Risk Budgeting for Pension Plans

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What is a risk budget?

budg·et (bŭj'ĭt)

n.

- An **itemized summary of** estimated or intended **expenditures** for a given period along with proposals for financing them: *submitted the annual budget to Congress.*
- A **systematic plan for the expenditure of a** usually **fixed resource**, such as money or time, during a given period: *A new car will not be part of our budget this year.*
- The **total sum** of money **allocated for a particular purpose** or period of time: *a project with an annual budget of five million dollars.*

v., -et·ed, -et·ing, -ets.

- To **plan in advance the expenditure of**: *needed help budgeting our income; budgeted my time wisely.*
- To enter or **account for in a budget**: *forgot to budget the car payments.*
- To **make or use a budget**.

Source: The American Heritage® Dictionary of the English Language

What is a risk budget?

- Itemized summary of expenditures:
  EXPENDITURE = EXPOSURE or BET

- Systematic plan for the expenditure of a fixed resource:
  FIXED RESOURCE = RISK

- Total sum allocated for a particular purpose:
  TOTAL SUM ALLOCATED = RISK TOLERANCE
  PARTICULAR PURPOSE = GENERATE RETURNS

- Plan in advance the expenditure of:
  EXPENDITURES = ASSET ALLOCATION, MANAGER SELECTION, SECURITY SELECTION, ETC

- Account for in a budget:
  ACCOUNT IN A BUDGET = KNOW YOUR BETS

- Make or use a budget:
  MAKE A BUDGET = TAKE YOUR BETS
  USE A BUDGET = MEASURE AND MONITOR YOUR BETS

Why budget risk?

- The traditional practice is to directly allocate money rather than risk to different asset classes, countries, sectors, and securities
- Budgeting risk can improve the investment process by enforcing discipline, eliminating unintended or disproportionate bets, and balancing the risk and return of each investment decision

Example: equally weighted bets

Asset Class	Bets	Asset Class Returns	Return Contribution (bp)
EM Bonds	-1.0%	18%	-18
Fixed Income	-1.0%	-4%	4
U.S. Large Cap	-1.0%	-14%	14
International Equity	1.0%	17%	17
U.S. Small Cap	1.0%	-18%	-18
Libor	1.0%	0.4%	0.4
Total			**-0.6**

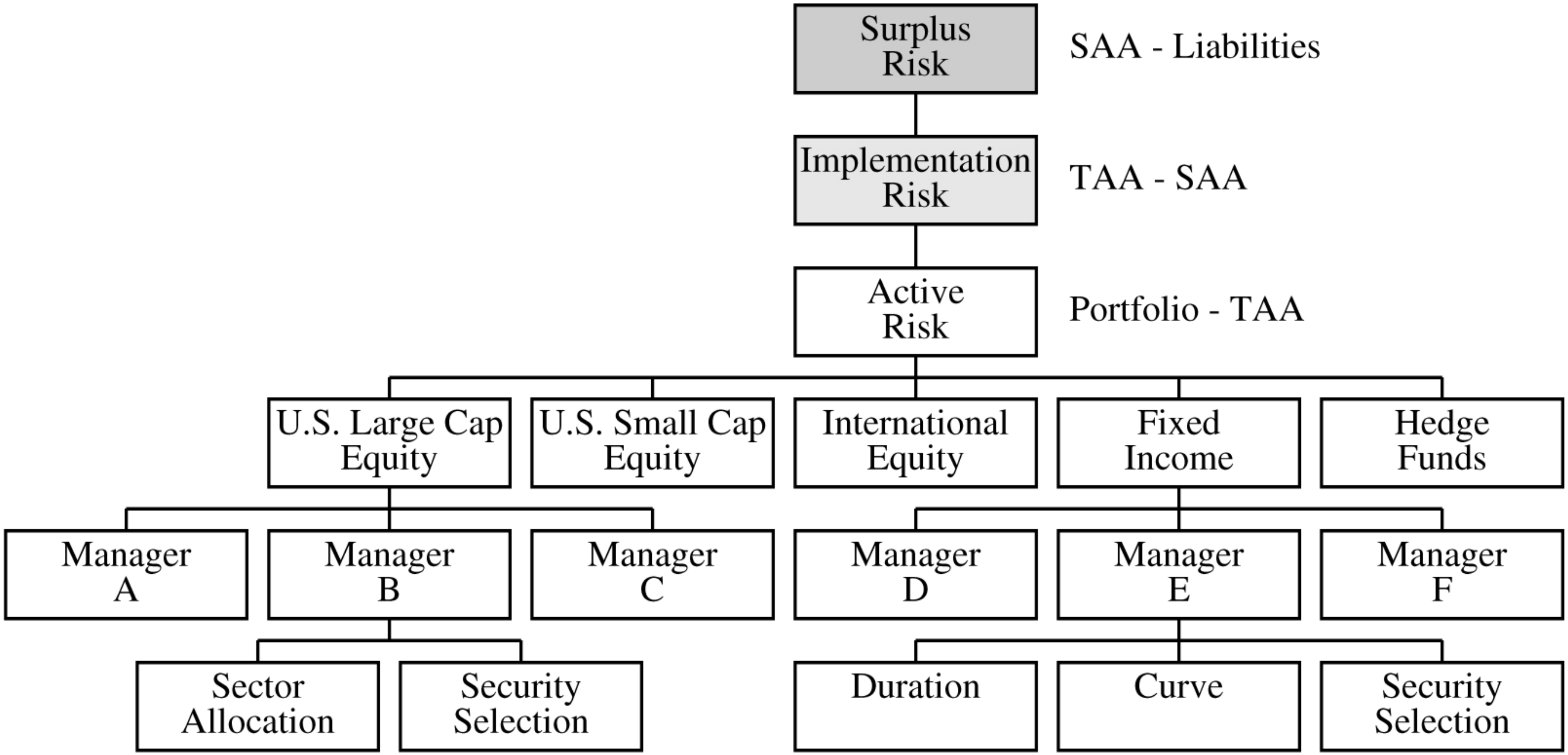
Example: risk weighted bets

Asset Class	Bets	Asset Class Returns	Return Contribution (bp)
EM Bonds	-0.2%	18%	-3.6
Fixed Income	-1.0%	-4%	4
U.S. Large Cap	-0.3%	-14%	4.2
International Equity	0.2%	17%	3.4
U.S. Small Cap	0.2%	-18%	-3.6
Libor	1.1%	0.4%	0.44
Total			**4.84**

Pension fund investing

1. Construct an ALM model and derive a strategic allocation to each asset class considered – Surplus risk or funding risk
2. Set a benchmark for each asset class – Implementation risk
3. Hire managers to invest relative to those benchmarks – Active risk

Overview of risk budgeting process for a pension plan



Risk budgeting can be used to formulate an investment policy

- Asset allocation: selection of asset classes according to the organization's strategic goals (e.g., fund pensions, minimize volatility of earnings)
- Allocation of passive and active risk
- Allocation of active risk across asset classes
- Allocation of active risk to managers within each asset class

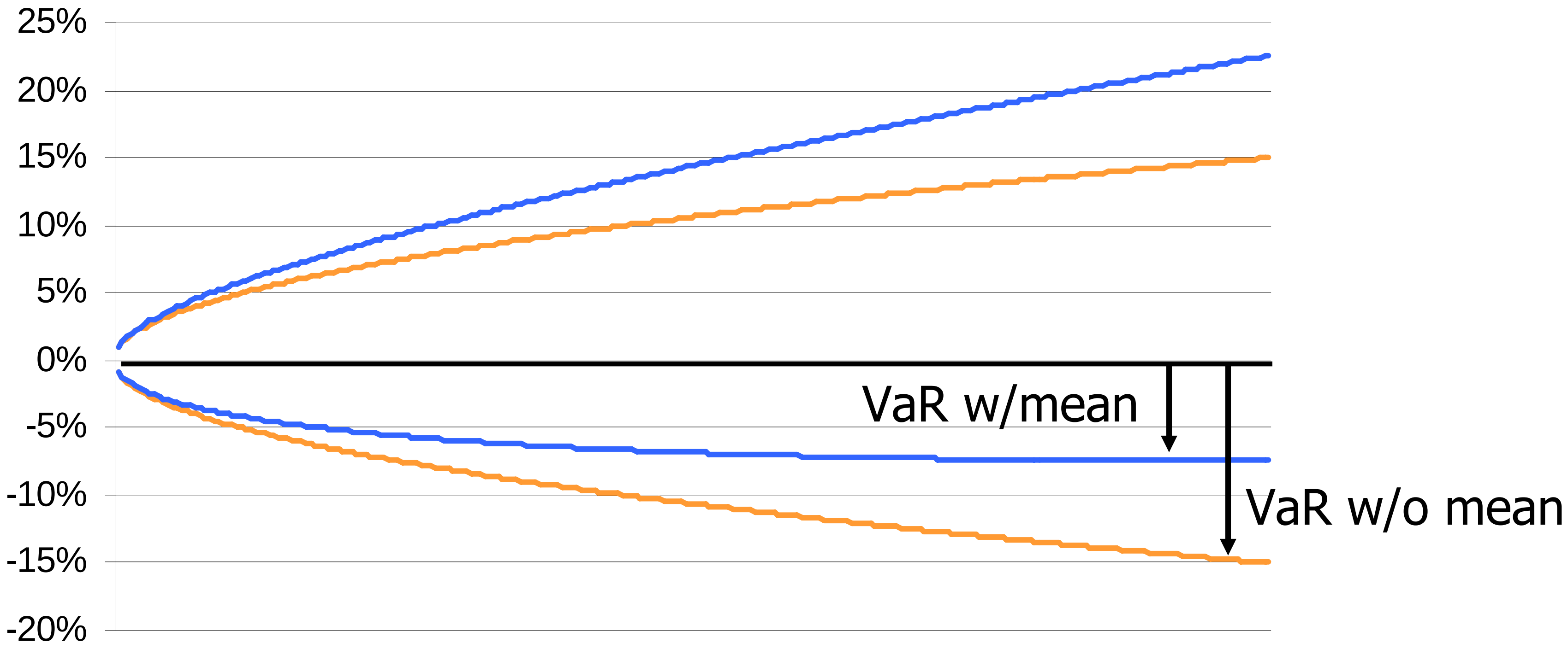
Risk budget: Surplus volatility

					Surplus Volatility			
	Market Value	Allocation	Policy	Delta	Total	Policy	Implementation	Active
Surplus	**1134**				**732**			
Liabilities	**5676**				**337**			
Assets	**6810**	**100%**	**100%**	**0%**	**395**	**315**	**52**	**29**
Equity	**4621**	**68%**	**60%**	**8%**	**408**	**329**	**52**	**28**
Large Cap	2771	41%	40%	1%	219	193	3	22
Small Cap	740	11%	10%	1%	81	71	6	4
International	859	13%	8%	5%	71	44	26	2
Emerging	251	4%	2%	2%	37	20	17	0
Fixed Income	**1689**	**25%**	**30%**	**-5%**	**-32**	**-39**	**7**	**0**
Real Estate	**500**	**7%**	**10%**	**-3%**	**19**	**25**	**-7**	**0**

Numbers in USD MM

Expected returns

Ignoring expected returns leads to overestimation of risk



Risk budget: Surplus at Risk

	Market Value	Allocation	Policy	Delta	Surplus at Risk			
					Total	**Policy**	**Implementation**	**Active**
Surplus	**1134**				**942**			
Liabilities	**5676**				**998**			
Assets	**6810**	**100%**	**100%**	**0%**	**-55**	**-39**	**61**	**-78**
Equity	**4621**	**68%**	**60%**	**8%**	**104**	**143**	**28**	**-67**
Large Cap	2771	41%	40%	1%	62	63	1	-2
Small Cap	740	11%	10%	1%	21	48	4	-31
International	859	13%	8%	5%	0	16	9	-26
Emerging	251	4%	2%	2%	22	16	14	-8
Fixed Income	**1689**	**25%**	**30%**	**-5%**	**-141**	**-165**	**29**	**-4**
Real Estate	**500**	**7%**	**10%**	**-3%**	**-19**	**-16**	**4**	**-7**

Numbers in USD MM

Surplus at Risk is calculated at the 95% level for a one year horizon

Different risk horizons impact volatility forecasting

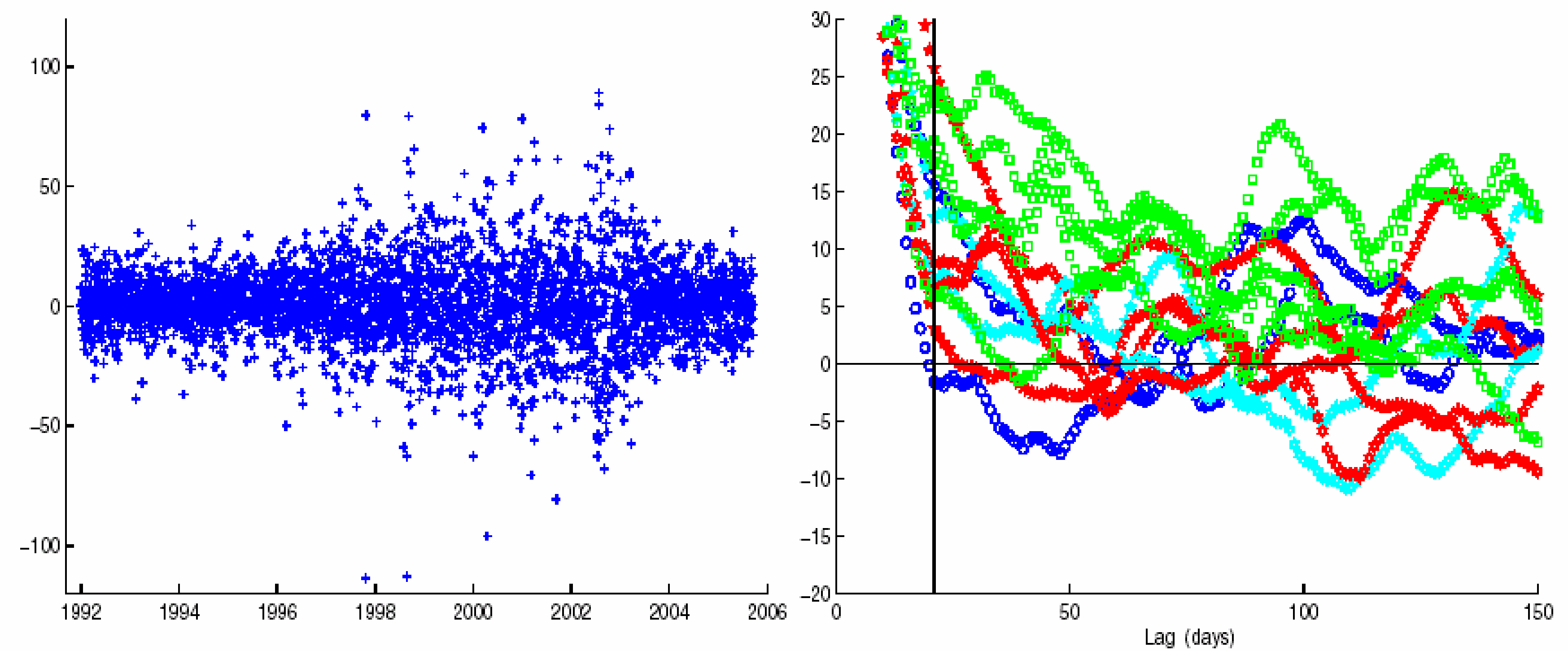
1 month — Short-term

1 year — Medium-term

10+ years — Long-term

- Short-term: monitor managers (external and internal), risk attribution
- Medium-term: tactical asset allocation, regulatory solvency risk (e.g., PVK), earnings risk (linked to accounting rules and planning horizon)
  - One year is short from an actuarial point of view (mortality assumptions not likely to change), but long from a financial and trading point of view (including the amount of data available to study)
  - At a one year horizon the risk of insolvency is remote, but the event that insolvency becomes “closer” is relevant
  - Measure the risk that the “distance” to insolvency drops below some barrier set by regulators
- Long-term: ALM study, solvency risk, contribution risk

Properties of financial time series: heteroskedasticity, volatility clustering and long memory



S&P 500 returns (left) and lagged correlation of return magnitudes (right). Time series represented are equity indices (green), European interest rates (red), US interest rates (light blue), and foreign exchange (blue). The vertical bar indicates a lag of one month.

Taken from Finger and Zumbach (2005)

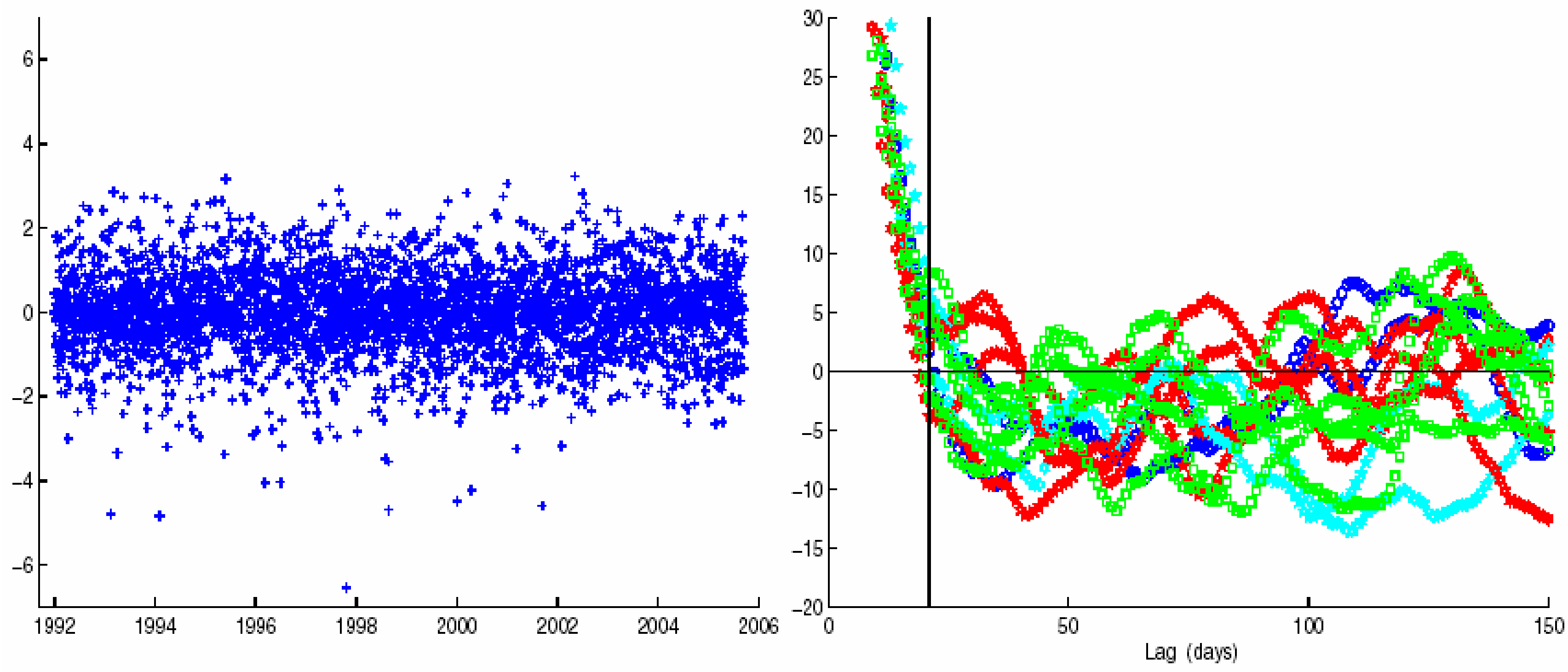
Volatility forecasting

- Short-term
  - Vast literature discussing volatility forecasting at short (one day to one month) horizons
  - Financial returns are heteroskedastic and exhibit volatility clustering
  - Possible to forecast the volatility of future returns given today's information
  - RiskMetrics popularized the use of exponentially weighted moving averages (EWMA) to forecast volatility

- Long-term
  - Moderate amount of literature
  - Recent information less relevant when forecasting volatility at long horizons
  - Mean reversion is important at long horizons

- Medium-term
  - Almost no literature available on the subject
  - Gaining importance with recent regulatory requirements in Europe
  - Data stills exhibits long memory at a one year horizon (the influence of past returns decays as a power law)
  - RiskMetrics is developing an LM-ARCH model to forecast volatility up to one year

Properties of time series of residuals from a LM-ARCH model



S&P 500 residuals (left) and lagged correlation of residual magnitudes (right). Time series represented are equity indices (green), European interest rates (red), US interest rates (light blue), and foreign exchange (blue). The vertical bar indicates a lag of one month.

Taken from Finger and Zumbach (2005)

Estimating expected returns

- Expected returns can be directly estimated from historical data or using expert opinions
- Alternatively, instead of estimating expected returns directly, find out what they would have to be for the current portfolio to be optimal
- This process is called reverse optimization. Sharpe(1974), Black & Litterman(1992), Litterman (1996), Sharpe (2002)

Reverse optimization and implied returns

$$\max w^\top \mu - \frac{1}{2}\gamma w^\top \Sigma w$$

The solution to this unconstrained optimization problem satisfies the condition:

$$\text{ITE}_i \propto w_i \mu_i$$

This means that if the portfolio is optimal, the proportion of total return provided by asset *i* is equal to the ITE of the asset expressed as a proportion of total tracking error

Reverse optimization and implied returns

Covariance Matrix

+

Portfolio Weights

→

Implied

Returns

Equilibrium expected returns provide a neutral starting point

- In equilibrium the optimal mean-variance portfolio is given by capitalization portfolio weights

Covariance Matrix

+

Market Cap Weights

→

Equilibrium

Returns

Example: using reverse optimization to imply asset class alpha

Asset Class	Weights	TE (bp)	ITE (bp)	ITE (%)
U.S. Large Cap	25%	250	29	21%
U.S. Small Cap	20%	500	74	54%
International Equity	10%	450	15	11%
Emerging Markets Equity	5%	600	7	5%
Fixed Income	40%	100	12	9%
Total	100%	136	136	100%

Budgeting tracking error at the manager level

- Risk attribution is an excellent tool to monitor managers
- Verify that they are making the kinds of bets the plan sponsor expects them to make in order to generate alpha
- The idea is to apply ex-ante (stochastic) returns to a performance attribution methodology
- Poses heavy data and analytical requirements:
  - Holdings information for the active portfolios and all benchmarks
  - Pricing data
  - Reference data (T&Cs, sector information, ratings)
  - Detailed pricing models
  - Sophisticated risk analytics

Tracking error budget

Tracking Error (bp)

		Equity			Fixed Income			
	Total	Total	Allocation	Selection	Total	Duration	Allocation	Selection
Total	532	466	113	353	66	5	12	49
Eq Mgr 1	132	132	26	106	-	-	-	-
Eq Mgr 2	174	174	38	136	-	-	-	-
Eq Mgr 3	160	160	48	112	-	-	-	-
FI Mgr 1	27	-	-	-	27	1	4	22
FI Mgr 2	39	-	-	-	39	4	8	27

Example: Brinson return attribution

Over/underperformance of sector *A* relative to the benchmark

Sector	Sector Allocation	Security Selection	Total
$\vdots$	$\vdots$	$\vdots$	$\vdots$
A	$(P_A - B_A)(r_A - r_T)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_A)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_T)$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
Total	$\sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s - \sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s$

Over/underweight (bet) in sector *A*

Example: Brinson return attribution

Over/underperformance of security *s* relative to sector *A*

Sector	Sector Allocation	Security Selection	Total
$\vdots$	$\vdots$	$\vdots$	$\vdots$
A	$(P_A - B_A)(r_A - r_T)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_A)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_T)$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
Total	$\sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s - \sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s$

Over/underweight (bet) in security *s*

Example: Brinson return attribution

Over/underperformance of security *s* relative to benchmark

Sector	Sector Allocation	Security Selection	Total
$\vdots$	$\vdots$	$\vdots$	$\vdots$
A	$(P_A - B_A)(r_A - r_T)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_A)$	$\sum_{s \in A}(P_s - B_s)(r_s - r_T)$
$\vdots$	$\vdots$	$\vdots$	$\vdots$
Total	$\sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s - \sum_A (P_A - B_A) r_A$	$\sum_{s \in T}(P_s - B_s) r_s$

Over/underweight (bet) in security *s*

Further reading

- Finger, C. and Zumbach, G. (2005). Forecasting for solvency risk. *Research Monthly*, RiskMetrics Group, December 2005.

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References available at http://www.riskmetrics.com/research.html