>
<th>YTM</th>
<th>OAS</th>
<th>VOL(Tot)</th>
<th>VOL(Curve)</th>
<th>VOL(Sprd)</th>
<th>VOL(ccy)</th>
<th>VOL(Vol)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>52</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
<td>4.727</td>
<td>6.31</td>
<td>223</td>
<td>100,000</td>
<td>3,108</td>
<td>94,713</td>
<td>0.264</td>
<td>0.149</td>
</tr>
<tr>
<td>FUND601n</td>
<td>45</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>5.49</td>
<td>4.727</td>
<td>6.31</td>
<td>223</td>
<td>100,000</td>
<td>63,868</td>
<td>27,257</td>
<td>9.247</td>
<td>-0.910</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>-5.49</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>32,752</td>
<td>24,100</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>DEV MARKETS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>11</td>
<td>5.5</td>
<td>5.5</td>
<td>1.2</td>
<td>2.52</td>
<td>2.494</td>
<td>2.46</td>
<td>117</td>
<td>31,862</td>
<td>38,317</td>
<td>0.163</td>
<td>-7,288</td>
<td>0.000</td>
</tr>
<tr>
<td>FUND601n</td>
<td>4</td>
<td>5.5</td>
<td>5.5</td>
<td>1.2</td>
<td>2.52</td>
<td>2.494</td>
<td>2.46</td>
<td>117</td>
<td>20,590</td>
<td>1,495</td>
<td>0.097</td>
<td>0.407</td>
<td>0.000</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>10,272</td>
<td>36,822</td>
<td>0.000</td>
<td>7,794</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>o DEV - US</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>2</td>
<td>6.7</td>
<td>6.8</td>
<td>1.9</td>
<td>1.44</td>
<td>1.439</td>
<td>1.43</td>
<td>69</td>
<td>-0.559</td>
<td>-0.022</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>FUND601n</td>
<td>2</td>
<td>6.7</td>
<td>6.8</td>
<td>1.9</td>
<td>1.44</td>
<td>1.439</td>
<td>1.43</td>
<td>69</td>
<td>1.329</td>
<td>1.239</td>
<td>0.038</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>o DEV - GERM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>1</td>
<td>3.3</td>
<td>0.9</td>
<td>0.5</td>
<td>3.87</td>
<td>3.766</td>
<td>4.22</td>
<td>125</td>
<td>0.279</td>
<td>-0.182</td>
<td>0.002</td>
<td>0.293</td>
<td>0.000</td>
</tr>
<tr>
<td>FUND601n</td>
<td>1</td>
<td>0.8</td>
<td>0.9</td>
<td>0.3</td>
<td>3.87</td>
<td>3.766</td>
<td>4.22</td>
<td>125</td>
<td>1.070</td>
<td>0.195</td>
<td>0.001</td>
<td>0.823</td>
<td>0.000</td>
</tr>
<tr>
<td>Difference:</td>
<td>2.5</td>
<td>0.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>EM100 Fd</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>36</td>
<td>85.6</td>
<td>85.9</td>
<td>96.8</td>
<td>5.99</td>
<td>5.122</td>
<td>6.45</td>
<td>233</td>
<td>66.497</td>
<td>61.834</td>
<td>27.160</td>
<td>7.647</td>
<td>-0.910</td>
</tr>
<tr>
<td>FUND601n</td>
<td>36</td>
<td>85.6</td>
<td>85.9</td>
<td>96.8</td>
<td>5.99</td>
<td>5.122</td>
<td>6.45</td>
<td>233</td>
<td>66.497</td>
<td>61.834</td>
<td>27.160</td>
<td>7.647</td>
<td>-0.910</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>o EM100 - ARG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>optim1</td>
<td>2</td>
<td>20.1</td>
<td>3.9</td>
<td>2.6</td>
<td>3.38</td>
<td>3.361</td>
<td>6.13</td>
<td>200</td>
<td>2.095</td>
<td>-0.887</td>
<td>2.980</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>FUND601n</td>
<td>2</td>
<td>4.8</td>
<td>3.9</td>
<td>1.2</td>
<td>3.38</td>
<td>3.361</td>
<td>6.13</td>
<td>200</td>
<td>2.896</td>
<td>1.510</td>
<td>1.196</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Difference:</td>
<td>15.3</td>
<td>0.0</td>
<td>1.4</td>
<td>1.4</td>
<td>0.00</td>
<td>0.000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Portfolio ID: optim1
Description: optim1 v. FUND601n
Compounding Frequency: Semi-annual
Base currency: USD
## Hedging via Risk Budgeting

### Tracking Error Report

<table>
<thead>
<tr>
<th>Portfolio Name</th>
<th>No Iss</th>
<th>FmtMkt</th>
<th>Eff DUR</th>
<th>Spd DUR</th>
<th>Eff CVX</th>
<th>OAS</th>
<th>Total Val</th>
<th>Curve Vol</th>
<th>Level Val</th>
<th>Slope Val</th>
<th>Shape Val</th>
<th>Spd Vol</th>
<th>Curr Val</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>52</td>
<td>100.0</td>
<td>0.00</td>
<td>4.73</td>
<td>0.35</td>
<td>223</td>
<td>103</td>
<td>35</td>
<td>14.8</td>
<td>2.4</td>
<td>3.6</td>
<td>101</td>
<td>0.7</td>
</tr>
<tr>
<td>FUND061</td>
<td>45</td>
<td>100.0</td>
<td>5.49</td>
<td>4.73</td>
<td>0.61</td>
<td>223</td>
<td>188</td>
<td>151</td>
<td>148.9</td>
<td>21.7</td>
<td>12.7</td>
<td>101</td>
<td>25.1</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>-5.49</td>
<td>0.00</td>
<td>-0.27</td>
<td>0</td>
<td>178</td>
<td>165</td>
<td>163.5</td>
<td>23.9</td>
<td>9.3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEV MARKETS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>11</td>
<td>5.5</td>
<td>-9.99</td>
<td>2.49</td>
<td>-4.79</td>
<td>117</td>
<td>3051</td>
<td>2844</td>
<td>2809.3</td>
<td>430.0</td>
<td>154.2</td>
<td>6</td>
<td>419.8</td>
</tr>
<tr>
<td>FUND061</td>
<td>4</td>
<td>5.5</td>
<td>2.52</td>
<td>2.49</td>
<td>0.09</td>
<td>117</td>
<td>36</td>
<td>65</td>
<td>63.0</td>
<td>10.8</td>
<td>11.3</td>
<td>6</td>
<td>24.0</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>******</td>
<td>0.00</td>
<td>-4.88</td>
<td>0</td>
<td>3126</td>
<td>2906</td>
<td>2872.1</td>
<td>420.0</td>
<td>164.0</td>
<td>0</td>
<td>441.3</td>
<td></td>
</tr>
<tr>
<td>o DEV - US</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>2</td>
<td>6.8</td>
<td>1.44</td>
<td>1.44</td>
<td>0.04</td>
<td>69</td>
<td>43</td>
<td>41.6</td>
<td>7.4</td>
<td>9.8</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FUND061</td>
<td>2</td>
<td>6.8</td>
<td>1.44</td>
<td>1.44</td>
<td>0.04</td>
<td>69</td>
<td>43</td>
<td>41.6</td>
<td>7.4</td>
<td>9.8</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>o DEV - GERMANY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>1</td>
<td>0.9</td>
<td>3.87</td>
<td>3.77</td>
<td>0.21</td>
<td>135</td>
<td>65</td>
<td>64.3</td>
<td>3.8</td>
<td>10.0</td>
<td>1</td>
<td>300.4</td>
<td></td>
</tr>
<tr>
<td>FUND061</td>
<td>1</td>
<td>0.9</td>
<td>3.87</td>
<td>3.77</td>
<td>0.21</td>
<td>135</td>
<td>65</td>
<td>64.3</td>
<td>3.8</td>
<td>10.0</td>
<td>1</td>
<td>300.4</td>
<td></td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>EMG US$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>35</td>
<td>85.9</td>
<td>5.99</td>
<td>5.12</td>
<td>0.70</td>
<td>233</td>
<td>203</td>
<td>163</td>
<td>160.6</td>
<td>24.8</td>
<td>13.6</td>
<td>112</td>
<td>22.5</td>
</tr>
<tr>
<td>FUND061</td>
<td>35</td>
<td>85.9</td>
<td>5.99</td>
<td>5.12</td>
<td>0.70</td>
<td>233</td>
<td>203</td>
<td>163</td>
<td>160.6</td>
<td>24.8</td>
<td>13.6</td>
<td>112</td>
<td>22.5</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>o EMG US$ - ARGENTINA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foptim1</td>
<td>2</td>
<td>3.9</td>
<td>3.38</td>
<td>3.36</td>
<td>0.18</td>
<td>200</td>
<td>95</td>
<td>94.7</td>
<td>3.2</td>
<td>10.3</td>
<td>85</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>FUND061</td>
<td>2</td>
<td>3.9</td>
<td>3.38</td>
<td>3.36</td>
<td>0.18</td>
<td>200</td>
<td>95</td>
<td>94.7</td>
<td>3.2</td>
<td>10.3</td>
<td>85</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Difference:</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
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