Module 14.4

Portfolio Issues
Keel Model

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Keel Model Overview

- Improve financial management of agencies, companies, and even families
  - Also known as liability driven investing
  - Focus should be on enterprise risks, but
    - Banks focus on making good loans and acquiring deposits (separately)
    - Pension funds focus on asset allocation
    - Families focus on increasing asset value
  - Enterprise perspective, based on keel model, will prove helpful

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Arthur Turrell (Physicist Turned Economist)

- "Rather than the rules that govern the behaviour of particles, it is concerned with the rules that govern the behaviour of people; in many ways a much more complex problem."
- "Economics can tell us how to make everyone better off, for instance through trade …" Article in *The Guardian* "Why I left physics for economics," 6/22/17

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Central finance concepts

- Keel model – attributes enterprise value changes to various risk factors
- Also useful for investment professionals for portfolio surplus management purposes
- General in form and can incorporate as many factors as desired
- Degree of granularity is not limited

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Keel Model Key Benefits

- Enterprise-level focus
- Optimize surplus (or equity) rather than just assets
- Dramatically reduce estimation error
- Mission-driven as opposed to view-driven risk management
- Results in coherent, simple, and low stress management strategies

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Key Assumptions

- Both asset and liability values change in response to:
  - Changes in time (Horizon)
  - Changes in spot interest rates (Spot Rate)
  - Changes in credit spreads (Spread)
- Spot Rates and Spreads have:
  - Infinite number of maturities
  - Typically, can be reduced to two or three factors (Level, Slope, Curvature) $\Delta\tilde{b}_n = \tilde{b}_{n,t+\Delta} - b_{n,t}$

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Keel Model

- Change in surplus key components
  - Horizon (mere passage of time)
  - Base-rate (changes in chosen base rate, UST)
  - Spread (changes in spreads, credit)
  - Growth (changes in cash flow growth, GDP)
  - Interaction (captures measurement errors)
- Rates, Spreads, and Growth can be further decomposed into factor duration, factor convexity, and factor cross-convexity

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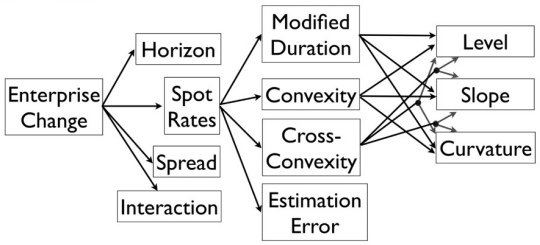
Figure 14.4.1. Illustration of Enterprise Change Attribution Provided by the Keel Model
a) Spot Rate Attribution



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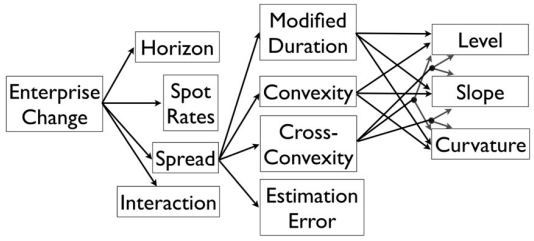
b) Spread Attribution



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Applications

- Banking Asset-Liability Management
  - Highlight flawed swap strategies
- Pension Management
  - Highlight the role of the present value of pension liabilities
- Wealth Management
  - Redefining alpha

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Three Motivating Examples

- Small Bank
  - Interest rate risk is typically the second largest risk (first is credit risk)
- Defined Benefit Retirement System
  - Popular in US and often significantly underfunded
- High Net Worth Family
  - Yearning (liabilities) is as important as earning (assets)

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Case Study #1: Small Bank

Table 14.4.1. Small Bank Balance Sheet (in millions)

Assets		Liabilities and Equity	
Cash and Due	15	Noninterest Bearing Deposits	50
Securities	40	Interest Bearing Deposits	170
Loans and Leases	200	Borrowings	50
Premises	5	*Total Liabilities*	*270*
Other Assets	40	*Total Equity*	*30*
Total Assets	*300*	*Total Liabilities and Equity*	*300*

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Table 14.4.2. Small Bank Duration and Convexity

Assets	Spot Rate Duration	Spot Rate Convexity	Spreads Duration	Spreads Convexity
Cash and Due	0.00	0.00		
Securities	3.55	14.06		
Loans and Leases	1.78	6.41	1.78	6.41
Premises	0.00	0.00		
Other Assets	2.29	6.63	2.29	6.63
Total Assets	*1.97*	*7.03*	*1.49*	*5.15*
Liabilities and Equity				
Nonint. Bearing Deposits	0.00	0.00		
Interest Bearing Deposits	3.47	16.00		
Borrowings	0.00	0.00		
Total Liabilities	*2.19*	*10.09*	*0.00*	*0.00*
Total Equity	***0.00***	*-20.30*	*14.84*	*51.27*
Total Liab. and Equity	*1.97*	*7.03*	*1.49*	*5.15*

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LSC Measures and Parameters

Table 14.4.3. LSC Model Risk Measures

Risk Measures	Base-Rate Level	Base-Rate Slope	Base-Rate Curvature	Spread Level	Spread Slope	Spread Curvature
Duration	0.00	1.49	0.16	14.84	4.31	3.65
Convexity	–20.30	1.54	–1.50	51.27	4.05	3.04
Cross-Convexity	–2.66	–5.53	–0.61	14.19	12.46	3.48

Note: Level / Cross-Convexity denotes cross-convexity between level and slope, Slope / Cross-Convexity denotes cross-convexity between slope and curvature, and Curvature / Cross-Convexity denotes cross-convexity between level and curvature.

Table 14.4.4. Initial and Horizon LSC Parameters (Horizon = 0.25 Years)

LSC Parameters	Base-Rate Initial	Base-Rate Horizon	Base-Rate Difference	Spread Initial	Spread Horizon	Spread Difference
Level	2.5%	2.5%	0.0%	0.5%	0.5%	0.0%
Slope	–2.4%	0.0%	2.4%	–0.4%	0.0%	0.4%
Curvature	–2.0%	0.0%	2.0%	–0.2%	0.0%	0.2%
Scalar	2.0	2.0		1.0	1.0	

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Figure 14.4.2a. Spot Rate Initial and Horizon Spot Rates (Horizon = 0.25 Years)

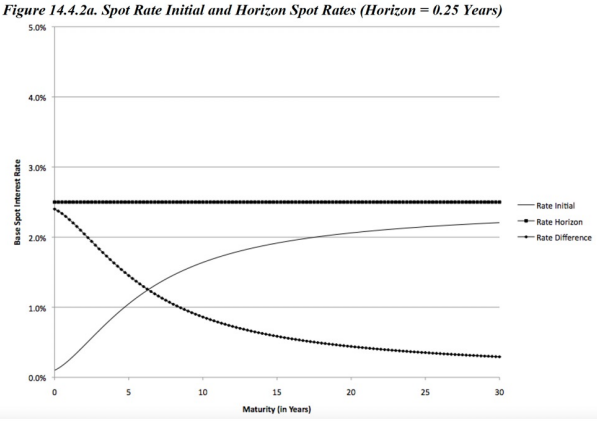

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Figure 14.4.2b. Spread Initial and Horizon Rates (Horizon = 0.25 Years)

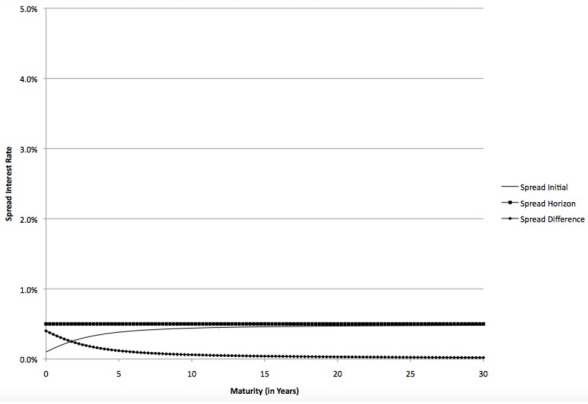

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Figure 14.4.2c. All-in Initial and Horizon Spot Rates (Horizon = 0.25 Years)

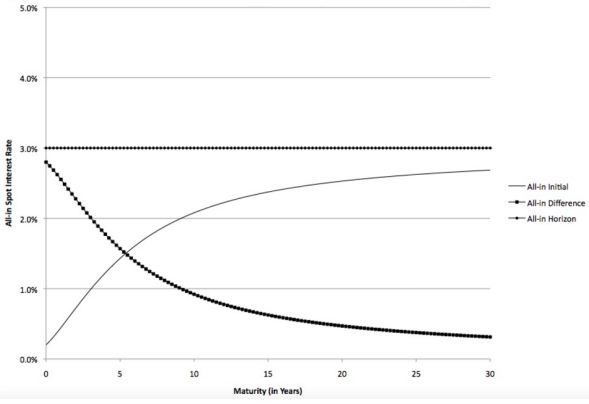

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Table 14.4.5. Factor Sensitivities and Surplus Decomposition Without Accounting Hedges

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*–$1.18*	*–3.9%*	*Actual*	*–$1.63*	*–5.44%*
FDS(r)	–$1.18	–3.9%	**Horizon**	$0.25	0.82%
FCS(r)	$0.0	0.0%	**Base-Rate**	–$1.18	–3.90%
FCCS(r)	–$0.01	0.0%	**Spread**	–$0.74	–2.45%
Total FS(sp)	*–$0.74*	*–2.5%*	**Interaction**	$0.04	0.14%
FDS(sp)	–$0.74	–2.5%			
FCS(sp)	$0.0	0.0%			
FCCS(sp)	$0.0	0.0%			

FS(r) denotes the factor sensitivity related to the base curve whereas FS(sp) denotes the factor sensitivity to the spread. FDS denotes factor duration sensitivity, FCS denotes factor convexity sensitivity, and FCCS denotes factor cross-convexity sensitivity.

Table 14.4.6. Factor Sensitivity Decomposition without Accounting Hedges

Factor Sensitivity	Base-Rate Level	Base-Rate Slope	Base-Rate Curvature	Spread Level	Spread Slope	Spread Curvature
Duration	0.00%	–3.59%	–0.32%	0.00%	–1.73%	–0.73%
Convexity	0.00%	0.04%	–0.03%	0.00%	0.01%	0.00%
Cross-Convexity	0.00%	0.00%	–0.03%	0.00%	0.00%	0.00%

Note: Level / Cross-Convexity denotes cross-convexity between level and slope, Slope / Cross-Convexity denotes cross-convexity between slope and curvature, and Curvature / Cross-Convexity denotes cross-convexity between level and curvature.

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Table 14.4.7. Risk Measures, Factor Sensitivities, and Surplus Decomposition with Borrowings-based Swap

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	−6.18	−0.89	−1.62	14.93	4.33	3.67
Convexity	−49.55	−2.74	−3.94	51.56	4.07	3.06
Cross-Convexity	−13.84	−13.97	−3.84	14.27	12.53	3.50
Factor Sensitivity	**Base-Rate**			**Spread**		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	0.00%	2.12%	3.24%	0.00%	−1.73%	−0.73%
Convexity	0.00%	−0.08%	−0.08%	0.00%	0.01%	0.00%
Cross-Convexity	0.00%	0.00%	−0.18%	0.00%	0.00%	0.00%

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*$1.52*	*5.1%*	*Actual*	*$0.90*	*2.99%*
FDS(r)	$1.62	5.4%	Horizon	$0.08	0.26%
FCS(r)	−$0.05	−0.2%	Base-Rate	$1.52	5.05%
FCCS(r)	−$0.06	−0.2%	Spread	−$0.74	−2.46%
Total FS(sp)	*−$0.74*	*−2.5%*	Interaction	$0.04	0.14%
FDS(sp)	−$0.74	−2.5%			
FCS(sp)	$0.00	0.0%			
FCCS(sp)	$0.00	0.0%			

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Table 14.4.8. Risk Measures, Factor Sensitivities, and Surplus Decomposition with Loans-based Swap

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	14.98	7.25	4.48	29.58	7.42	6.61
Convexity	50.42	11.92	4.40	120.80	7.12	5.84
Cross-Convexity	24.42	14.90	7.21	28.77	26.40	6.41
Factor Sensitivity	**Base-Rate**			**Spread**		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	0.00%	−17.73%	−9.12%	0.00%	−3.03%	−1.35%
Convexity	0.00%	0.35%	0.09%	0.00%	0.01%	0.00%
Cross-Convexity	0.00%	0.00%	0.35%	0.00%	0.00%	0.01%

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*−$7.87*	*−26.2%*	*Actual*	*−$8.36*	*−27.85%*
FDS(r)	−$8.11	−27.0%	Horizon	$0.76	2.52%
FCS(r)	$0.13	0.4%	Base-Rate	−$7.88	−25.61%
FCCS(r)	$0.11	0.4%	Spread	−$1.32	−4.28%
Total FS(sp)	*−$1.31*	*−4.4%*	Interaction	$0.08	0.26%
FDS(sp)	−$1.32	−4.4%			
FCS(sp)	$0.00	0.0%			
FCCS(sp)	$0.00	0.0%			

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Case Study #2: DB Plan

Table 14.4.9. Defined Benefit Retirement System Balance Sheet (in billions)

Assets		Liabilities and Surplus	
Cash and Receivables	0.9	Payables	0.1
Stocks	18	Present Value of Defined Benefits	39.9
Bonds	10	*Total Liabilities*	*40*
Real Estate	1	*Surplus*	*−10*
Property	0.1		
Total Assets	*30*	*Total Liabilities and Surplus*	*30*

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Table 14.4.10. Defined Benefit Retirement System Duration and Convexity

Assets	Spot Rate Duration	Spot Rate Convexity	Spreads Duration	Spreads Convexity
Cash and Receivables	0.00	0.00	0.00	0.00
Stocks	12.75	162.56	12.75	162.56
Bonds	2.83	8.62	2.83	8.62
Real Estate	12.75	162.56	12.75	162.56
Property	0.00	0.00	0.00	0.00
Total Assets	*9.03*	*106.06*	*9.03*	*106.06*
Liabilities and Equity				
Payables	0.00	0.00	0.00	0.00
PV(Defined Benefits)	9.81	155.49	0.00	0.00
Total Liabilities	*9.79*	*155.11*	*0.00*	*0.00*
Total Surplus	***12.17***	*309.39*	*-28.41*	*-333.59*
Total Liab. and Equity	*9.03*	*106.06*	*9.03*	*106.06*

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Table 14.4.11. Initial and Horizon LSC Parameters (Horizon = 0.25 Years)

LSC Parameters	Base-Rate			Spread		
	Initial	Horizon	Difference	Initial	Horizon	Difference
Level	2.5%	1.5%	−1.0%	5.0%	6.0%	1.0%
Slope	−2.4%	−1.4%	1.0%	−4.0%	−3.0%	1.0%
Curvature	−2.0%	−2.0%	0.0%	−3.0%	−2.0%	1.0%
Scalar	2.0	2.0		1.0	1.0	

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Table 14.4.12. Retirement System Market Value Balance Sheet

Assets	$I(i)$	Value (r,sp) t	Value (r+,sp+) t+Δ	Actual Change	Actual Return
Cash and Receivables	0	$0.90	$0.90	$0.00	0.03%
Stocks	1	$18.00	$17.62	−$0.38	−2.11%
Bonds	1	$10.00	$9.83	−$0.17	−1.75%
Real Estate	1	$1.00	$0.98	−$0.02	−2.11%
Property	0	$0.10	$0.10	$0.00	0.03%
Total Assets		$30.00	$29.43	−$0.57	−1.92%
Liabilities and Equity					
Payables	0	$0.10	$0.10	$0.00	0.03%
Present Value of Defined Benefits	0	$39.90	$43.60	$3.70	9.27%
Total Liabilities		$40.00	$43.70	$3.70	9.25%
Total Equity		−$10.00	−$14.28	−$4.27	42.75%*
Total Liabilities and Equity		$30.00	$29.43	−$0.57	−1.92%

*Note the positive number indicates a loss due to negative equity. (r+,sp+) denote after the rate and spread shock.

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Table 14.4.13. Retirement System Risk Measures, Factor Sensitivities, and Surplus Decomposition

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	12.17	1.51	1.26	–28.41	–2.96	–2.77
Convexity	309.39	2.72	2.05	–333.59	–2.88	–2.59
Cross-Convexity	23.77	22.62	2.35	–28.22	–27.76	–2.72
Factor Sensitivity	**Base-Rate**			**Spread**		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	–$1.21	$0.15	$0.00	–$2.71	–$0.28	–$0.26
Convexity	–$0.15	$0.00	$0.00	$0.32	$0.00	$0.00
Cross-Convexity	$0.02	$0.00	$0.00	$0.03	$0.03	$0.00

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*–$1.16*	*11.6%*	*Actual*	*–$4.27*	*42.75%*
FDS(r)	–$1.03	10.3%	Horizon	$0.30	–3.05%
FCS(r)	–$0.15	1.5%	Base-Rate	–$1.17	12.10%
FCCS(r)	$0.02	–0.2%	Spread	–$3.10	31.96%
Total FS(sp)	*–$2.92*	*29.2%*	Interaction	–$0.31	3.18%
FDS(sp)	–$3.31	33.1%	Funding Ratio:		
FCS(sp)	$0.33	–3.3%	Initial: 74.94%	Horizon:	67.26%
FCCS(sp)	$0.06	–0.6%			

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Table 14.4.14. Retirement System Balance Sheet Applying Spread to Benefits

Assets	*I*(*i*)	Value (*r*,*sp*) *t*	Value (*r*+,*sp*+) *t*+Δ	Actual Change	Actual Return
Cash and Receivables	0	$0.90	$0.90	$0.00	0.03%
Stocks	1	$18.00	$17.62	–$0.38	–2.11%
Bonds	1	$10.00	$9.83	–$0.17	–1.75%
Real Estate	1	$1.00	$0.98	–$0.02	–2.11%
Property	0	$0.10	$0.10	$0.00	0.03%
Total Assets		$30.00	$29.43	–$0.57	–1.92%
Liabilities and Equity					
Payables	0	$0.10	$0.10	$0.00	0.03%
Present Value of Defined Benefits	1	$27.41	$26.94	–$0.48	–1.74%
Total Liabilities		$27.51	$27.04	–$0.48	–1.73%
Total Equity		$2.49	$2.39	–$0.10	–3.97%
Total Liabilities and Equity		$30.00	$29.43	–$0.57	–1.92%

* Note the positive number indicates a loss due to negative equity. (*r*+,*sp*+) denote after the rate and spread shock.

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Table 14.4.15. Retirement System Risk Measures, Factor Sensitivities, and Surplus Decomposition Applying Spread to Benefits

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	27.52	3.64	4.15	27.52	1.61	1.93
Convexity	216.89	8.09	9.33	216.89	1.87	1.99
Cross-Convexity	56.36	58.33	8.77	27.84	27.96	1.98
Factor Sensitivity	**Base-Rate**			**Spread**		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	$0.69	–$0.09	$0.00	–$0.69	–$0.04	–$0.05
Convexity	$0.03	$0.00	$0.00	$0.05	$0.00	$0.00
Cross-Convexity	–$0.01	$0.00	$0.00	$0.01	$0.01	$0.00

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*$0.63*	*25.3%*	*Actual*	*–$0.10*	*–3.97%*
FDS(r)	$0.61	24.7%	Horizon	$0.08	3.28%
FCS(r)	$0.03	1.2%	Base-Rate	$0.63	24.39%
FCCS(r)	–$0.01	–29.2%	Spread	–$0.76	–29.38%
Total FS(sp)	*–$0.73*	*–29.2%*	Interaction	–$0.05	–2.03%
FDS(sp)	–$0.80	–32.1%	Funding Ratio:		
FCS(sp)	$0.06	2.3%	Initial: 109.08%	Horizon:	108.87%
FCCS(sp)	$0.01	0.6%			

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Table 14.4.16. Retirement System Balance Sheet When Asset Categories Moved to Cash

Assets	*I*(*i*)	Value (*r*,*sp*) *t*	Value (*r*+,*sp*+) *t*+Δ	Actual Change	Actual Return
Cash and Receivables	0	$0.90	$0.90	$0.00	0.03%
Stocks	0	$18.00	$18.01	$0.01	0.03%
Bonds	0	$10.00	$10.00	$0.00	0.03%
Real Estate	0	$1.00	$1.00	$0.00	0.03%
Property	0	$0.10	$0.10	$0.00	0.03%
Total Assets		$30.00	$30.01	$0.01	0.03%
Liabilities and Equity					
Payables	0	$0.10	$0.10	$0.00	0.03%
Present Value of Defined Benefits	0	$39.90	$43.60	$3.70	9.27%
Total Liabilities		$40.00	$43.70	$3.70	9.25%
Total Equity		–$10.00	–$13.69	$3.69	36.90%
Total Liabilities and Equity		$30.00	$30.01	$0.01	0.03%

* Note the positive number indicates a loss due to negative equity. (*r*+,*sp*+) denote after the rate and spread shock.

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Table 14.4.17. Retirement System Risk Measures, Factor Sensitivities, and Surplus Decomposition When Asset Categories Moved to Cash

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	38.64	6.70	5.37	0.00	0.00	0.00
Convexity	612.25	12.38	10.10	0.00	0.00	0.00
Cross-Convexity	75.34	71.91	10.98	0.00	0.00	0.00
Factor Sensitivity	**Base-Rate**			**Spread**		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	–$3.92	$0.68	$0.00	$0.00	$0.00	$0.00
Convexity	–$0.31	–$0.01	$0.00	$0.00	$0.00	$0.00
Cross-Convexity	$0.08	$0.00	$0.00	$0.00	$0.00	$0.00

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	*–$3.49*	*34.9%*	*Actual*	*–$3.69*	*36.90%*
FDS(r)	–$3.25	32.5%	Horizon	–$0.18	1.82%
FCS(r)	–$0.32	3.2%	Base-Rate	–$3.51	34.46%
FCCS(r)	$0.08	–0.8%	Spread	$0.00	0.00%
Total FS(sp)	*$0.00*	*0.0%*	Interaction	$0.00	0.00%
FDS(sp)	$0.00	0.0%	Funding Ratio:		
FCS(sp)	$0.00	0.0%	Initial: 74.94%	Horizon:	68.60%
FCCS(sp)	$0.00	0.0%			

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Table 14.4.18. Retirement System Balance Sheet With Additional Spread Exposure

Assets	*I*(*i*)	Value (*r*,*sp*) *t*	Value (*r*+,*sp*+) *t*+Δ	Actual Change	Actual Return
Cash and Receivables	0	$0.90	$0.90	$0.00	0.03%
Stocks	1	$18.00	$12.02	–$5.98	–33.22%
Bonds	1	$10.00	$9.03	–$0.97	–9.70%
Real Estate	1	$1.00	$0.67	–$0.33	–33.22%
Property	0	$0.10	$0.10	$0.00	0.03%
Total Assets		$30.00	$22.72	–$7.28	–24.27%
Liabilities and Equity					
Payables	0	$0.10	$0.10	$0.00	0.03%
Present Value of Defined Benefits	0	$39.90	$43.60	$3.70	9.27%
Total Liabilities		$40.00	$43.70	$3.70	9.25%
Total Equity		–$10.00	–$20.98	–$10.98	109.82%
Total Liabilities and Equity		$30.00	$22.72	–$7.28	–24.27%

* Note the positive number indicates a loss due to negative equity. (*r*+,*sp*+) denote after the rate and spread shock.

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Table 14.4.19. Retirement System Surplus Decomposition With Additional Spread Exposure

Surplus Decomposition	Dollar Change	Return
Actual	–$10.98	109.82%
Horizon	$0.30	–3.05%
Base-Rate	–$1.17	12.10%
Spread	–$9.19	94.80%
Interaction	–$0.92	9.52%
Funding Ratio:		
Initial: 74.94%	**Horizon:**	51.88%

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Case Study #3: Family

Table 14.4.20. Family Market Value Balance Sheet (in thousands)

Assets		Liabilities and Equity	
Cash and Other Liquid	300	Payables	10
Home and Related	1,000	Mortgage	700
Bonds	500	Other Obligations	3,000
Stocks	2,000	*Total Liabilities*	*3,710*
Family Firm	15,000	*Equity*	*15,090*
Total Assets	*18,800*	*Total Liabilities and Equity*	*18,800*

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Enterprise Perspective

Assets	Liabilities and Equity
Cash	Liabilities
Bonds	Payables
Stocks	Mortgages
Real Estate	Other Explicit
Private Firms	Implicit
	Net Worth
Total Assets	Total Liabilities and Net Worth

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Keel Model Premise

- Asset values depend primarily on a small set of factors, such as
  - Interest rates (term structure of some base rate)
  - Credit spreads (term structure of several spreads)
  - Growth rates (term structure of asset performance)
- Liability values also often depend primarily on the same set of factors, for example,
  - Mortgages and other explicit debts
  - College costs and other implicit debts
  - Implicit liabilities reflecting client's culture

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Illustration: Client's T-Account

- Following slides illustrate the Keel Model applied to wealth management
- r denotes interest rates, a maturity-appropriate base-rate (e.g., UST or LIBOR)
- sp denotes spread(s), a maturity-appropriate, instrument-appropriate rate (e.g., credit spread or equity risk premium)
- g denotes cash flow growth of instruments, such as growth rate assume for a common stock

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Current Practice

Assets	Liabilities and Equity
Cash	
Bonds	
Stocks	

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Advanced Current Practice

Assets	Liabilities and Equity
Cash	Liabilities
Bonds	Payables
Stocks	Mortgages
Real Estate	
Private Firms	
	Net Worth
Total Assets	Total Liabilities and Net Worth

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Focus: Rates, Spreads and Growth

Assets	Liabilities and Equity
Cash (r)	Liabilities
Bonds (r, sp)	Payables
Stocks (r, sp, g)	Mortgages
Real Estate	
Private Firms	
	Net Worth
Total Assets	Total Liabilities and Net Worth

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Perhaps Incorporate Other Assets

Assets	Liabilities and Equity
Cash (r)	Liabilities
Bonds (r, sp)	Payables
Stocks (r, sp, g)	Mortgages
Real Estate (r, sp, g)	
Private Firms (r, sp, g)	
	Net Worth
Total Assets (r, sp, g)	Total Liabilities and Net Worth

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Keel Model

Assets	Liabilities and Equity
Cash (r)	Liabilities
Bonds (r, sp)	Payables (r)
Stocks (r, sp, g)	Mortgages (r)
Real Estate (r, sp, g)	Other Explicit (r)
Private Firms (r, sp, g)	Implicit (r, sp, g)
	Net Worth (r, sp, g)
Total Assets (r, sp, g)	Total Liabilities and Net Worth (r, sp, g)

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Table 14.4.21. Family Duration and Convexity

Assets	Spot Rate Duration	Spot Rate Convexity	Spreads Duration	Spreads Convexity
Cash and Other Liquid	0.00	0.00	0.00	0.00
Home and Related	0.00	0.00	0.00	0.00
Bonds	2.83	8.62	2.83	8.62
Stocks	12.75	162.56	12.75	162.56
Family Firm	29.75	885.06	29.75	885.06
Total Assets	*25.20*	*724.71*	*25.20*	*724.71*
Liabilities and Equity				
Payables	0.00	0.00	0.00	0.00
Mortgage	4.73	30.66	0.00	0.00
Other Obligations	2.35	7.61	0.00	0.00
Total Liabilities	*2.80*	*11.95*	*0.00*	*0.00*
Total Equity	***30.61***	*896.82*	*31.29*	*899.70*
Total Liab. and Equity	*25.20*	*724.71*	*25.20*	*724.71*

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Table 14.4.22. Initial and Horizon LSC Parameters (Horizon = 0.25 Years)

LSC Parameters	Base-Rate Initial	Base-Rate Horizon	Base-Rate Difference	Spread Initial	Spread Horizon	Spread Difference
Level	2.5%	3.5%	1.0%	5.0%	5.0%	0.0%
Slope	–2.4%	0.0%	2.4%	–4.0%	0.0%	4.0%
Curvature	–2.0%	0.0%	2.0%	–3.0%	0.0%	3.0%
Scalar	2.0	2.0		1.0	1.0	

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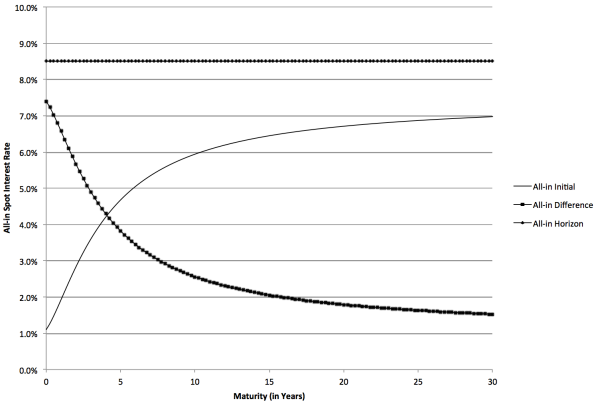

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Table 14.4.23. Family's Balance Sheet

Assets	I(i)	Value (r,sp) t	Value (r+,sp+) t+Δ	Actual Change	Actual Return
Cash and Receivables	0	$300.00	$300.10	$0.10	0.03%
Home	0	$1,000.00	$1,000.32	$0.32	0.03%
Bonds	1	$500.00	$441.34	−$58.66	−11.73%
Stocks	1	$2,000.00	$1,532.53	−$467.47	−23.37%
Family firm	1	$15,000.00	$9,692.00	−$5,308.00	−35.39%
Total Assets		$18,800.00	$12,966.29	−$5,833.71	−31.03%
Liabilities and Equity					
Payables	0	$10.00	$10.00	$0.00	0.03%
Mortgage	0	$700.00	$631.72	−$68.28	−9.75%
Other Obligations	0	$3,000.00	$2,818.40	−$181.60	−6.05%
Total Liabilities		$3,710.00	$3,460.12	−$249.88	−6.74%
Total Equity		$15,090.00	$9,506.16	−$5,583.84	−37.00%
Total Liabilities and Equity		$18,800.00	$12,966.29	−$5,833.71	−31.03%

* Note the positive number indicates a loss due to negative equity. (r+,sp+) denote after the rate and spread shock.

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Table 14.4.24. Family's Risk Measures, Factor Sensitivities, and Surplus Decomposition

Risk Measures	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	30.61	1.99	2.09	31.29	1.15	1.15
Convexity	896.82	4.10	4.30	899.70	1.15	1.14
Cross-Convexity	61.43	61.67	4.23	31.28	31.27	1.15
Factor Sensitivity	Base-Rate			Spread		
	Level	Slope	Curvature	Level	Slope	Curvature
Duration	−$4,627.87	−$720.08	−$631.23	$0.00	−$698.39	−$521.08
Convexity	$678.05	$17.83	$13.00	$0.00	$27.88	$15.56
Cross-Convexity	$222.89	$186.49	$30.69	$0.00	$0.00	$20.81

Factor Sensitivities	Dollar Change	Percentage	Surplus Decomposition	Dollar Change	Return
Total FS(r)	−$4,925.55	−32.6%	*Actual*	−$5,583.84	−37.00%
FDS(r)	−$6,096.46	−40.4%	**Horizon**	$318.29	2.11%
FCS(r)	$722.38	4.8%	**Base-Rate**	−$5,061.53	−32.85%
FCCS(r)	$448.53	3.0%	**Spread**	−$1,200.05	−7.79%
Total FS(sp)	−$1,176.93	−7.8%	**Interaction**	$359.45	2.33%
FDS(sp)	−$1,242.39	−8.2%			
FCS(sp)	$44.25	0.3%			
FCCS(sp)	$21.20	0.1%			

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Cases Summary

- Keel model would have avoided the 90% loss of wealth
- Transition focus from financial markets to enterprise characteristics
- Enterprise characteristics are much easier to forecast than market movements

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Current Wealth Management Practice

- View-driven: Focus is almost exclusively on markets and market-driven investment *strategies*
- Very difficult to predict future consistently
- Focus is on coherent story of global markets and a corresponding investment strategy
- How is the current practice working?

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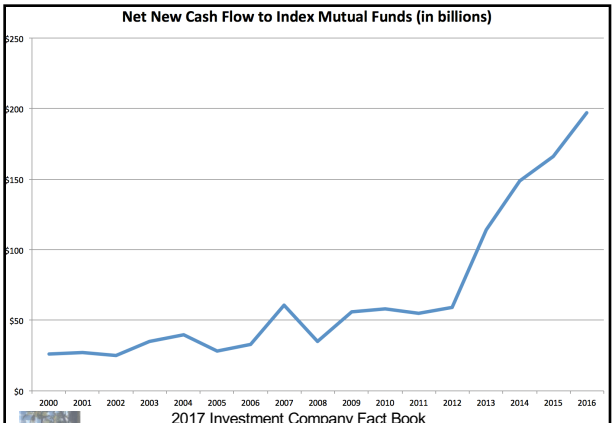

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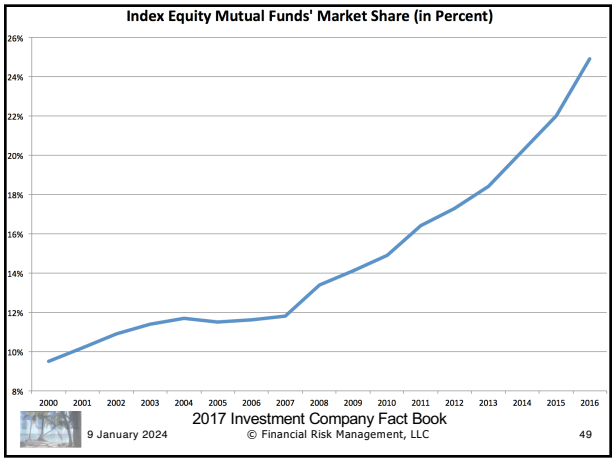

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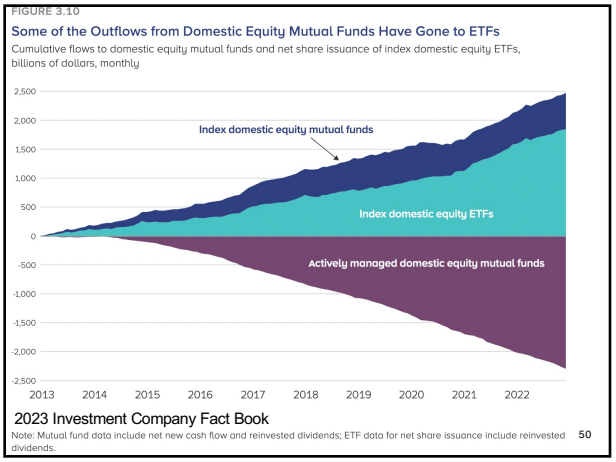

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Current Performance Evaluation

- Performance measurement: Alpha or excess return over some benchmark
- Heavy emphasis on excellent client relationships and making them *feel* good
- Performance attribution: Cannot be done at the client level
- Client interface: Risk aversion questionnaire

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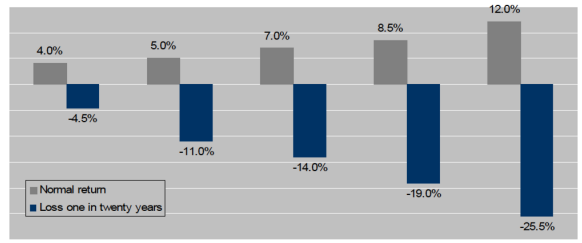
Client Questionnaire Example

18. The charts below show the normally expected annual return (grey bars) for five hypothetical investment portfolios. The blue bars show the potential maximum 1-year loss for each portfolio, which might occur once every 20 years. Select the portfolio that best represents the combination of desired annual return and maximum downside risk that you are willing to take with your investment account.

[0] ☐ Portfolio A [6] ☐ Portfolio B [8] ☐ Portfolio C [12] ☐ Portfolio D [16] ☐ Portfolio E



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Current Performance Measure

- Assets under management
- "The market value of assets that an investment company manages on behalf of investors. Assets under management (AUM) is looked at as a measure of success against the competition and consists of growth/decline due to both capital appreciation/losses and new money inflow/outflow." Investopedia

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Keel Model (KM)

- Needs-driven: Focus is primarily on each client's *culture* (defined here as a way of life) and admittedly tough to quantify
- Focus is on coherent story of each client's culture and, only then, an integrated investment philosophy and resultant mitigating-focused investment strategy.

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Keel Model Foundation

- Academic work
  - Blanchett and Straehl, *Financial Analysts Journal*, (2015), Morningstar
  - Merton, *Harvard Business Review*, (2014), Dimensional Fund Advisors
- Non-financial assets as well as liabilities are sensitive to the same key factors driving financial asset valuations and can be exploited

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Blanchett and Straehl (2015)

- No portfolio is an island – focused on assets only
- Incorporates human capital, housing wealth, and pension
- "We found significant evidence that the optimal allocation for an investor's financial assets varies materially for different compositions of total wealth." (p. 15)
- "… average increase in risk-adjusted return of 30 bps." (p. 15) Implies $5 billion economic value *lost* per year by U.S. equity indexed mutual funds.

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Robert Merton (HBR, 2014)

- "(I)nvestment value and asset volatility are simply the wrong measures if your goal is to obtain a particular future income."
- "Clearly, there is a big disconnect about what is and is not risky when it comes to the way we express the value of pension savings."
- "… relevant risk is retirement income uncertainty, not portfolio value."
- Metric: Probability of achieving income goals

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KM Performance Evaluation

- Performance measurement: Surplus measure based on client assets *and liabilities* (reflecting client's culture)
- Performance attribution: Straightforward measures of key drivers of client surplus
- Client interface: Build dynamic liability portfolio, benchmark is surplus measure reflecting culture
- Heavy emphasis on enhancing the client's culture and producing enduring wealth

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KM Performance Measurement

- Wealth manager's key performance measure: Enhancing client's culture
- Heavy emphasis on excellent client relationships by significantly improving the likelihood the client's culture is preserved and enhanced
- Clients will likely feel good with successful execution of their vision

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Case Study: Alternative Strategies

- Risk preference strategy
  - Ignores what is happening within the client's culture and the resultant risk exposures.
  - Misplaced focus on asset performance
- Bucketing strategy
  - Silo approach that misses client's culture as a whole
  - Misses interaction between categories
- Keel model allows for a blended strategy based on surplus view

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Key Challenge Going Forward

- Quantifying sensitivities of non-financial assets, explicit liabilities, and even implicit liabilities to changes in interest rates, credit spreads, and growth rates
- Reorienting financial practice to this perspective
  - Reporting requirements
  - Measuring the probability of enhancing client culture
  - Explaining the value-added proposition

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Quantitative finance concepts

- Introduce mathematical framework
- Factor risk measures
- Surplus view
- Keel model mathematical framework

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Mathematical Framework

- Assets

$$A_t = \sum_{l=1}^{M_A} A_{l,t} = \sum_{l=1}^{M_A} Q_{A_l,t} V_{A_l,t}(r,sp,g) > 0$$

- Liabilities

$$L_t = \sum_{l=1}^{M_L} L_{l,t} = \sum_{l=1}^{M_L} Q_{L_l,t} V_{L_l,t}(r,sp,g) < 0$$

- Key Focus: Change in Surplus

$$\Delta\tilde{S} = \sum_{l=1}^{M} Q_{l,t} V_{l,t} \tilde{R}_{l,\Delta}(r,sp,g)$$

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Selected Definitions

- Factor duration–measure of sensitivity to interest rates (1st partial derivative)

$$FD_{n,l} = -\frac{1}{V_{l,t+\Delta}(\underline{b}_t)} \frac{\partial V_{l,t+\Delta}(\underline{b}_t)}{\partial b_{n,t}}$$

- Factor convexity–2nd partial derivative

$$FC_{n,l} = \frac{1}{V_{l,t+\Delta}(\underline{b}_t)} \frac{\partial^2 V_{l,t+\Delta}(\underline{b}_t)}{\partial b_{n,t}^2}$$

- Factor cross-convexity–cross partial derivatives $FCC_{n,n',l} = \frac{1}{V_{l,t+\Delta}(\underline{b}_t)} \frac{\partial^2 V_{l,t+\Delta}(\underline{b}_t)}{\partial b_{n,t} \partial b_{n',t}}$

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Surplus View of Enterprise

- Surplus (S) = Assets – Liabilities
- Liabilities modeled as negative quantity assets (Q < 0), future cash flows discounted at spot rate plus multiple spreads
- Spot rates and spreads modeled using LSC model

$$S_t = \sum_{l=1}^{M} Q_{l,t} \sum_{i=0}^{N_l} E_t\left(\widetilde{CF}_{l,i} \middle| \Im_t\right) e^{-\left[\sum_{n=0}^{N_F^r} C_{l,r,n}(\tau_i; s_{r,n}) b_{n,r,t} + \sum_{j=1}^{N_{sp}} \alpha_{l,j} \sum_{n=0}^{N_F^{spj}} C_{l,spj,n}(\tau_i; s_{spj,n}) b_{n,spj,t} + \varepsilon_{l,i,t}\right] \tau_i}$$

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Keel Model

$$\Delta\tilde{S} = \sum_{l=1}^{M} Q_{l,t} V_{l,t} \tilde{R}_{l,\Delta} = \sum_{l=1}^{M} Q_{l,t} V_{l,t} \left[R_{l,\Delta}^h + (1 + R_{l,\Delta}^h)(\tilde{R}_{l,\Delta}^r + \tilde{R}_{l,\Delta}^{sp} + \tilde{I}_{l,\Delta})\right]$$

$$= \sum_{l=1}^{M} Q_{l,t} V_{l,t} R_{l,\Delta}^h + \sum_{l=1}^{M} Q_{l,t} V_{l,t} (1 + R_{l,\Delta}^h) \tilde{R}_{l,\Delta}^r + \sum_{l=1}^{M} Q_{l,t} V_{l,t} (1 + R_{l,\Delta}^h) \tilde{R}_{l,\Delta}^{sp} + \sum_{l=1}^{M} Q_{l,t} V_{l,t} (1 + R_{l,\Delta}^h) \tilde{I}_{l,\Delta}$$

or in words

$$\Delta\tilde{S} = \text{Horizon} + \text{Spot Rate} + \text{Spread} + \text{Interaction}.$$

$$\tilde{R}_{l,\Delta}^r = \frac{\tilde{V}_{l,t+\Delta}(\tilde{r}_\Delta, sp) - V_{l,t+\Delta}(r, sp)}{V_{l,t+\Delta}(r, sp)}$$

$$= -\sum_{n=0}^{N_F^r} FD_{n,r,l} \Delta\tilde{b}_{n,r} + \frac{1}{2} \sum_{n=0}^{N_F^r} FC_{n,r,l} \Delta\tilde{b}_{n,r,l}^2 + \sum_{n=0}^{N_F^r} \sum_{n'=n+1}^{N_F^r} FCC_{n,n',r,l} \Delta\tilde{b}_{n,r} \Delta\tilde{b}_{n',r} + \tilde{R}_{l,r}^\eta$$

$$= FD\tilde{S}_r + FC\tilde{S}_r + FCC\tilde{S}_r + \tilde{R}_{l,r}^\eta$$

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$\widetilde{FDS}_r = -\sum_{n=0}^{N_t} FD_{n,r,l}\Delta\widetilde{b}_{n,r}$ – Factor duration sensitivity to spot rate related factors,

$\widetilde{FCS}_r = \frac{1}{2}\sum_{n=0}^{N_t} FC_{n,r,l}\Delta\widetilde{b}^2_{n,r,l}$ – Factor convexity sensitivity to spot rate related factors, and

$\widetilde{FCCS}_r = \sum_{n=0}^{N_t}\sum_{n=n+1}^{N_t} FCC_{n,n',r,l}\Delta\widetilde{b}_{n,r}\Delta\widetilde{b}_{n',r}$ – Factor cross-convexity sensitivity to spot rate related factors.

$$\Delta\widetilde{S} = \sum_{l=1}^{M} Q_{l,t}V_{l,t}R^h_{l,\Delta} + \sum_{l=1}^{M} Q_{l,t}V_{l,t}\left(1+R^h_{l,\Delta}\right)\left(\widetilde{FDS}_r + \widetilde{FCS}_r + \widetilde{FCCS}_r + \widetilde{R}^{\eta}_{l,r}\right)$$
$$+\sum_{l=1}^{M} Q_{l,t}V_{l,t}\left(1+R^h_{l,\Delta}\right)\left(\widetilde{FDS}_{sp} + \widetilde{FCS}_{sp} + \widetilde{FCCS}_{sp} + \widetilde{R}^{\eta}_{l,sp}\right) + \sum_{l=1}^{M} Q_{l,t}V_{l,t}\left(1+R^h_{l,\Delta}\right)\widetilde{I}_{l,\Delta}$$

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Summary

- An enterprise view should be considered
- Tie performance measures to client's culture through modeling implicit liabilities
- Performance measures and performance attribution is conducted at the client level, not market level
- Improve client's survey questions

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Credits

- Background photo on first page: Painting by Edward Moran, 1898, in Theodore Sutro, *Thirteen Chapters of American* History, 1905, page 38. http://www.gutenberg.org/files/24990/24990-h/24990-h.htm
- David M. Blanchett and Philip U. Straehl, "Not Portfolio is an Island," *Financial Analysts Journal* 71, 3, 15-33.
  - $8 trillion x 20% x 0.003 = $4.8 billion

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