Financial Econometrics In Action: Analyzing Hedge Funds and Systemic Risk

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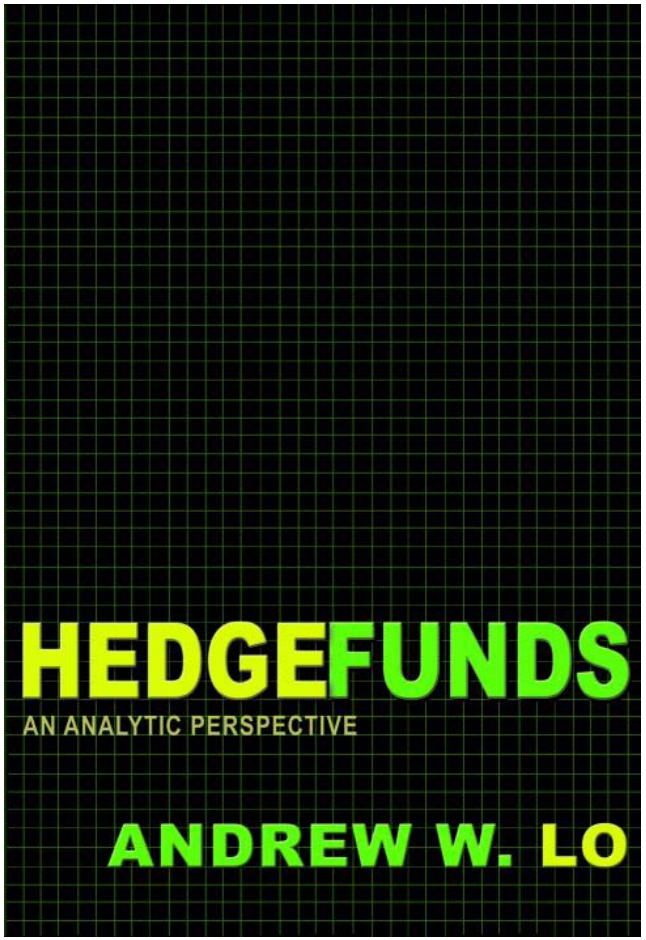
Econometric Methods Lecture

July 16, 2010

Outline of Presentation

- Basic Facts About Hedge Funds
- Hedge-Fund Returns
- Hedge-Fund Risks and Liquidity
- Hedge Funds and Systemic Risk
- August 1998, August 2007, May 2010,…



Basic Facts About Hedge Funds

References

- Fung, W. and D. Hsieh, 1999, "A Primer on Hedge Funds", *Journal of Empirical Finance* 6, 309–331.
- Lo, A., 2002, "The Statistics of Sharpe Ratios", *Financial Analysts Journal* 58, 36–52.
- Lo, A., 2008, *Hedge Funds: An Analytic Perspective*, Chapters 1–2. Princeton, NJ: Princeton University Press.

What Are Hedge Funds?

Unregulated Investment Companies

- For "qualified" (sophisticated) investors
- Need not satisfy regulatory requirements (few investment constraints)
- High fees, high performance (historically), and high attrition

Alfred Winslow Jones

- First "hedge fund" in 1949 (market exposure vs. stock selection):

$$\text{Market Exposure} = \frac{\text{Long Position} - \text{Short Position}}{\text{Capital}}$$

- Magnify stock selection (leverage). reduce market exposure (short positions)
- Hence the term "hedge"
- Charged 20% incentive fee
- Eventually included several managers (fund of funds)

What Are Hedge Funds?

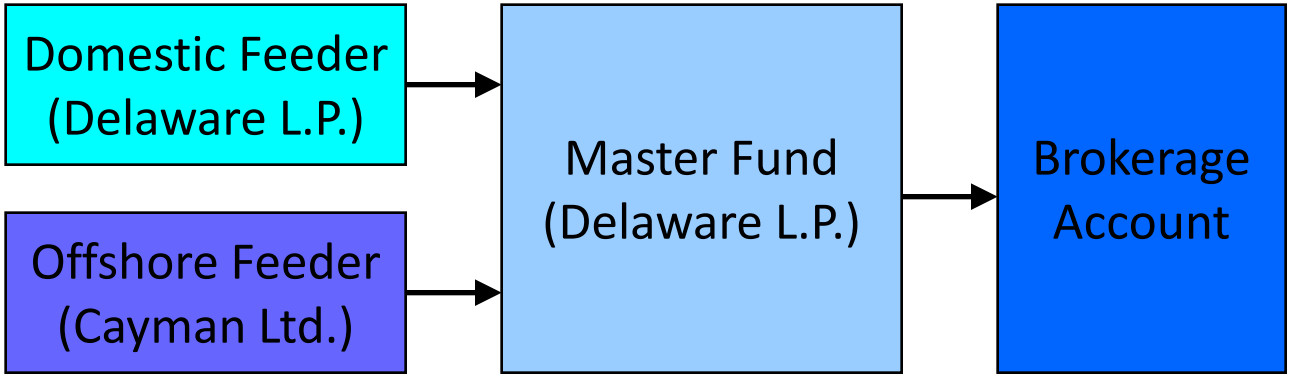
An Example

- Suppose a mutual fund has $10MM of capital
  - It can purchase $10MM of IBM
  - If IBM goes up by 10%, mutual fund makes $1MM
  - If IBM goes down by 10%, mutual fund loses $1MM
- Suppose a hedge fund has $10MM
  - It can purchase $30MM of IBM (like a margin account)
  - It can simultaneously sell $30MM of GE
  - If IBM goes up by 10%, hedge fund makes $3MM
  - If GE goes down by 10%, hedge fund makes $3MM
  - What if IBM goes down and GE goes up by 10%?

What Are Hedge Funds?

Today:

- Over 10,000 hedge funds worldwide, controlling $1.7 trillion in assets
- Typical fee structure: 2% fixed, 20% incentive, high-water mark
- Most hedge funds are **Registered Investment Advisors**
- Most common legal form: **Limited Liability Corporation** (LLC)
- Most common corporate structure:
  - Management company (the business entity)
  - Fund (the assets), **master-feeder** structure



What Are Hedge Funds?

The Hedge-Fund Industry Is Heterogeneous:

- Closer to 20–30 cottage industries
- CSFB/Tremont Index Categories:

Hedge Funds	Event-Driven Multi-Strategy
Convertible Arbitrage	Fixed Income Arbitrage
Dedicated Shortseller	Global Macro
Distressed	Long/Short Equity
Emerging Markets	Managed Futures
Equity Market Neutral	Multi-Strategy
Event-Driven	Risk Arbitrage

- Does not include private equity, venture capital, real estate, natural resources, insurance

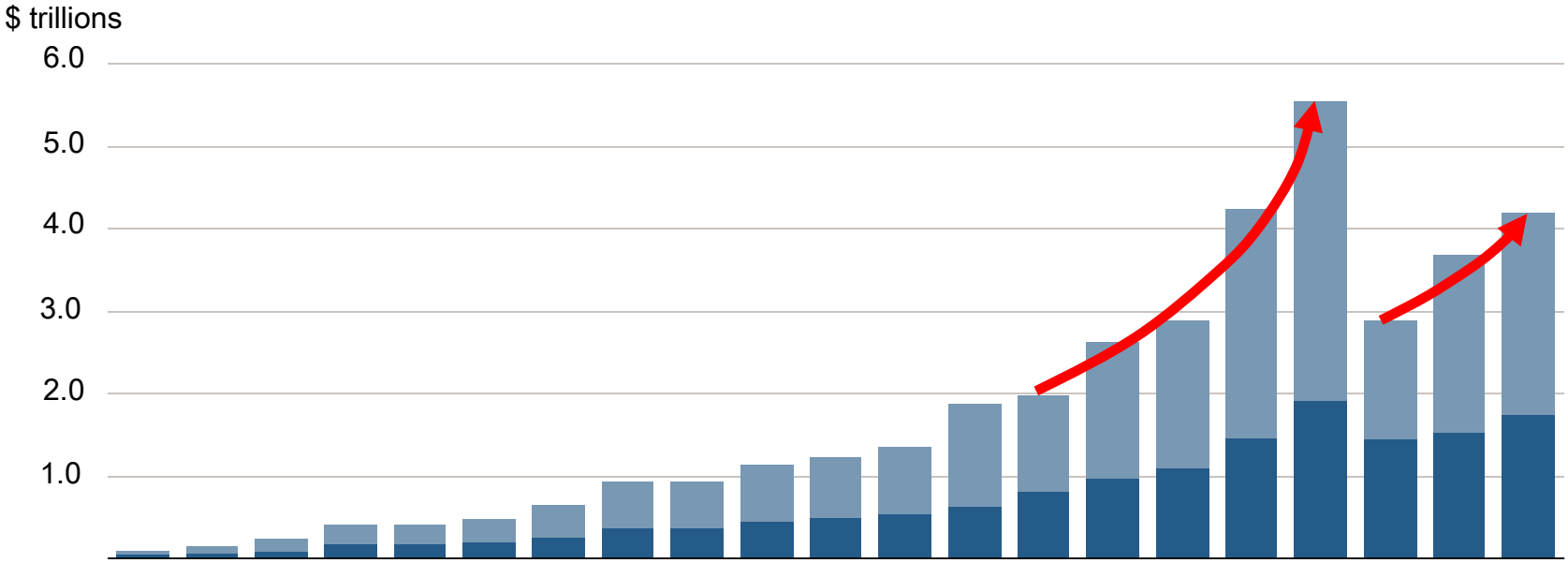
What Are Hedge Funds?

Why Should We Care About Hedge Funds?

- Hedge funds play a key role in the financial industry
  - During normal times, hedge funds are the "tip of the spear"
  - During bad times, hedge funds are the "canary in the cage"
- As unregulated entities, hedge funds innovate rapidly
- Due to leverage, hedge funds have disproportionate impact on markets
- Investors in hedge funds include:
  - Private investors
  - Fund of funds
  - Central banks and sovereign wealth funds
  - Insurance companies
  - Pension funds

What Are Hedge Funds?

Assets In The Hedge Fund Industry, 1990–2010



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Estimated assets	38	58	95	167	167	185	256	367	374	456	490	539	625	820	972	1,105	1,464	1,910	1,440	1,600	1,770
Market positions	95	145	238	418	418	463	640	918	935	1,140	1,225	1,887	1,877	1,968	2,620	2,674	4,247	5,231	2,730	3,670	4,200

Sources: through Q4 2009 – HFR industry report. 2010 projections – based on CS analysis

What Are Hedge Funds?

Thought Leadership Series
APRIL 2009

CONTENTS

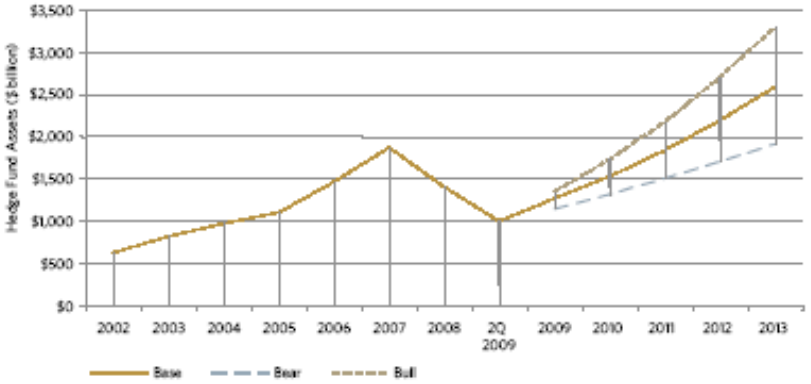
The Hedge Fund of Tomorrow:
Building an Enduring Firm

- The hedge fund industry is facing a transformational crisis. The industry must address key shortcomings in its business and operating models in order to position itself as the future of active asset management.
- We forecast that hedge fund assets will reach almost $2.6 trillion by the end of 2013, after reaching their low point in 2009.
- Institutions are committed to hedge fund investing and accounted for less than 17% of net redemptions during 2008 and 2009. North American institutions will be the greatest source of institutional net flows into hedge funds between now and 2013.
- Global high-net-worth investors' commitment to hedge funds will depend on capital market conditions and hedge fund returns during the next several years. High-net-worth and retail investors accounted for more than 80% of redemptions for 2008 and 2009.
- Funds of hedge funds will maintain their role as the primary hedge fund distribution channel, capturing almost 60% of net flows between 2010 and 2013. Funds of hedge funds will likely oversee close to 50% of total hedge fund assets in 2013, compared with 36% in 2005 and 17% in 2000.
- Investors will carve their previously amorphous hedge fund allocation into three distinct categories: Market Directional Liquid, "Classic" Hedge Liquid and Illiquid. There is growing recognition that hedge funds may not be an asset class, but instead represent an investment framework applicable across all traditional asset classes and investment programs.
- We predict that, regardless of capital market returns, "Classic" Hedge strategies will experience the most stable demand.
- Successful hedge funds will rebuild their operating models. Managers will have to invest in robust systems, processes and controls and rely on independent third parties for key administrative and operational activities.
- The Enduring Firm will be built upon a foundation of strong alignments. Hedge funds have to restructure fee models, liquidity terms and compensation, and align client requirements with business needs across four functional areas: management, operations, distribution and investments.
- Fee models will evolve to ensure better, more stable revenues for managers. Performance fees will vary by strategy, firm and liquidity terms, and will incorporate rolling periods and deferrals.
- There are four viable business models the hedge fund of tomorrow can pursue. The Multi-Capability Platform (a better designed and more durable model) will see the greatest growth in share.

Casey Quirk

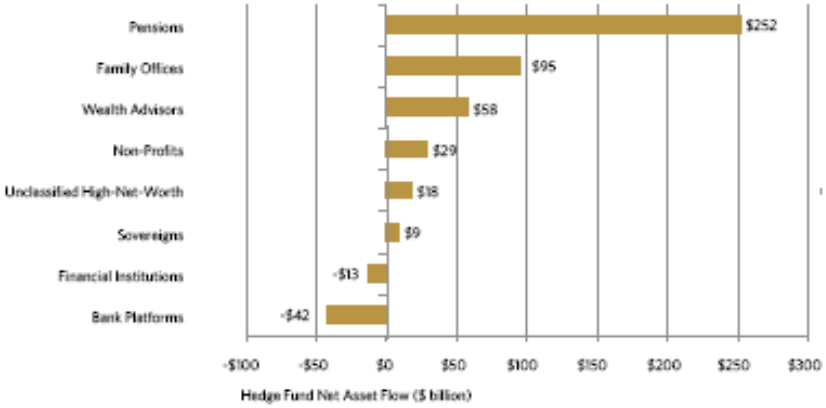
THE BANK OF NEW YORK MELLON

Exhibit 18: Projected Hedge Fund Assets by Scenario
December 2002 through December 2013



Source: Hedge Fund Research, The Bank of New York Mellon and Casey Quirk Analysis 2009

Exhibit 19: Cumulative Net Hedge Fund Flows by Investor Type
December 2008 through December 2013



Source: The Bank of New York Mellon and Casey Quirk Analysis 2009

What Are Hedge Funds?

Hedge Funds Are The "Galapagos Islands" of Finance

- Relatively low barriers to entry and exit
- High levels of compensation
- Competition and adaptation are extreme
- New "species" are coming and going constantly
- Strategies wax and wane over time:
  - Risk arbitrage waxing
  - Statistical arbitrage waning
- Supports Adaptive Markets Hypothesis (Lo, 2004, 2005)

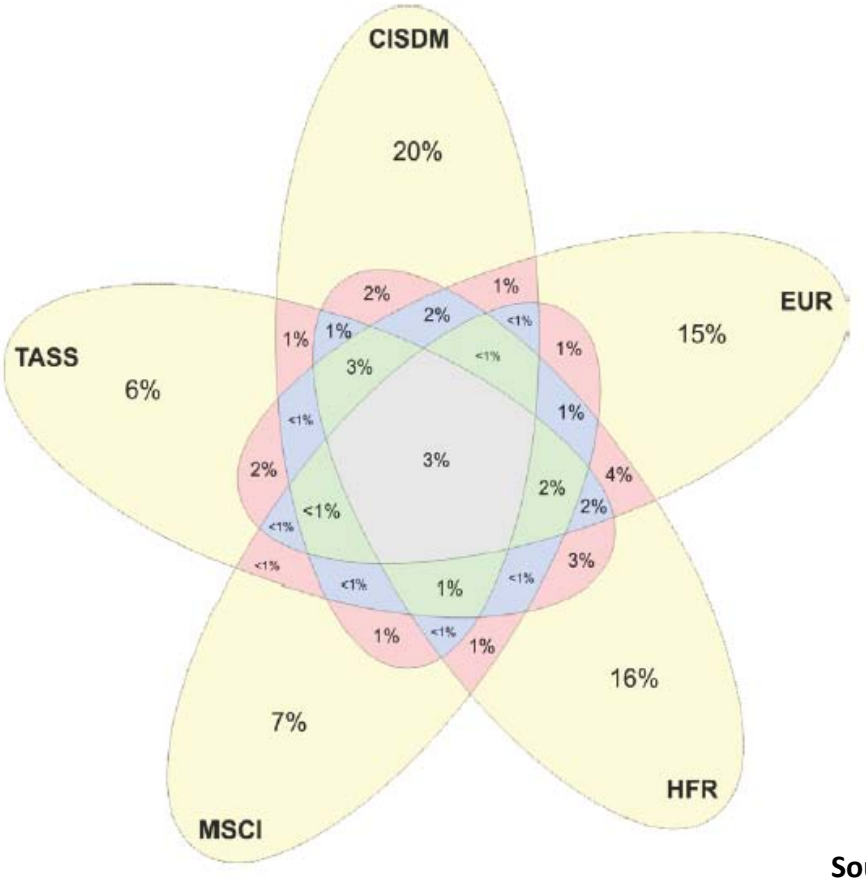
Basic Empirical Facts

Aggregate and Individual Data:

- CSFB/Tremont hedge-fund indexes
  - 14 indexes (13 style categories)
  - Jan 1994 to present
- TASS individual hedge-fund returns
  - Feb 1977 to present
  - Monthly returns, AUM, style, fund info
- Other sources for individual hedge-fund data
  - HFR, CISDM, MSCI, Eureka
  - Some overlap, but many unique funds in each dataset
  - See Fung and Hsieh (2007)

Basic Empirical Facts

Intersections of Hedge-Fund Databases as of 2005



Source: Fung and Hsieh (2007)

Basic Empirical Facts

Number of Funds in TASS, HFR, and CISDM Databases

	TASS (as of Feb 2005)				HFR (as of Jan 2005)				CISDM (as of Dec 2004)			
Year	Start	Entry	Exit	End	Start	Entry	Exit	End	Start	Entry	Exit	End
1994	650	211	29	832	823	270	23	1,070	513	224	25	712
1995	832	249	58	1,023	1,070	384	55	1,399	712	220	98	834
1996	1,023	295	119	1,199	1,399	374	171	1,602	834	293	87	1,040
1997	1,199	316	90	1,425	1,602	374	172	1,804	1,040	334	117	1,257
1998	1,425	307	145	1,587	1,804	381	320	1,865	1,257	290	192	1,355
1999	1,587	367	176	1,778	1,865	419	222	2,062	1,355	313	198	1,470
2000	1,778	365	206	1,937	2,062	407	310	2,159	1,470	256	191	1,535
2001	1,937	384	229	2,092	2,159	451	251	2,359	1,535	249	216	1,568
2002	2,092	406	233	2,265	2,359	489	252	2,596	1,568	257	233	1,592
2003	2,265	339	221	2,383	2,596	457	245	2,808	1,592	164	234	1,522
2004	2,383	250	193	2,431	2,808	329	198	2,939	1,522	133	340	1,315

Source: Fung and Hsieh (2007)

Basic Empirical Facts

Change in Style Composition of TASS Hedge Funds (Percentage of Total AUM)

Year	Convertible Arbitrage	Dedicated Shorts	Emerging Market	Equity Market Neutral	Event Driven	Fixed Income Arbitrage	Macro	Long/Short Equity	Managed Futures	Other	Total # / $b
Panel B. Assets Under Management											
1994	1%	0.3%	13%	2%	13%	7%	32%	26%	6%	0.3%	57.0
1995	2%	0.2%	10%	2%	13%	7%	30%	30%	6%	0.2%	72.3
1996	3%	0.3%	10%	3%	15%	8%	26%	30%	4%	0.5%	99.1
1997	4%	0.2%	10%	3%	16%	8%	26%	29%	3%	0.4%	144.6
1998	4%	0.4%	5%	4%	17%	8%	24%	33%	4%	0.4%	153.8
1999	4%	0.3%	5%	5%	16%	6%	15%	45%	3%	0.4%	197.2
2000	5%	0.3%	3%	6%	18%	5%	10%	49%	3%	0.3%	217.7
2001	8%	0.3%	3%	7%	20%	5%	9%	44%	3%	0.5%	261.4
2002	8%	0.5%	3%	8%	19%	6%	10%	38%	3%	4.5%	310.3
2003	8%	0.2%	3%	7%	17%	7%	11%	33%	5%	8.5%	489.5
2004	6%	0.2%	4%	5%	19%	7%	10%	32%	5%	10.1%	673.8

Source: TASS

Source: Fung and Hsieh (2007)

Basic Empirical Facts

Summary Statistics, Jan 1994 to Feb 2009

	Min	Mean	Median	Max	SD	Sharpe Ratio	Skew	Kurt	ρ_1
Credit Suisse Tremont Indexes									
Total	-90.6%	8.6%	9.4%	102.3%	7.9%	1.09	-0.17	28.59	22%
Distressed	-149.5%	10.1%	13.6%	49.1%	6.7%	1.50	-2.36	147.13	41%
Emerging Markets	-276.3%	7.5%	16.0%	197.0%	15.8%	0.48	-0.73	56.07	32%
Equity Market Neutral	-485.4%	5.9%	8.5%	39.1%	11.1%	0.53	-11.73	1804.07	8%
Event Driven	-141.3%	9.3%	11.7%	44.2%	6.1%	1.52	-2.68	176.56	39%
Event Driven Multi-Strategy	-138.3%	8.9%	10.8%	55.9%	6.5%	1.37	-2.06	127.89	33%
Fixed Income Arbitrage	-168.4%	3.7%	8.4%	24.8%	6.0%	0.61	-4.66	363.33	51%
Global Macro	-138.6%	12.4%	13.7%	127.2%	10.5%	1.18	-0.04	37.11	10%
Multi-Strategy	-88.2%	7.2%	9.1%	43.3%	5.5%	1.31	-1.91	77.85	33%
Risk Arbitrage	-73.9%	6.9%	6.9%	45.7%	4.3%	1.61	-1.09	62.02	31%
Convertible Arbitrage	-151.1%	5.9%	11.5%	68.6%	6.9%	0.85	-3.33	223.06	54%
Dedicated Short Bias	-104.3%	1.1%	-3.5%	272.5%	16.9%	0.06	0.76	20.46	9%
Long Short Equity	-137.2%	9.6%	9.5%	156.1%	10.2%	0.94	0.04	42.72	22%
Managed Futures	-112.3%	7.6%	4.2%	119.4%	11.8%	0.64	0.00	1.84	7%
S&P 500	-201.5%	6.1%	14.2%	117.4%	15.4%	0.40	-0.81	15.07	12%
Russell 3000	-213.4%	4.2%	14.5%	96.4%	15.5%	0.27	-0.93	18.29	15%
MSCI World	-228.5%	2.6%	11.1%	106.9%	15.0%	0.18	-1.04	25.80	17%
JPMorgan Hedged USD GBI Global	-25.6%	6.4%	6.9%	41.6%	3.3%	1.95	-0.15	4.09	24%
US Dollar	-72.2%	-0.3%	-1.3%	93.4%	7.8%	-0.04	0.24	7.95	10%
Euro	-116.3%	1.3%	2.7%	121.0%	9.7%	0.13	-0.03	16.07	8%
Yen	-180.1%	-0.2%	1.7%	122.4%	11.4%	-0.02	-0.52	30.77	3%
Oil	-388.3%	12.8%	15.5%	436.8%	32.1%	0.40	-0.12	13.11	7%
Gold	-208.6%	7.0%	3.6%	208.2%	15.0%	0.47	0.23	24.90	-9%
VIX	-183.4%	2.3%	-0.4%	246.0%	15.0%	0.15	1.12	78.53	1%

Basic Empirical Facts

Sharpe Ratio Measures Reward/Risk Trade-Off

- For monthly returns:

$$\hat{\mu} = \frac{1}{T}\sum_{t=1}^{T} R_t \quad , \quad \hat{\sigma} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(R_t - \hat{\mu})^2}$$

$$\text{SR} = \sqrt{12} \times \frac{\hat{\mu} - R_f}{\hat{\sigma}}$$

- Sometimes, R_f is assumed to be 0
- SR measures reward per unit risk
- Typical SR for long-only equities is 0.25 to 0.50
- Typical SR for liquid hedge funds is 0.25 to 1.00
- Typical SR for illiquid hedge funds is 0.50 to 1.50

Basic Empirical Facts

High Sharpe Ratios May Be Due To:

- High-frequency trading (market-making)
- Illiquid securities (low volatility from smooth returns)
- Good information (too good?)
- Fraud?

Investors Are Drawn To

High Sharpe Ratios

Basic Empirical Facts

Consider A Simple Example of Market-Making:

- Each day, you can make or lose 0.5%
- Probability of winning is 58%, probability of losing is 42%
- Expected return is 8 basis points a day (0.08%)
- Suppose risk-free rate is 1% per year
- Assume 250 days of independent bets
- Sharpe ratio is:

$$\begin{aligned} \text{SR} &= \frac{\text{E}[\prod_{t=1}^{250}(1+R_t)] - (1+R_f)}{\sqrt{\text{Var}[\prod_{t=1}^{250}(1+R_t) - 1]}} \\ &= \frac{22.1\% - 1\%}{9.3\%} = 2.22 \end{aligned}$$

Basic Empirical Facts

An Aside On Estimating Sharpe Ratios (Lo, 2002):

- For IID returns with finite fourth moments:

$$\sqrt{T}\,(\hat{\mu}-\mu) \;\overset{a}{\sim}\; \mathcal{N}\left(\,0\,,\;\sigma^2\,\right)$$
$$\sqrt{T}\,(\hat{\sigma}^2-\sigma^2) \;\overset{a}{\sim}\; \mathcal{N}\left(\,0\,,\;2\sigma^4\,\right)$$

$$\sqrt{T}\,(\widehat{\mathrm{SR}}-\mathrm{SR}) \;\overset{a}{\sim}\; \mathcal{N}\left(\,0\,,\;V_{\mathrm{IID}}\,\right)$$

$$V_{\mathrm{IID}} \;\equiv\; \left(\frac{\partial g}{\partial \mu}\right)^2 \sigma^2 \;+\; \left(\frac{\partial g}{\partial \sigma^2}\right)^2 2\sigma^4$$

$$= \;1\; + \;\frac{(\mu - R_f)^2}{2\sigma^2} \;=\; 1 \;+\; \tfrac{1}{2}\mathrm{SR}^2$$

$$\mathrm{SE}(\widehat{\mathrm{SR}}) \;=\; \sqrt{(1+\tfrac{1}{2}\mathrm{SR}^2)/T}$$

An Aside On Estimating Sharpe Ratios (Lo, 2002):

- For stationary and ergodic returns, use GMM:

$$\sqrt{T}\,(\widehat{\mathrm{SR}} - \mathrm{SR}) \quad \overset{a}{\sim} \quad \mathcal{N}\,(\,0\,,\,V_{\mathrm{GMM}}\,)$$

$$V_{\mathrm{GMM}} \quad = \quad \frac{\partial g}{\partial \boldsymbol{\theta}}\boldsymbol{\Sigma}\frac{\partial g}{\partial \boldsymbol{\theta}'} \quad , \quad \mathrm{SE}[\widehat{\mathrm{SR}}] \quad \overset{a}{=} \quad \sqrt{\widehat{V}_{\mathrm{GMM}}/T}$$

$$\widehat{\boldsymbol{\Sigma}} \quad = \quad \widehat{\boldsymbol{\Omega}}_0 \; + \; \sum_{j=1}^{m} \omega(j,m)(\widehat{\boldsymbol{\Omega}}_j + \widehat{\boldsymbol{\Omega}}_j') \;\; , \;\; m \ll T$$

$$\widehat{\boldsymbol{\Omega}}_j \quad \equiv \quad \frac{1}{T}\sum_{t=j+1}^{T} \boldsymbol{\varphi}(R_t, \hat{\boldsymbol{\theta}})\boldsymbol{\varphi}(R_{t-j}, \hat{\boldsymbol{\theta}})' \quad , \quad \omega(j,m) \quad \equiv \quad 1 \; - \; \frac{j}{m+1}$$

$$\widehat{V}_{\mathrm{GMM}} \quad = \quad \frac{\partial g(\hat{\boldsymbol{\theta}})}{\partial \boldsymbol{\theta}}\widehat{\boldsymbol{\Sigma}}\frac{\partial g(\hat{\boldsymbol{\theta}})}{\partial \boldsymbol{\theta}'}$$

Basic Empirical Facts

An Aside On Estimating Sharpe Ratios (Lo, 2002):

- Time aggregation:

$$
\begin{aligned}
R_t(q) &\equiv R_t + R_{t-1} + \cdots + R_{t-q+1} \\
\mathrm{Var}[R_t(q)] &= \sum_{i=0}^{q-1}\sum_{j=0}^{q-1} \mathrm{Cov}[R_{t-i}, R_{t-j}] = q\sigma^2 + 2\sigma^2 \sum_{k=1}^{q-1}(q-k)\rho_k \\
\mathrm{SR}(q) &= \eta(q)\,\mathrm{SR} \\
\eta(q) &\equiv \frac{q}{\sqrt{q + 2\sum_{k=1}^{q-1}(q-k)\rho_k}} \\
&= \sqrt{q} \ \text{ if } \rho_k \equiv 0 \text{ for all } k > 0
\end{aligned}
$$

Basic Empirical Facts

Summary Statistics for Individual Mutual Funds and Hedge Funds

Fund	Start Date	End Date	Sample Size	Mean (%)	SD (%)	ρ_1 (%)	ρ_2 (%)	ρ_3 (%)	$p(Q_{11})$ (%)
Mutual Funds									
Vanguard 500 Index	Oct-76	Jun-00	286	1.30	4.27	**-4.0**	-6.6	-4.9	**64.5**
Fidelity Magellan	Jan-67	Jun-00	402	1.73	6.23	**12.4**	-2.3	-0.4	**28.6**
Investment Company of America	Jan-63	Jun-00	450	1.17	4.01	**1.8**	-3.2	-4.5	**80.2**
Janus	Mar-70	Jun-00	364	1.52	4.75	**10.5**	0.0	-3.7	**58.1**
Fidelity Contrafund	May-67	Jun-00	397	1.29	4.97	**7.4**	-2.5	-6.8	**58.2**
Washington Mutual Investors	Jan-63	Jun-00	450	1.13	4.09	**-0.1**	-7.2	-2.6	**22.8**
Janus Worldwide	Jan-92	Jun-00	102	1.81	4.36	**11.4**	3.4	-3.8	**13.2**
Fidelity Growth and Income	Jan-86	Jun-00	174	1.54	4.13	**5.1**	-1.6	-8.2	**60.9**
American Century Ultra	Dec-81	Jun-00	223	1.72	7.11	**2.3**	3.4	1.4	**54.5**
Growth Fund of America	Jul-64	Jun-00	431	1.18	5.35	**8.5**	-2.7	-4.1	**45.4**
Hedge Funds									
Convertible/Option Arbitrage	May-92	Dec-00	104	1.63	0.97	**42.7**	29.0	21.4	**0.0**
Relative Value	Dec-92	Dec-00	97	0.66	0.21	**25.9**	19.2	-2.1	**4.5**
Mortgage-Backed Securities	Jan-93	Dec-00	96	1.33	0.79	**42.0**	22.1	16.7	**0.1**
High Yield Debt	Jun-94	Dec-00	79	1.30	0.87	**33.7**	21.8	13.1	**5.2**
Risk Arbitrage A	Jul-93	Dec-00	90	1.06	0.69	**-4.9**	-10.8	6.9	**30.6**
Long/Short Equities	Jul-89	Dec-00	138	1.18	0.83	**-20.2**	24.6	8.7	**0.1**
Multi-Strategy A	Jan-95	Dec-00	72	1.08	0.75	**48.9**	23.4	3.3	**0.3**
Risk Arbitrage B	Nov-94	Dec-00	74	0.90	0.77	**-4.9**	2.5	-8.3	**96.1**
Convertible Arbitrage A	Sep-92	Dec-00	100	1.38	1.60	**33.8**	30.8	7.9	**0.8**
Convertible Arbitrage B	Jul-94	Dec-00	78	0.78	0.62	**32.4**	9.7	-4.5	**23.4**
Multi-Strategy B	Jun-89	Dec-00	139	1.34	1.63	**49.0**	24.6	10.6	**0.0**
Fund of Funds	Oct-94	Dec-00	75	1.68	2.29	**29.7**	21.1	0.9	**23.4**

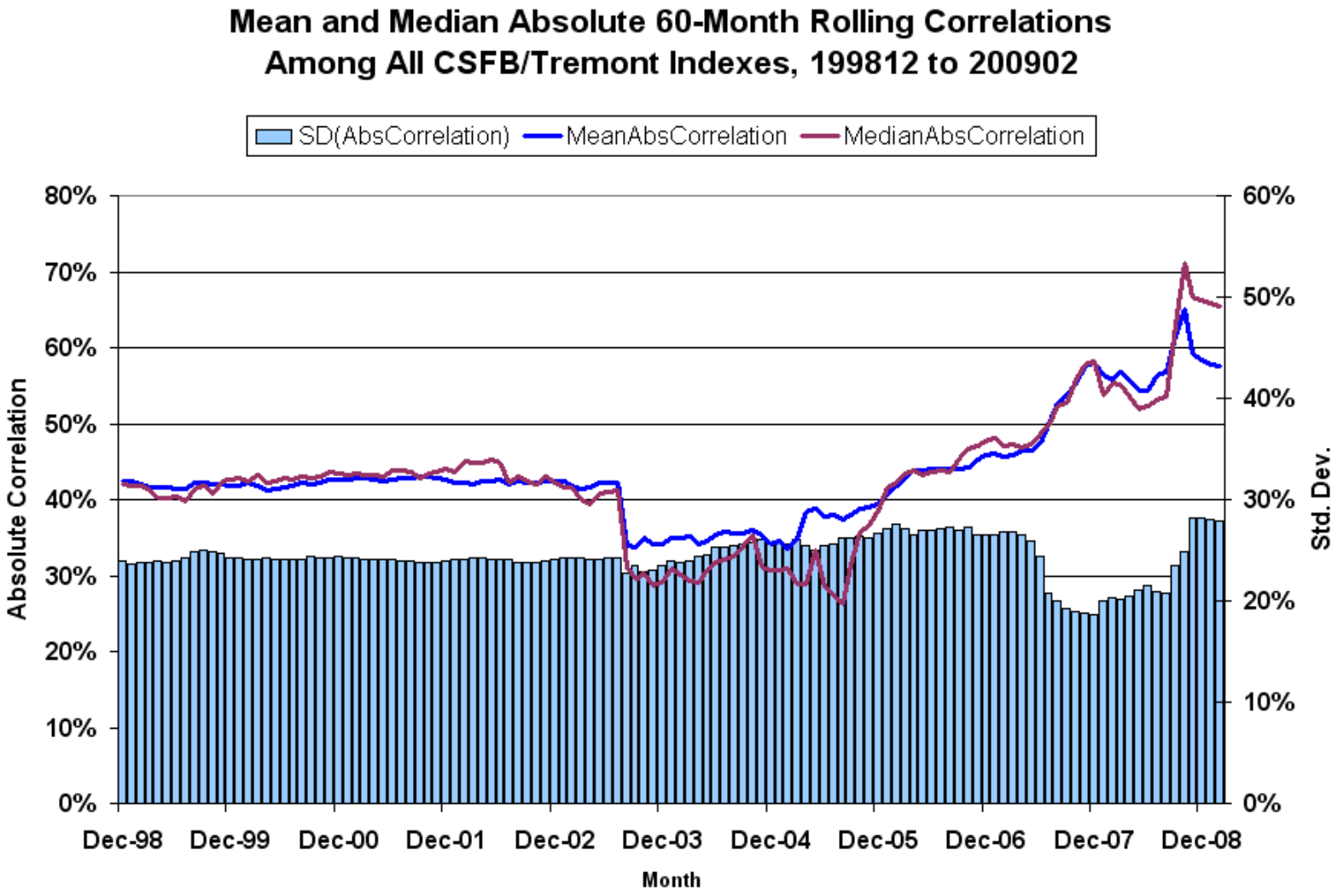
Basic Empirical Facts

Correlations Between CS/Tremont Indexes and Other Indexes

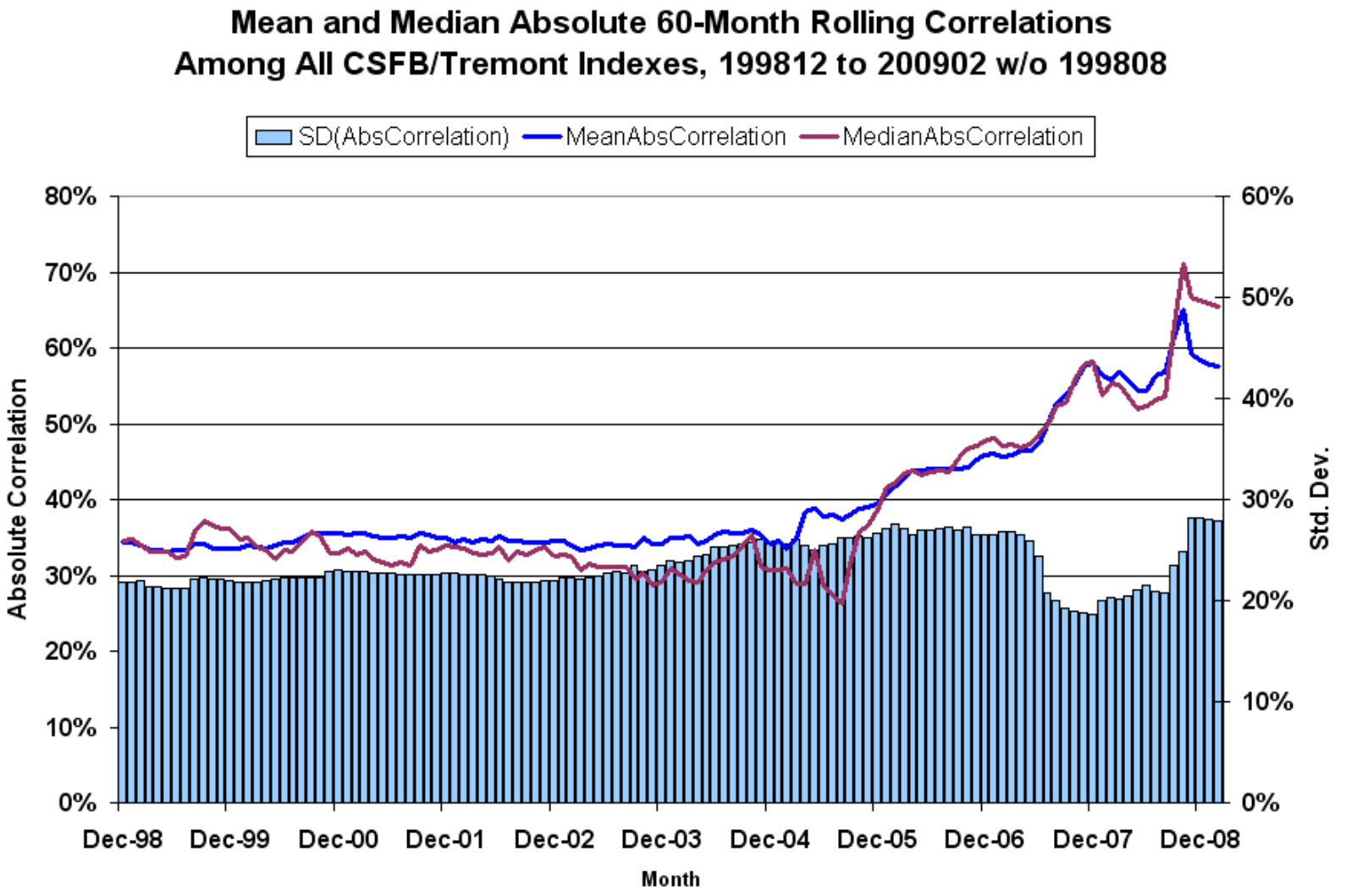
January 1994 to February 2009

CS/Tremont HF Index	Gold	S&P 500	Russell 3000	MSCI World	JPM Bond	DXY	Euro	Yen	Oil	VIX
Total	12%	54%	57%	57%	6%	2%	-3%	28%	23%	-36%
Distressed	8%	61%	63%	64%	-10%	-4%	1%	13%	22%	-43%
Emerging Markets	17%	52%	54%	58%	-13%	1%	-4%	11%	16%	-41%
Equity Market Neutral	-15%	25%	27%	25%	-16%	-7%	2%	1%	19%	1%
Event Driven	9%	61%	64%	66%	-14%	-3%	0%	16%	25%	-46%
Event Driven Multi-Strategy	7%	54%	57%	59%	-16%	0%	-3%	18%	24%	-42%
Fixed Income Arbitrage	13%	31%	33%	36%	-3%	-12%	13%	35%	33%	-25%
Global Macro	10%	25%	26%	24%	23%	12%	-9%	35%	7%	-17%
Multi-Strategy	13%	30%	32%	38%	-11%	-22%	20%	14%	27%	-18%
Risk Arbitrage	17%	48%	52%	52%	-5%	-17%	17%	3%	15%	-47%
Convertible Arbitrage	15%	32%	34%	36%	-3%	-5%	5%	28%	21%	-31%
Dedicated Short Bias	-10%	-73%	-76%	-70%	12%	4%	1%	5%	-8%	50%
Long Short Equity	16%	63%	68%	67%	-1%	-14%	11%	6%	28%	-45%
Managed Futures	21%	-14%	-14%	-8%	25%	-21%	20%	-11%	12%	14%

Basic Empirical Facts



Basic Empirical Facts



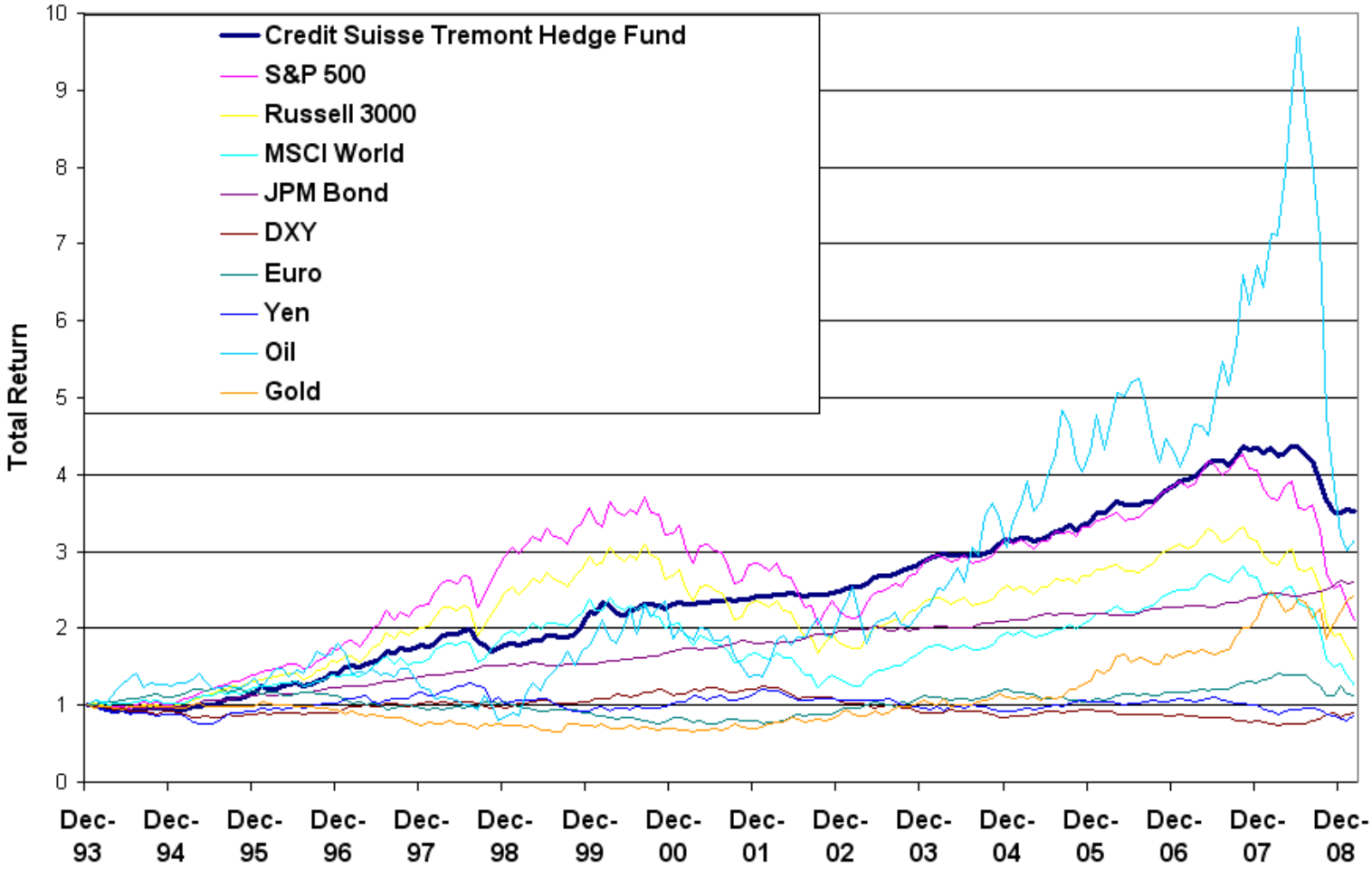
Hedge-Fund Returns

References

- Ackermann, C., McEnally, R. and D. Ravenscraft, 1999, "The Performance of Hedge Funds: Risk, Return, and Incentives'', *Journal of Finance* 54, 833–874.
- Lo, A., 2008, "Where Do Alphas Come From?: A New Measure of the Value of Active Investment Management", *Journal of Investment Management* 6, 1–29.

Motivation

Total Return Comparison, Jan 1994 to Feb 2009



Motivation

What Do We Mean By "Active" Management?

- Excess expected return above some benchmark
- "Active" bets means departures from the benchmark F_t
- Benchmarks are considered "passive"
  - Easy to achieve, very little skill involved, low fees
- Traditional measure of active management—IR:

$$R_{pt} - R_f = \alpha_p + \beta_p F_t + \epsilon_{pt} \quad , \quad \text{IR}_p = \frac{\alpha_p}{\sigma_{\epsilon_p}}$$

- But what if there are other "systematic" factors?
- Such factors can yield positive IR, but require no skill

Motivation

- For example:

$$R_{it} - R_f = \beta_{1i} F_{1t} + \beta_{2i} F_{2t} + \cdots + \beta_{Ki} F_{Kt} + \epsilon_{it}$$

$$\mathsf{E}[R_{it}] - R_f = \beta_{1i} \mathsf{E}[F_{1t}] + \underbrace{\beta_{2i} \mathsf{E}[F_{2t}] + \cdots + \beta_{Ki} \mathsf{E}[F_{Kt}]}_{\alpha_i \text{??}}$$

- In this case, excess returns may be passively achieved
- One natural implication: "hedge-fund beta" products
- So what do we really mean by "active management" in a multi-factor world?

$\Rightarrow$ **Where Do Alphas Come From?**

A New Measure

A New Definition of Active Management:

- Active management consists of time-varying portfolio weights based on information $\{\omega_{it}(\mathbf{X}_{t-1})\}$
- Passive management consists of either non-stochastic portfolios, or where the time-variation is not information-based, e.g., value-weighted portfolios, random portfolios
- To measure the value of active management, ask whether time-variation in weights increases expected return $E[R_t]$
- We don't need to know $\mathbf{X}_{t-1}$ to estimate the value of active management

A New Measure

A New Measure of the Value of Active Management:

- Recall the definition of covariance:

$$\begin{aligned} \text{Cov}[X,Y] &= \text{E}[XY] - \text{E}[X]\text{E}[Y] \\ \text{E}[XY] &= \text{Cov}[X,Y] + \text{E}[X]\text{E}[Y] \end{aligned}$$

- True for sample estimators as well:

$$\begin{aligned} \frac{1}{T}\sum_{t=1}^{T} X_t Y_t &= \frac{1}{T}\sum_{t=1}^{T}(X_t-\hat{\mu}_x)(Y_t-\hat{\mu}_y) + \hat{\mu}_x\hat{\mu}_y \\ \hat{\mu}_x &= \frac{1}{T}\sum_{t=1}^{T} X_t \quad , \quad \hat{\mu}_y = \frac{1}{T}\sum_{t=1}^{T} Y_t \end{aligned}$$

A New Measure

A New Measure of the Value of Active Management:

$$R_{pt} = \sum_{i=1}^{n} \omega_{it}(\mathbf{X}_{t-1}) R_{it}$$

$$\mathrm{E}[R_{pt}] = \sum_{i=1}^{n} \mathrm{E}[\omega_{it}(\mathbf{X}_{t-1}) R_{it}]$$

$$= \sum_{i=1}^{n} \mathrm{Cov}[\omega_{it}(\mathbf{X}_{t-1}), R_{it}] + \sum_{i=1}^{n} \mathrm{E}[\omega_{it}(\mathbf{X}_{t-1})]\mathrm{E}[R_{it}]$$

$$\mathrm{E}[R_{pt}] = \sum_{i=1}^{n} \mathrm{Cov}[\omega_{it}(\mathbf{X}_{t-1}), R_{it}] + \sum_{i=1}^{n} \overline{\omega}_i \mu_i$$

Active

Passive

A New Measure

A New Measure of the Value of Active Management:

$$\mathsf{E}[R_{pt}] = \sum_{i=1}^{n} \rho(\omega_{it}, R_{it})\sigma_{\omega_i}\sigma_i + \sum_{i=1}^{n} \overline{\omega}_i\mu_i$$

- Two sources of expected returns:
  1. Average exposures to risk premia μ_i
  2. Correlation between weights and returns (asset-timing ability)
- Note: weights are determined **prior** to returns (otherwise, arbitrage is possible: buy low/sell high), hence they capture predictability of current asset returns by past information

A New Measure

A New Measure of the Value of Active Management:

$$\text{Active Ratio } \theta \equiv \frac{\sum_{i=1}^{n} \rho(\omega_{it}, R_{it})\sigma_{\omega_i}\sigma_i}{\mathsf{E}[R_{pt}]}$$

$$= 1 - \frac{\sum_{i=1}^{n} \overline{\omega}_i \mu_i}{\mathsf{E}[R_{pt}]}$$

- Active component can be estimated without covariances
- Active component can be estimated without weights ω_i
- In fact, only **average weights and returns** are needed
- Ideal for institutional investors of active managers and hedge funds (position transparency unnecessary)

A New Measure

Implicit Assumptions:

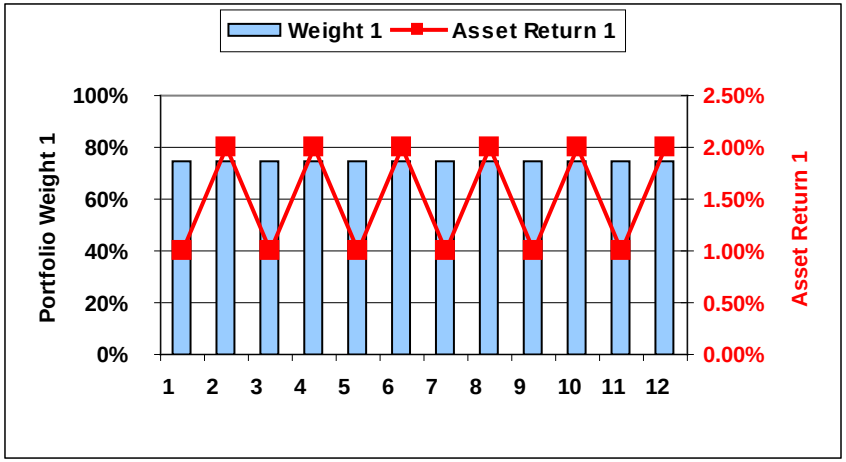
- Returns are stationary and parameters are known
- $\mathbf{X}_t$ is information (need not be private)

Properties of $\{\omega_{it}(\mathbf{X}_{t-1})\}$ Determine Active Value-Added

- If weights are non-stochastic, covariances are 0
- If weights are uncorrelated with returns, covariances are 0
- Passive portfolio $\{\overline{\omega}_i\}$ earns risk premia $\{\mu_i\}$ on average
- Unlike IR, θ is a dynamic measure of predictability

Example 1

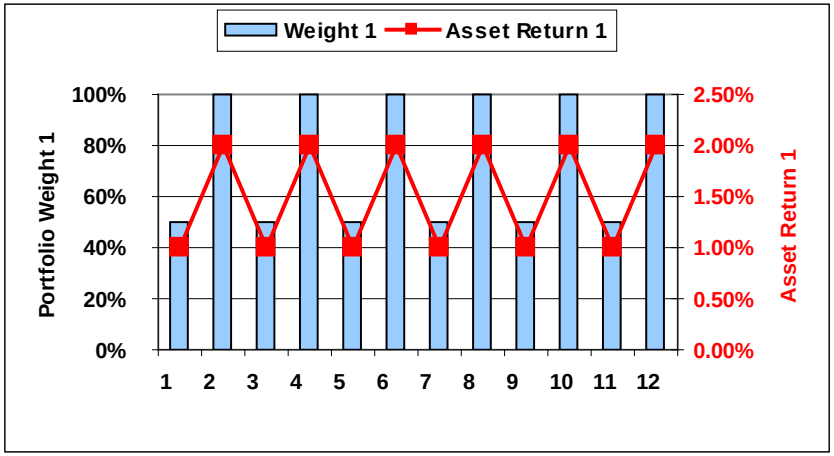
Month	ω_1	R_1	ω_2	R_2	R_p
			Strategy A1		
1	75%	1.00%	25%	0.15%	0.79%
2	75%	2.00%	25%	0.15%	1.54%
3	75%	1.00%	25%	0.15%	0.79%
4	75%	2.00%	25%	0.15%	1.54%
5	75%	1.00%	25%	0.15%	0.79%
6	75%	2.00%	25%	0.15%	1.54%
7	75%	1.00%	25%	0.15%	0.79%
8	75%	2.00%	25%	0.15%	1.54%
9	75%	1.00%	25%	0.15%	0.79%
10	75%	2.00%	25%	0.15%	1.54%
11	75%	1.00%	25%	0.15%	0.79%
12	75%	2.00%	25%	0.15%	1.54%
Mean:	75.00%	1.50%	25.00%	0.15%	1.16%
SD:	0.00%	0.52%	0.00%	0.00%	0.39%
Corr[w,R]:	0.00%		0.00%		
Cov[w,R]:	0.00%	+	0.00%	=	0.00%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.16%
				θ:	0.00%



- Constant weights (no timing)
- No active management
- Active component: 0%
- Passive component: 100%

Example 1

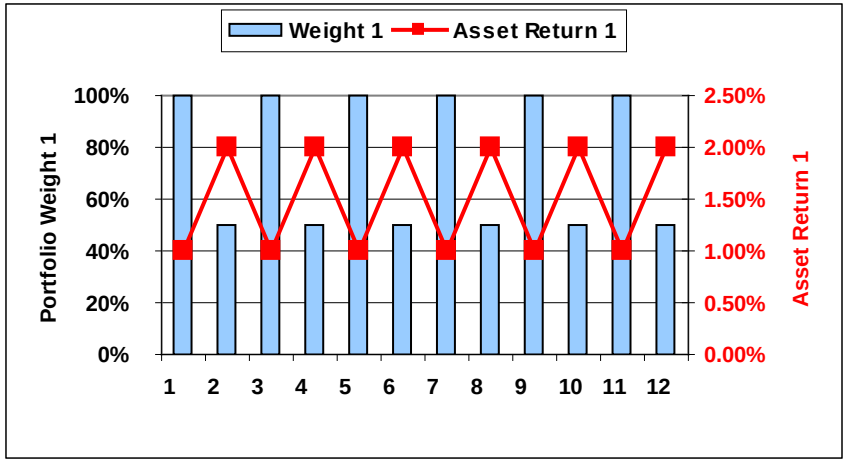
Month	ϖ_1	R_1	ϖ_2	R_2	R_p
			Strategy A2		
1	50%	1.00%	50%	0.15%	0.58%
2	100%	2.00%	0%	0.15%	2.00%
3	50%	1.00%	50%	0.15%	0.58%
4	100%	2.00%	0%	0.15%	2.00%
5	50%	1.00%	50%	0.15%	0.58%
6	100%	2.00%	0%	0.15%	2.00%
7	50%	1.00%	50%	0.15%	0.58%
8	100%	2.00%	0%	0.15%	2.00%
9	50%	1.00%	50%	0.15%	0.58%
10	100%	2.00%	0%	0.15%	2.00%
11	50%	1.00%	50%	0.15%	0.58%
12	100%	2.00%	0%	0.15%	2.00%
Mean:	75.00%	1.50%	25.00%	0.15%	1.29%
SD:	26.11%	0.52%	26.11%	0.00%	0.74%
Corr[w,R]:	100.00%		0.00%		
Cov[w,R]:	0.13%	+	0.00%	=	0.13%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.29%
				θ:	9.71%



- Time-varying weights
- Adds 0.13% per month
- Active component: 9.7%
- Passive component: 90.3%

Example 1

Month	ω_1	R_1	ω_2	R_2	R_p
			Strategy A3		
1	100%	1.00%	0%	0.15%	1.00%
2	50%	2.00%	50%	0.15%	1.08%
3	100%	1.00%	0%	0.15%	1.00%
4	50%	2.00%	50%	0.15%	1.08%
5	100%	1.00%	0%	0.15%	1.00%
6	50%	2.00%	50%	0.15%	1.08%
7	100%	1.00%	0%	0.15%	1.00%
8	50%	2.00%	50%	0.15%	1.08%
9	100%	1.00%	0%	0.15%	1.00%
10	50%	2.00%	50%	0.15%	1.08%
11	100%	1.00%	0%	0.15%	1.00%
12	50%	2.00%	50%	0.15%	1.08%
Mean:	75.00%	1.50%	25.00%	0.15%	1.04%
SD:	26.11%	0.52%	26.11%	0.00%	0.04%
Corr[w,R]:	-100.00%		0.00%		
Cov[w,R]:	-0.13%	+	0.00%	=	-0.13%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.04%
				θ:	-12.05%



- Time-varying weights
- Subtracts 0.13% per month
- Active component: -12.05%
- Passive component: 112.05%

Example 2

Market Timing

- Equities vs. cash, where equity returns follow AR(1):

$$R_t = \mu + \rho(R_{t-1} - \mu) + \epsilon_t$$
$$\text{where} \quad \rho \in (-1, 1) \quad , \quad \epsilon_t \sim \mathcal{N}(0, \sigma_\epsilon^2)$$

- Consider 0/1 investment policy based on lagged return

$$\omega_t = \begin{cases} 1 & \text{if } R_{t-1} > \delta \\ 0 & \text{if } R_{t-1} \leq \delta \end{cases}$$
$$R_{pt} = \omega_t R_t + (1 - \omega_t) R_f$$

Example 2

Market Timing

- Then expected returns can be computed explicitly:

$$\begin{aligned}
\mathsf{E}[R_{pt}] &= \mathsf{Cov}[\omega_t, R_t] + \mathsf{E}[\omega_t]\mathsf{E}[R_t] + (1 - \mathsf{E}[\omega_t])\, R_f \\
&= \rho\sigma\phi\left(\frac{\delta-\mu}{\sigma}\right) + \mu\left(1 - \Phi\left(\frac{\delta-\mu}{\sigma}\right)\right) + \\
&\qquad R_f\,\Phi\left(\frac{\delta-\mu}{\sigma}\right) \\
\theta &= \frac{\rho\sigma\phi\left(\frac{\delta-\mu}{\sigma}\right)}{\mathsf{E}[R_{pt}]}
\end{aligned}$$

Example 2

$$R_f = 5\%/12 \ , \ \mathrm{E}[R_t] = 10\%/12 \ , \ \mathrm{SD}[R_t] = 20\%/\sqrt{12}$$

α	ρ	Annualized					
		$E[R_{pt}]$	Active	Passive	%Active	$E[\omega_t]$	$1\text{-}E[\omega_t]$
-1.0%	-25%	1.6%	-6.6%	8.1%	-423.1%	62.5%	37.5%
-0.5%	-25%	1.2%	-6.7%	8.0%	-547.6%	59.1%	40.9%
0.0%	-25%	0.9%	-6.8%	7.8%	-720.9%	55.7%	44.3%
0.5%	-25%	0.7%	-6.9%	7.6%	-962.5%	52.3%	47.7%
1.0%	-25%	0.5%	-6.9%	7.4%	-1290.0%	48.8%	51.2%
-1.0%	0%	8.1%	0.0%	8.1%	0.0%	62.5%	37.5%
-0.5%	0%	8.0%	0.0%	8.0%	0.0%	59.1%	40.9%
0.0%	0%	7.8%	0.0%	7.8%	0.0%	55.7%	44.3%
0.5%	0%	7.6%	0.0%	7.6%	0.0%	52.3%	47.7%
1.0%	0%	7.4%	0.0%	7.4%	0.0%	48.8%	51.2%
-1.0%	25%	14.7%	6.6%	8.1%	44.7%	62.5%	37.5%
-0.5%	25%	14.7%	6.7%	8.0%	45.8%	59.1%	40.9%
0.0%	25%	14.6%	6.8%	7.8%	46.8%	55.7%	44.3%
0.5%	25%	14.5%	6.9%	7.6%	47.5%	52.3%	47.7%
1.0%	25%	14.3%	6.9%	7.4%	48.1%	48.8%	51.2%
-1.0%	50%	21.3%	13.1%	8.1%	61.8%	62.5%	37.5%
-0.5%	50%	21.4%	13.5%	8.0%	62.8%	59.1%	40.9%
0.0%	50%	21.5%	13.7%	7.8%	63.7%	55.7%	44.3%
0.5%	50%	21.4%	13.8%	7.6%	64.4%	52.3%	47.7%
1.0%	50%	21.3%	13.8%	7.4%	65.0%	48.8%	51.2%

The Sampling Interval

Consider Warren Buffett vs. Steven Cohen

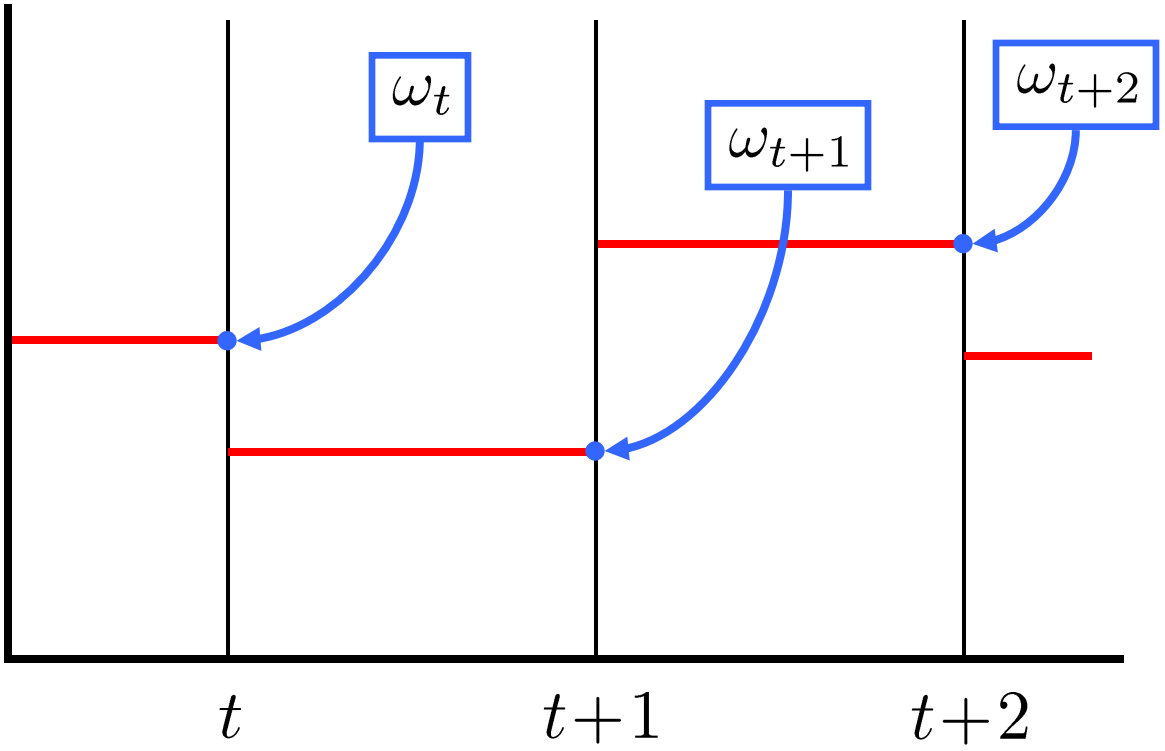
- Buffett makes a few decisions per year
- Cohen makes a few decisions per minute
- One symptom: very different Sharpe ratios!
- How frequently do we need to sample their weights?

$$\widehat{\text{Cov}}[\omega_{it}(\mathbf{X}_{t-1}), R_{it}] = \frac{1}{T}\left\{ (\omega_{i1} - \overline{\omega}_i)(R_{i1} - \widehat{\mu}_i) + (\omega_{i2} - \overline{\omega}_i)(R_{i2} - \widehat{\mu}_i) + \vdots + (\omega_{iT} - \overline{\omega}_i)(R_{iT} - \widehat{\mu}_i) \right\}$$

Do these terms capture the variation in the manager's weights, i.e., decisions?

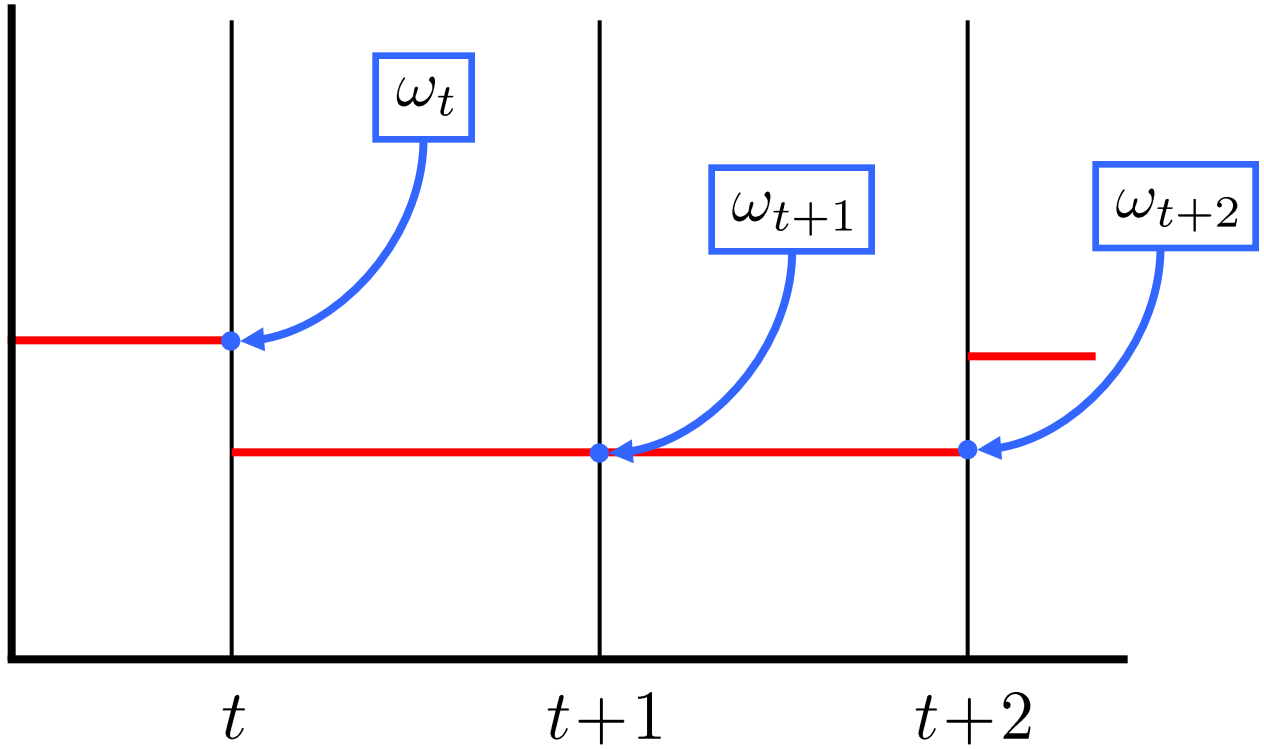
The Sampling Interval

Case 1: Decision Interval Coincides with Sampling Interval



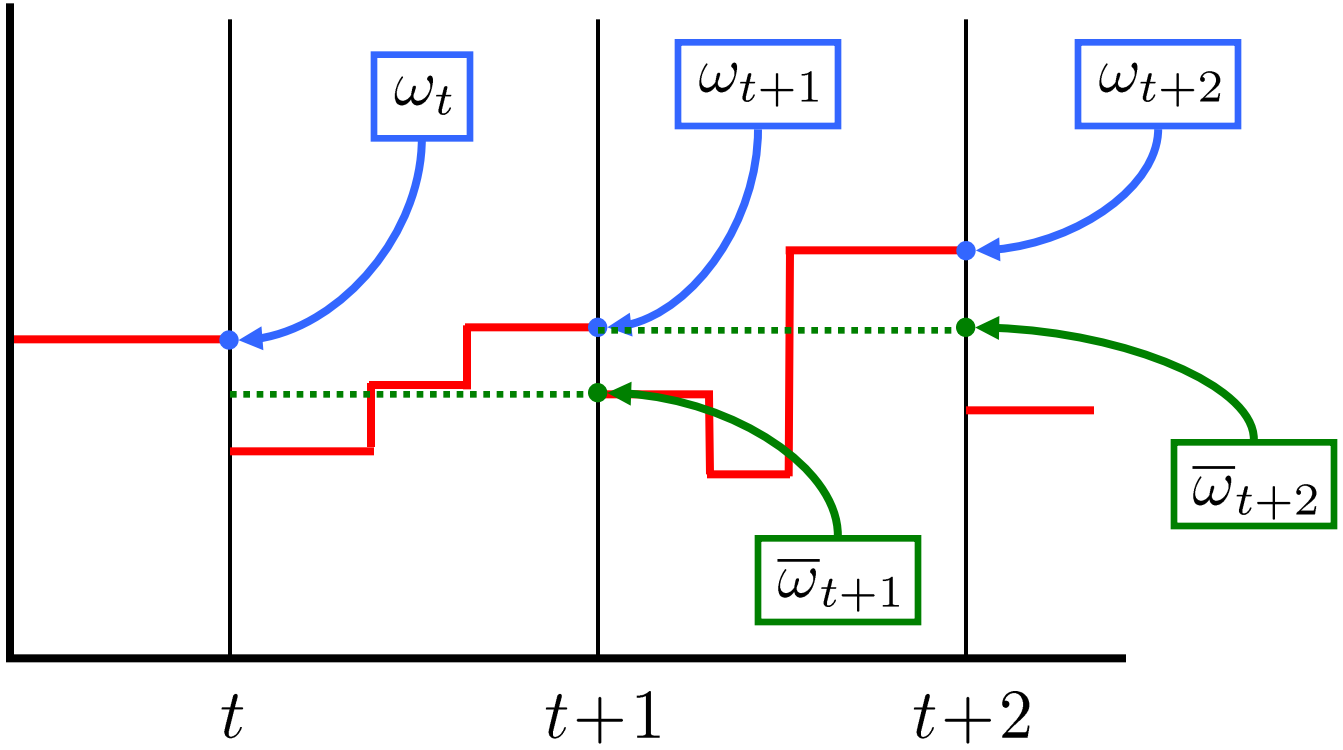
The Sampling Interval

Case 2: Decision Interval Longer Than Sampling Interval



The Sampling Interval

Case 3: Decision Interval Longer Than Sampling Interval



A New Measure

A New Measure of the Value of Active Management:

- Recall the definition of covariance:

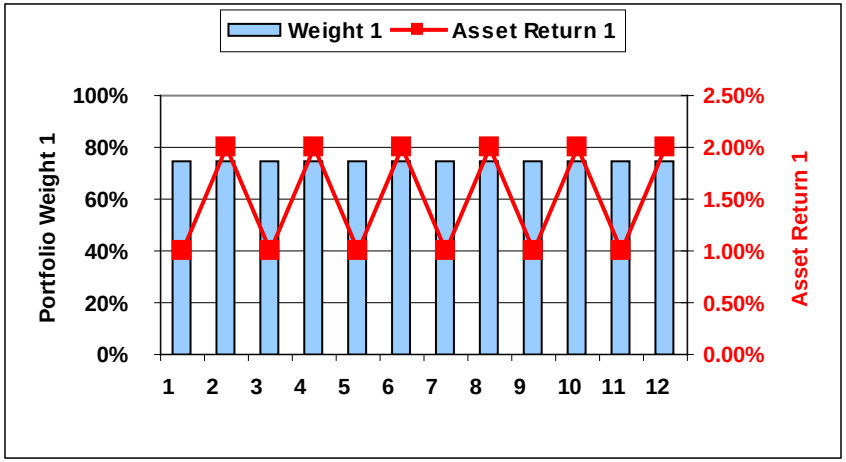
$$\begin{aligned} \text{Cov}[X,Y] &= \text{E}[XY] - \text{E}[X]\text{E}[Y] \\ \text{E}[XY] &= \text{Cov}[X,Y] + \text{E}[X]\text{E}[Y] \end{aligned}$$

- True for sample estimators as well:

$$\begin{aligned} \frac{1}{T}\sum_{t=1}^{T} X_t Y_t &= \frac{1}{T}\sum_{t=1}^{T}(X_t-\hat{\mu}_x)(Y_t-\hat{\mu}_y) + \hat{\mu}_x\hat{\mu}_y \\ \hat{\mu}_x &= \frac{1}{T}\sum_{t=1}^{T} X_t \quad , \quad \hat{\mu}_y = \frac{1}{T}\sum_{t=1}^{T} Y_t \end{aligned}$$

Example 1

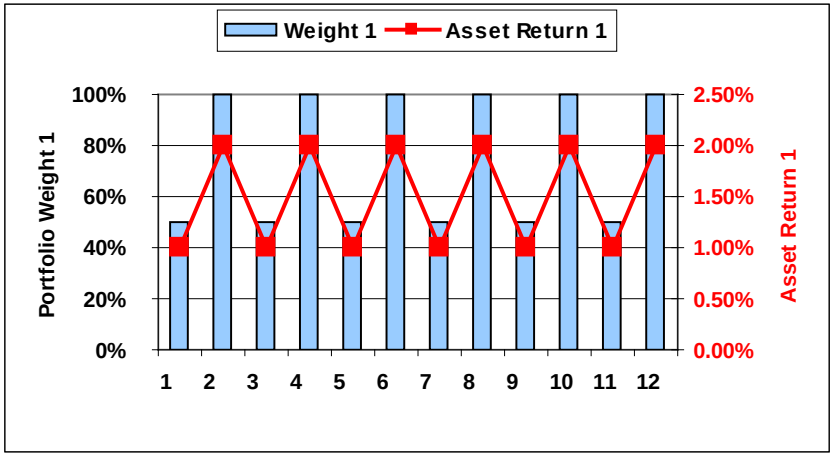
Month	ω_1	R_1	ω_2	R_2	R_p
			Strategy A1		
1	75%	1.00%	25%	0.15%	0.79%
2	75%	2.00%	25%	0.15%	1.54%
3	75%	1.00%	25%	0.15%	0.79%
4	75%	2.00%	25%	0.15%	1.54%
5	75%	1.00%	25%	0.15%	0.79%
6	75%	2.00%	25%	0.15%	1.54%
7	75%	1.00%	25%	0.15%	0.79%
8	75%	2.00%	25%	0.15%	1.54%
9	75%	1.00%	25%	0.15%	0.79%
10	75%	2.00%	25%	0.15%	1.54%
11	75%	1.00%	25%	0.15%	0.79%
12	75%	2.00%	25%	0.15%	1.54%
Mean:	75.00%	1.50%	25.00%	0.15%	1.16%
SD:	0.00%	0.52%	0.00%	0.00%	0.39%
Corr[w,R]:	0.00%		0.00%		
Cov[w,R]:	0.00%	+	0.00%	=	0.00%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.16%
				θ:	0.00%



- Constant weights (no timing)
- No active management
- Active component: 0%
- Passive component: 100%

Example 1

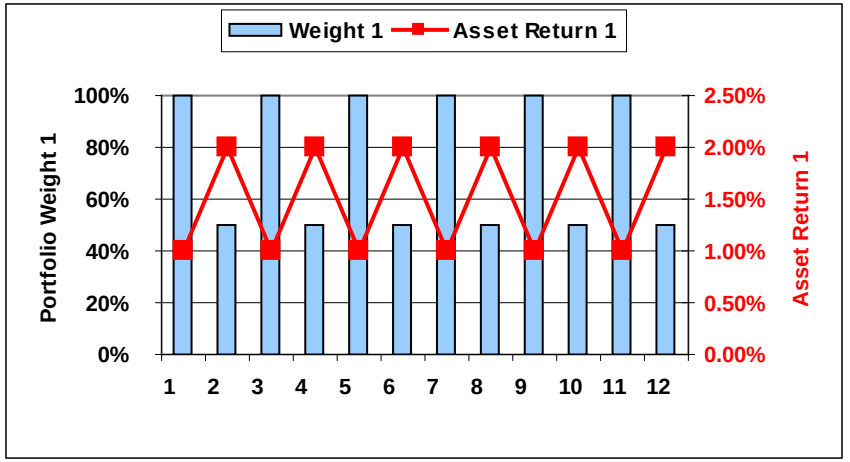
Month	ϖ_1	R_1	ϖ_2	R_2	R_p
			Strategy A2		
1	50%	1.00%	50%	0.15%	0.58%
2	100%	2.00%	0%	0.15%	2.00%
3	50%	1.00%	50%	0.15%	0.58%
4	100%	2.00%	0%	0.15%	2.00%
5	50%	1.00%	50%	0.15%	0.58%
6	100%	2.00%	0%	0.15%	2.00%
7	50%	1.00%	50%	0.15%	0.58%
8	100%	2.00%	0%	0.15%	2.00%
9	50%	1.00%	50%	0.15%	0.58%
10	100%	2.00%	0%	0.15%	2.00%
11	50%	1.00%	50%	0.15%	0.58%
12	100%	2.00%	0%	0.15%	2.00%
Mean:	75.00%	1.50%	25.00%	0.15%	1.29%
SD:	26.11%	0.52%	26.11%	0.00%	0.74%
Corr[w,R]:	100.00%		0.00%		
Cov[w,R]:	0.13%	+	0.00%	=	0.13%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.29%
				θ:	9.71%



- Time-varying weights
- Adds 0.13% per month
- Active component: 9.7%
- Passive component: 90.3%

Example 1

Month	ω_1	R_1	ω_2	R_2	R_p
			Strategy A3		
1	100%	1.00%	0%	0.15%	1.00%
2	50%	2.00%	50%	0.15%	1.08%
3	100%	1.00%	0%	0.15%	1.00%
4	50%	2.00%	50%	0.15%	1.08%
5	100%	1.00%	0%	0.15%	1.00%
6	50%	2.00%	50%	0.15%	1.08%
7	100%	1.00%	0%	0.15%	1.00%
8	50%	2.00%	50%	0.15%	1.08%
9	100%	1.00%	0%	0.15%	1.00%
10	50%	2.00%	50%	0.15%	1.08%
11	100%	1.00%	0%	0.15%	1.00%
12	50%	2.00%	50%	0.15%	1.08%
Mean:	75.00%	1.50%	25.00%	0.15%	1.04%
SD:	26.11%	0.52%	26.11%	0.00%	0.04%
Corr[w,R]:	-100.00%		0.00%		
Cov[w,R]:	-0.13%	+	0.00%	=	-0.13%
E[w]E[R]:	1.13%	+	0.04%	=	1.16%
Total:					1.04%
				θ:	-12.05%



- Time-varying weights
- Subtracts 0.13% per month
- Active component: -12.05%
- Passive component: 112.05%

Example 2

Market Timing

- Equities vs. cash, where equity returns follow AR(1):

$$R_t = \mu + \rho(R_{t-1} - \mu) + \epsilon_t$$
$$\text{where} \quad \rho \in (-1, 1) \quad , \quad \epsilon_t \sim \mathcal{N}(0, \sigma_\epsilon^2)$$

- Consider 0/1 investment policy based on lagged return

$$\omega_t = \begin{cases} 1 & \text{if } R_{t-1} > \delta \\ 0 & \text{if } R_{t-1} \leq \delta \end{cases}$$
$$R_{pt} = \omega_t R_t + (1 - \omega_t) R_f$$

Example 2

Market Timing

- Then expected returns can be computed explicitly:

$$\begin{aligned}
\mathsf{E}[R_{pt}] &= \mathsf{Cov}[\omega_t, R_t] + \mathsf{E}[\omega_t]\mathsf{E}[R_t] + (1 - \mathsf{E}[\omega_t])\, R_f \\
&= \rho\sigma\phi\left(\frac{\delta-\mu}{\sigma}\right) + \mu\left(1 - \Phi\left(\frac{\delta-\mu}{\sigma}\right)\right) + \\
&\qquad R_f\, \Phi\left(\frac{\delta-\mu}{\sigma}\right) \\
\theta &= \frac{\rho\sigma\phi\left(\frac{\delta-\mu}{\sigma}\right)}{\mathsf{E}[R_{pt}]}
\end{aligned}$$

Example 2

$$R_f = 5\%/12 \ , \ \mathrm{E}[R_t] = 10\%/12 \ , \ \mathrm{SD}[R_t] = 20\%/\sqrt{12}$$

α	ρ	Annualized					
		$E[R_{pt}]$	Active	Passive	%Active	$E[\omega_t]$	$1\text{-}E[\omega_t]$
-1.0%	-25%	1.6%	-6.6%	8.1%	-423.1%	62.5%	37.5%
-0.5%	-25%	1.2%	-6.7%	8.0%	-547.6%	59.1%	40.9%
0.0%	-25%	0.9%	-6.8%	7.8%	-720.9%	55.7%	44.3%
0.5%	-25%	0.7%	-6.9%	7.6%	-962.5%	52.3%	47.7%
1.0%	-25%	0.5%	-6.9%	7.4%	-1290.0%	48.8%	51.2%
-1.0%	0%	8.1%	0.0%	8.1%	0.0%	62.5%	37.5%
-0.5%	0%	8.0%	0.0%	8.0%	0.0%	59.1%	40.9%
0.0%	0%	7.8%	0.0%	7.8%	0.0%	55.7%	44.3%
0.5%	0%	7.6%	0.0%	7.6%	0.0%	52.3%	47.7%
1.0%	0%	7.4%	0.0%	7.4%	0.0%	48.8%	51.2%
-1.0%	25%	14.7%	6.6%	8.1%	44.7%	62.5%	37.5%
-0.5%	25%	14.7%	6.7%	8.0%	45.8%	59.1%	40.9%
0.0%	25%	14.6%	6.8%	7.8%	46.8%	55.7%	44.3%
0.5%	25%	14.5%	6.9%	7.6%	47.5%	52.3%	47.7%
1.0%	25%	14.3%	6.9%	7.4%	48.1%	48.8%	51.2%
-1.0%	50%	21.3%	13.1%	8.1%	61.8%	62.5%	37.5%
-0.5%	50%	21.4%	13.5%	8.0%	62.8%	59.1%	40.9%
0.0%	50%	21.5%	13.7%	7.8%	63.7%	55.7%	44.3%
0.5%	50%	21.4%	13.8%	7.6%	64.4%	52.3%	47.7%
1.0%	50%	21.3%	13.8%	7.4%	65.0%	48.8%	51.2%

The Sampling Interval

Consider Warren Buffett vs. Steven Cohen

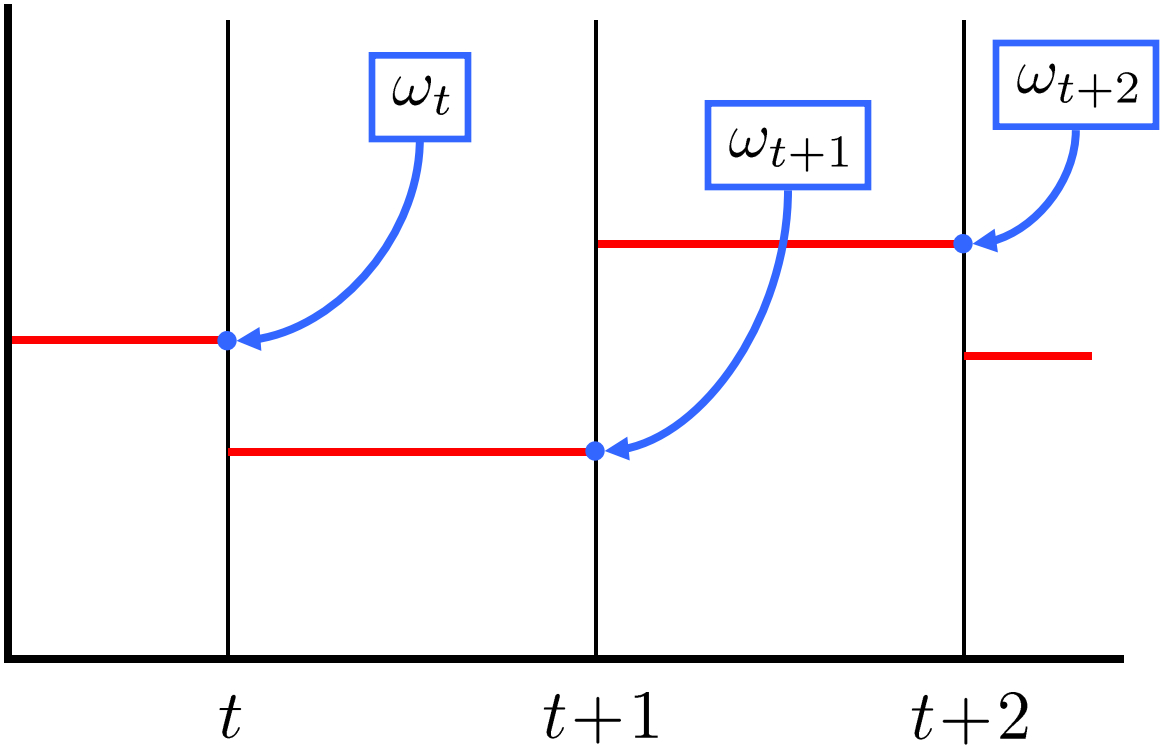
- Buffett makes a few decisions per year
- Cohen makes a few decisions per minute
- One symptom: very different Sharpe ratios!
- How frequently do we need to sample their weights?

$$\widehat{\text{Cov}}[\omega_{it}(\mathbf{X}_{t-1}), R_{it}] = \frac{1}{T}\left\{ (\omega_{i1} - \overline{\omega}_i)(R_{i1} - \widehat{\mu}_i) + (\omega_{i2} - \overline{\omega}_i)(R_{i2} - \widehat{\mu}_i) + \vdots + (\omega_{iT} - \overline{\omega}_i)(R_{iT} - \widehat{\mu}_i) \right\}$$

Do these terms capture the variation in the manager's weights, i.e., decisions?

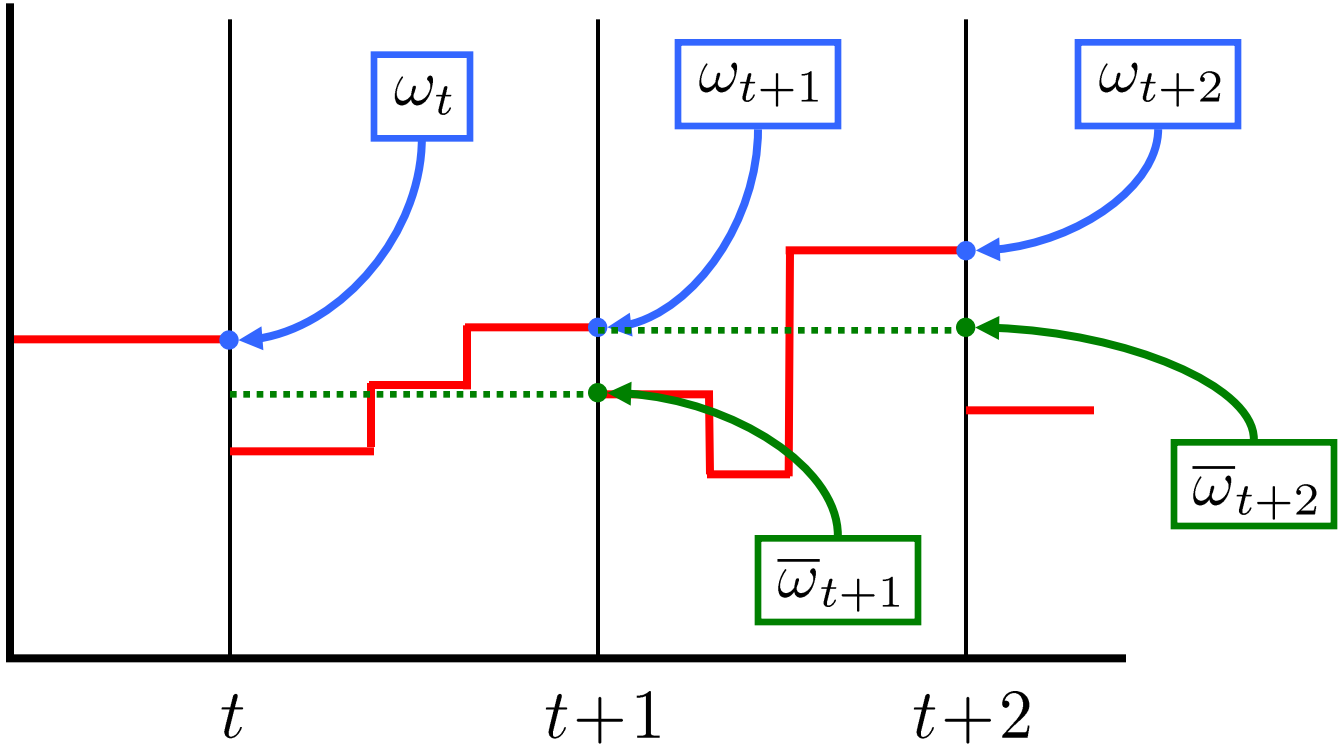
The Sampling Interval

Case 1: Decision Interval Coincides with Sampling Interval



The Sampling Interval

Case 3: Decision Interval Longer Than Sampling Interval



Empirical Analysis

Consider Contrarian Trading Strategy:

- Lo and MacKinlay (1990)

$$\omega_{it}(k) = -\frac{1}{n}(R_{it-k} - R_{mt-k}) \qquad i = 1, \ldots, n$$

$$R_{mt-k} \equiv \frac{1}{n}\sum_{i=1}^{n} R_{it-k}$$

$$\forall\ t,\ k \quad \sum_{i=1}^{n} \omega_{it}(k) = 0 \quad , \quad I_t = \frac{1}{2}\sum_{i=1}^{n} |\omega_{it}(k)|$$

Empirical Analysis

- Profitability can be quantified:

$$\begin{aligned}
\text{Profit } \pi_t(k) &= \sum_{i=1}^{n} \omega_{it}(k) R_{it} \\
\mathrm{E}[\pi_t(k)] &= \frac{\iota' \mathbf{\Gamma}_k \iota}{n^2} - \frac{1}{n}\mathrm{tr}(\mathbf{\Gamma}_k) - \frac{1}{n}\sum_{i=1}^{n}(\mu_i - \mu_m)^2 \\
&= \frac{1}{n^2}\left[\iota' \mathbf{\Gamma}_k \iota - \mathrm{tr}(\mathbf{\Gamma}_k)\right] - \left(\frac{n-1}{n^2}\right) \cdot \mathrm{tr}(\mathbf{\Gamma}_k) - \\
&\qquad \frac{1}{n}\sum_{i=1}^{n}(\mu_i - \mu_m)^2
\end{aligned}$$

Empirical Analysis

Apply This To NASDAQ Size-Decile Returns

- January 2, 1990 to December 29, 1995
- Use only 5 smallest deciles to maximize returns
- May not be realistic, but is illustrative

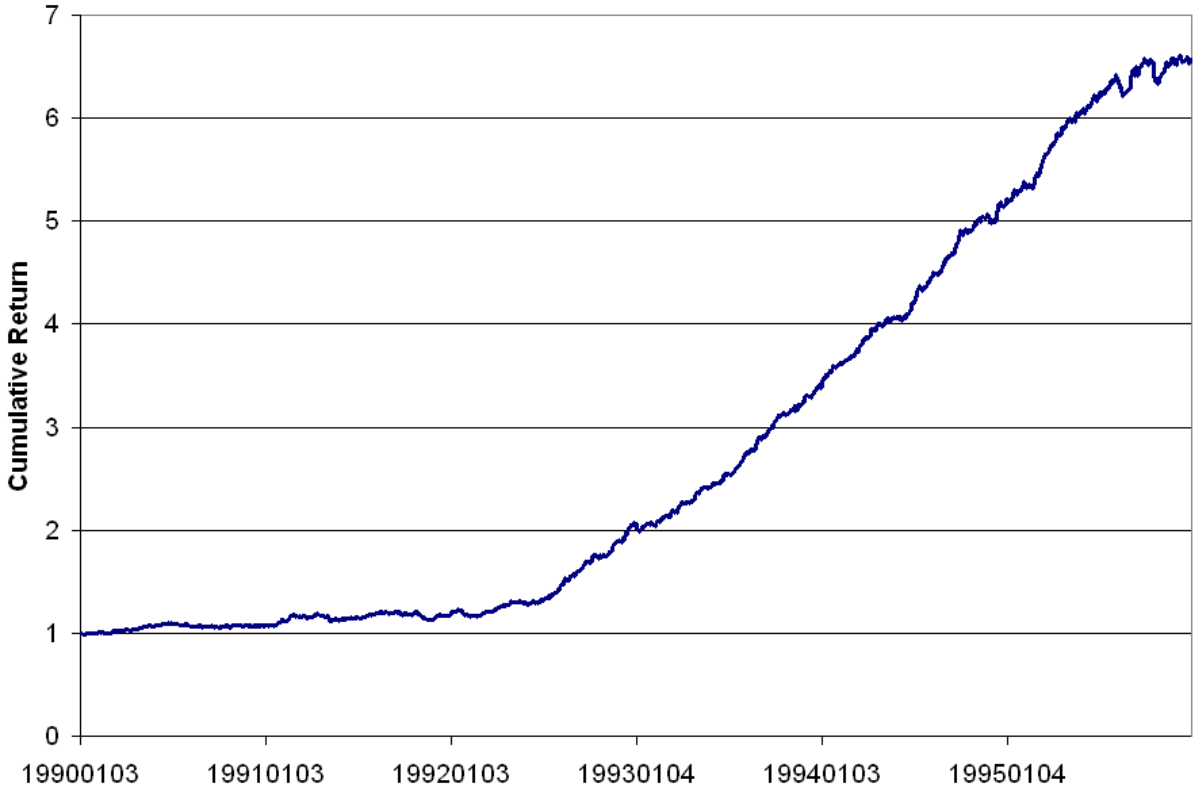
Lead/Lag Effect Among NASDAQ Five Smallest Size-Decile Portfolios

	R_{1t+1}	R_{2t+1}	R_{3t+1}	R_{4t+1}	R_{5t+1}
R_{1t}	10.0%	21.5%	15.8%	18.1%	16.7%
R_{2t}	23.4%	15.4%	20.2%	19.7%	15.8%
R_{3t}	26.2%	25.0%	15.2%	23.9%	21.6%
R_{4t}	25.4%	27.0%	24.3%	18.2%	18.7%
R_{5t}	25.4%	26.6%	26.5%	26.2%	19.4%

Empirical Analysis

Cumulative Return of Contrarian Strategy on NASDAQ Deciles 1–5

January 2, 1990 to December 29, 1995



Empirical Analysis

Summary Statistics for NASDAQ Deciles and Contrarian Strategy, Daily

January 2, 1990 to December 29, 1995

Statistic	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	R_{pt}
Mean*250	27.4%	17.5%	14.0%	13.7%	12.8%	**31.4%**
SD*sqrt(250)	12.2%	9.8%	8.9%	9.1%	9.5%	**7.9%**
SR*sqrt(250)	2.25	1.78	1.58	1.50	1.35	**3.95**
Min	-2.9%	-2.7%	-2.7%	-3.3%	-3.5%	**-2.2%**
Median	0.1%	0.1%	0.1%	0.1%	0.1%	**0.1%**
Max	6.7%	3.6%	2.0%	2.1%	2.3%	**2.4%**
Skew	0.6	0.0	-0.5	-0.7	-0.9	**-0.1**
XSKurt	5.1	2.4	2.1	3.1	3.9	**1.7**
ρ_1	10.0%	15.4%	15.2%	18.2%	19.4%	**4.7%**
ρ_2	10.3%	7.7%	10.1%	13.9%	10.5%	**0.9%**
ρ_3	5.7%	4.2%	7.5%	9.2%	11.0%	**7.5%**

Empirical Analysis

Measure of Active Management (Daily):

	Estimate	SE	t-stat
Portfolio Mean * 250	31.4%	0.3%	91.00
Risk Premia * 250	-0.6%	3.5%	-0.17
Active Component * 250	32.0%	3.5%	9.24
Active Ratio	101.9%	0.3%	354.40

- More than 100% of returns are active!
- Why is passive component negative? Mean reversion!
  - On average, holding losers and shorting winners is costly

Empirical Analysis

Now Consider Monthly Transparency

- Manager provides month-end weights and monthly returns (summed) for all positions
- How informative is this information for the strategy?
- Note:

$$
\begin{aligned}
R_{pt} &= \sum_{i=1}^{n} \omega_{it} R_{it} \\
R_p(\text{Monthly}) &\approx \sum_{t=1}^{21} R_{pt} = \sum_{t=1}^{21} \sum_{i=1}^{n} \omega_{it} R_{it} = \sum_{i=1}^{n} \sum_{t=1}^{21} \omega_{it} R_{it} \\
&\neq \sum_{i=1}^{n} \omega_{i,21} \sum_{t=1}^{21} R_{pt} = \sum_{i=1}^{n} \omega_{i,21} R_i(\text{Monthly})
\end{aligned}
$$

Empirical Analysis

Summary Statistics for NASDAQ Deciles and Contrarian Strategy, Monthly

January 1990 to December 1995

Statistic	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	R_{pt}
Mean*12	27.5%	17.4%	13.9%	13.7%	12.8%	**-4.0%**
SD*sqrt(12)	20.6%	17.7%	15.6%	15.0%	15.9%	**8.8%**
SR*sqrt(12)	1.34	0.98	0.89	0.91	0.80	**-0.45**
Min	-8.0%	-11.3%	-9.0%	-9.7%	-11.4%	**-6.6%**
Median	1.6%	1.0%	1.2%	1.0%	1.5%	**-0.5%**
Max	26.4%	21.5%	18.1%	16.8%	16.2%	**9.7%**
Skew	1.2	0.9	0.7	0.5	0.1	**1.2**
XSKurt	3.3	3.0	2.1	2.0	1.2	**4.7**
ρ_1	36.4%	43.7%	43.2%	41.4%	45.0%	**8.2%**
ρ_2	17.3%	16.6%	18.9%	10.1%	13.7%	**15.7%**
ρ_3	-5.6%	-2.7%	-3.1%	-7.8%	-7.0%	**-3.2%**

Empirical Analysis

Measure of Active Management (Monthly):

	Estimate	SE	t-stat
Portfolio Mean * 12	-4.0%	1.0%	-3.98
Risk Premia * 12	0.1%	4.0%	0.03
Active Component * 12	-4.1%	4.1%	-1.01
Active Ratio	102.6%	11.8%	8.66

- Total return is negative based on month-end weights!
- Active component is responsible for this negative return
- Results bear no relation to the daily strategy!

Extension To Multi-Factor Models

Consider Multi-Factor Model for Individual Securities:

$$\begin{aligned} R_{it} - R_f &= \alpha_i + \beta_{1i} F_{1t} + \cdots + \beta_{Ki} F_{Kt} + \epsilon_{it} \\ \mathsf{E}[R_{it}] - R_f &= \alpha_i + \beta_{1i} \mathsf{E}[F_{1t}] + \cdots + \beta_{Ki} \mathsf{E}[F_{Kt}] \end{aligned}$$

Possible Factors:

- S&P 500
- Lehman Bond
- US Dollar
- GSCI
- VIX
- Credit
- MSCI
- U.S. Growth/Value
- U.S. Large/Small Cap
- Foreign Growth/Value
- Foreign Large/Small Cap
- Liquidity
- Option-Based Strategies
- Property & Casualty
- Real Estate
- Timber
- Hurricane
- Earthquakes

Extension To Multi-Factor Models

Now Consider An Active Manager:

$$R_{pt} - R_f = \sum_{i=1}^{n} \omega_{it} \left(\alpha_i + \beta_{i1} F_{1t} + \cdots + \beta_{iK} F_{Kt} + \epsilon_{it} \right)$$

Security Selection

Factor Exposures

$$= \sum_{i=1}^{n} \omega_{it} \alpha_i + \left(\sum_{i=1}^{n} \omega_{it} \beta_{i1} \right) F_{1t} + \cdots +$$

Factor Timing

$$\left(\sum_{i=1}^{n} \omega_{it} \beta_{iK} \right) F_{Kt} + \sum_{i=1}^{n} \omega_{it} \epsilon_{it}$$

$$R_{pt} - R_f = \alpha_{pt} + \beta_{p1,t} F_{1t} + \cdots + \beta_{pK,t} F_{Kt} + \epsilon_{pt}$$

Extension To Multi-Factor Models

Expected Returns Are the Sum of Three Components:

1. Risk Premia (Average Betas)
2. Security Selection (Alpha)
3. Factor Timing (Time-Varying Portfolio Betas)

$$\begin{aligned}
\mathrm{E}[R_{pt}] - R_f &= \mathrm{E}[\alpha_{pt}] + \mathrm{E}[\beta_{p1,t}\mathrm{F}_{1t}] + \cdots + \mathrm{E}[\beta_{pK,t}\mathrm{F}_{Kt}] \\
&= \sum_{i=1}^{n} \alpha_i \mathrm{E}[\omega_{it}] + \sum_{k=1}^{K} \mathrm{Cov}[\beta_{pk,t}, \mathrm{F}_{kt}] + \sum_{k=1}^{K} \mathrm{E}[\beta_{pk,t}]\mathrm{E}[\mathrm{F}_{kt}]
\end{aligned}$$

$$\mathrm{E}[R_{pt}] - R_f = \text{Security Selection} + \text{Factor Timing} + \text{Risk Premia}$$

Active

Passive

Extension To Multi-Factor Models

Expected Returns Are the Sum of Three Components:

1. Risk Premia (Average Betas)
2. Security Selection (Alpha)
3. Factor Timing (Time-Varying Portfolio Betas)

$$\mathsf{E}[\beta_{pk,t}] = \sum_{i=1}^{n} \beta_{ik}\mathsf{E}[\omega_{it}], \quad k = 1, \ldots, K$$

$$\mathsf{Cov}[\beta_{pk,t}, F_{kt}] = \sum_{i=1}^{n} \beta_{ik}\mathsf{Cov}[\omega_{it}, F_{kt}], \quad k = 1, \ldots, K$$

Summary

"Active" Management Involves Changing Weights

- Measure of active management must involve weights
- Correlation between weights and returns is key
- Good managers have large positive correlations
- Implies new definitions for "active" and "passive"
  - Constant- or undirected-weight component is "passive"
  - "Passive" is not always simple, but is often easier to implement
  - Investors should pay less for passive management
  - Investors should pay more for active management
- Implies new methods for performance attribution
  - Requires new data: average weights, average returns
  - Sampling interval must be at least as fine as decision interval
  - Factor models provide additional transparency

Hedge-Fund Risks and Liquidity

References

- Fung, W. and D. Hsieh, 2001, "The Risk in Hedge Fund Strategies: Theory and Evidence from Trend Followers'', *Review of Financial Studies* 14, 313–341.
- Getmansky, M., Lo, A. and I. Makarov, 2004, "An Econometric Analysis of Serial Correlation and Illiquidity in Hedge-Fund Returns", *Journal of Financial Economics* 74, 529–609.
- Lo, A., 2001, "Risk Management For Hedge Funds: Introduction and Overview", *Financial Analysts Journal* 57, 16–33.

Risk Models

Hedge Fund Risk Exposures are Different:

- Heterogeneity of Hedge-Fund Styles

  Long/Short Equity Fund
  - Market Beta
  - Industry/Sector Exposure
  - Value/Growth
  - Stock-Loan Constraints
  - Execution Costs

  Fixed-Income Arb Fund
  - Yield Curve Model
  - Credit Exposure
  - Liquidity Exposure
  - Leverage Constraints
  - Macroeconomic Factors

- Phase-Locking Regime Shifts
- Nonlinearities

Risk Models

Correlation Analysis Can Be Misleading:

- Correlation Is A *Linear* Measure
- Hedge Fund Returns May Be *Nonlinear*
- One Example: "Phase-Locking"

$$
\begin{aligned}
R_{it} &= \alpha_i + \beta_i \Lambda_t + Z_t \mathrm{I}_t + \epsilon_{it} \\
\mathrm{I}_t &= \begin{cases} 0 & \text{with prob } p \\ 1 & \text{with prob } 1-p \end{cases} \\
Z_t &\sim \mathcal{N}(\mu_z, \sigma_z^2) \quad , \quad \mu_z \ll 0 \quad , \quad \sigma_z \gg \sigma_\epsilon
\end{aligned}
$$

Risk Models

- When no event occurs ($I_t = 0$):

$$\begin{aligned}\text{Corr}[R_{it}, R_{jt} | I_t = 0] &= \frac{\beta_i \beta_j \sigma_\lambda^2}{\sqrt{\beta_i^2 \sigma_\lambda^2 + \sigma_{\epsilon_i}^2}\sqrt{\beta_j^2 \sigma_\lambda^2 + \sigma_{\epsilon_j}^2}} \\ &\approx 0 \quad \text{for } \beta_i \ , \ \beta_j \approx 0\end{aligned}$$

- When an event occurs ($I_t = 1$):

$$\begin{aligned}\text{Corr}[R_{it}, R_{jt} | I_t = 1] &= \frac{\beta_i \beta_j \sigma_\lambda^2 + \sigma_z^2}{\sqrt{\beta_i^2 \sigma_\lambda^2 + \sigma_z^2 + \sigma_{\epsilon_i}^2}\sqrt{\beta_j^2 \sigma_\lambda^2 + \sigma_z^2 + \sigma_{\epsilon_j}^2}} \\ &\approx \frac{1}{\sqrt{1 + \sigma_{\epsilon_i}^2 / \sigma_z^2}\sqrt{1 + \sigma_{\epsilon_j}^2 / \sigma_z^2}} \quad \text{for } \beta_i \ , \ \beta_j \approx 0\end{aligned}$$

Risk Models

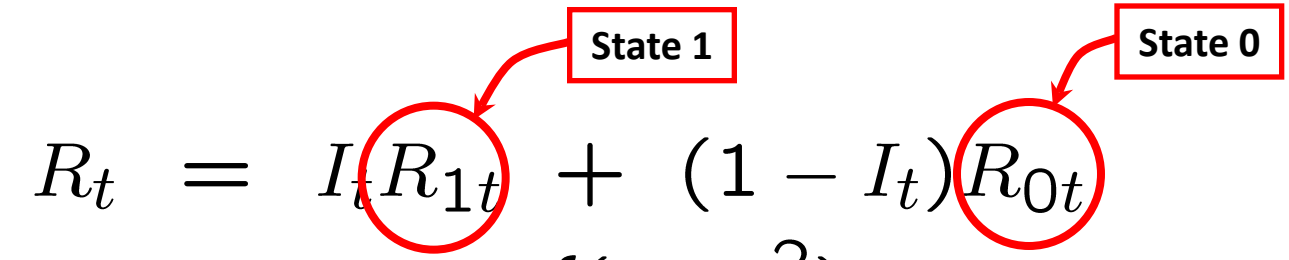
- Unconditional Correlation:

$$\begin{aligned}\text{Corr}[R_{it}, R_{jt}] &= \frac{\beta_i \beta_j \sigma_\lambda^2 + p\sigma_z^2}{\sqrt{\beta_i^2 \sigma_\lambda^2 + p\sigma_z^2 + \sigma_{\epsilon_i}^2}\sqrt{\beta_j^2 \sigma_\lambda^2 + p\sigma_z^2 + \sigma_{\epsilon_j}^2}} \\ &\approx \frac{p}{\sqrt{p + \sigma_{\epsilon_i}^2/\sigma_z^2}\sqrt{p + \sigma_{\epsilon_j}^2/\sigma_z^2}} \quad \text{for } \beta_i \ , \ \beta_j \approx 0\end{aligned}$$

- Let $p = 0.001$, $\sigma_z = 10\sigma_\varepsilon$:

$$\Rightarrow \quad \text{Corr}[R_{it}, R_{jt}] = 0.0099$$

Two-State Markov Regime-Switching Model:



$$R_t = I_t R_{1t} + (1 - I_t) R_{0t}$$

$$R_{it} \sim \text{IID } \mathcal{N}(\mu_i, \sigma_i^2) \quad i = 0, 1$$

$$P \equiv \begin{array}{c} \\ I_t = 1 \\ I_t = 0 \end{array} \begin{array}{c} \begin{array}{cc} I_{t+1} = 1 & I_{t+1} = 0 \end{array} \\ \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} \end{array}$$

Risk Models

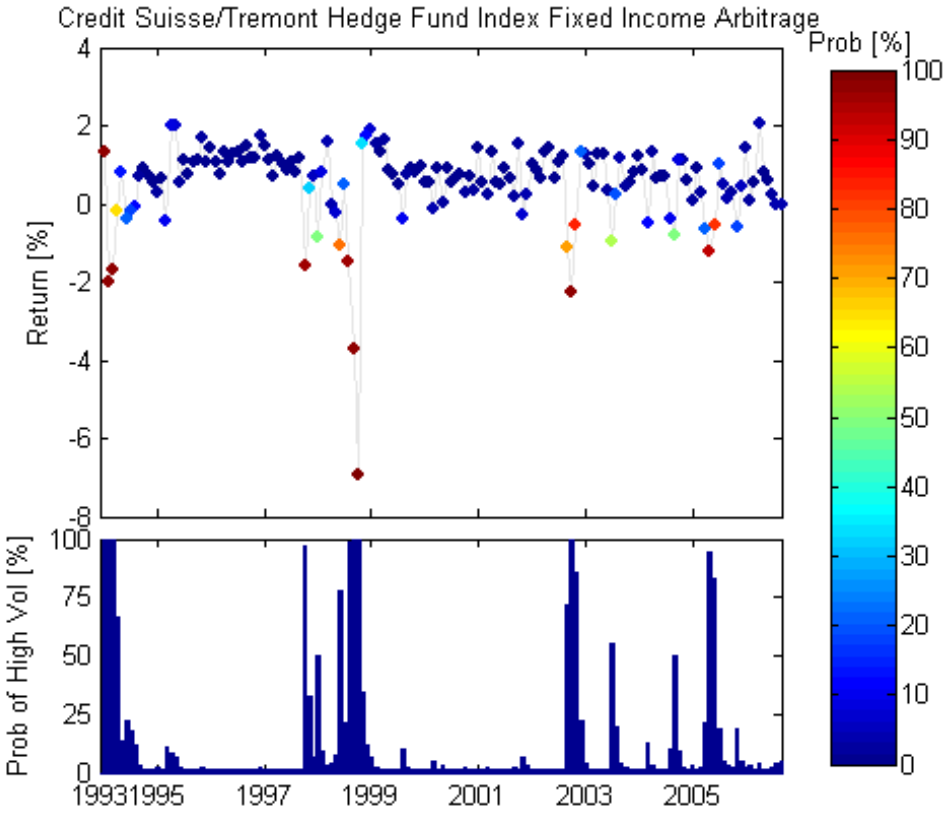
Regime-Switching Probability Estimates for CSFB/Tremont Hedge-Fund Indexes

January 1994 to September 2006

Index	Current p_1	p_{11}	p_{21}	p_{12}	p_{22}	Annualized Mean		Annualized SD		Log(L)
						State 1	State 2	State 1	State 2	
Hedge Funds	100.0%	100.0%	1.2%	0.0%	98.8%	8.0%	12.5%	3.4%	9.9%	396.9
Convertible Arbitrage	95.9%	90.1%	17.5%	9.9%	82.5%	15.5%	-2.3%	2.0%	5.8%	481.0
Dedicated Shortseller	0.0%	24.0%	10.6%	76.0%	89.4%	-76.4%	10.2%	2.4%	15.6%	252.4
Emerging Markets	100.0%	100.0%	1.2%	0.0%	98.8%	13.7%	6.5%	8.0%	20.3%	277.5
Equity Mkt Neutral	100.0%	100.0%	1.2%	0.0%	98.8%	7.4%	11.4%	1.9%	3.4%	527.1
Event Driven	99.7%	98.3%	45.9%	1.7%	54.1%	13.2%	-47.0%	3.8%	13.9%	454.7
Distressed	99.7%	98.3%	57.4%	1.7%	42.6%	14.9%	-56.9%	4.6%	15.5%	429.3
ED Multi-Strategy	99.8%	98.8%	42.7%	1.2%	57.3%	12.0%	-54.7%	4.5%	14.8%	435.0
Risk Arbitrage	95.0%	92.7%	25.5%	7.3%	74.5%	6.5%	3.8%	2.6%	7.1%	479.6
Fixed Income Arb	95.6%	95.6%	34.7%	4.4%	65.3%	9.1%	-12.9%	2.1%	6.4%	524.4
Global Macro	100.0%	100.0%	1.2%	0.0%	98.8%	12.5%	14.0%	3.5%	14.2%	363.1
Long/Short Equity	99.0%	98.9%	2.4%	1.1%	97.6%	7.7%	20.9%	6.3%	15.3%	348.8
Managed Futures	0.0%	13.0%	2.2%	87.0%	97.8%	2.0%	5.7%	0.0%	12.0%	304.4
Multi-Strategy	99.3%	98.8%	23.3%	1.2%	76.7%	10.6%	-7.5%	3.3%	9.3%	466.5

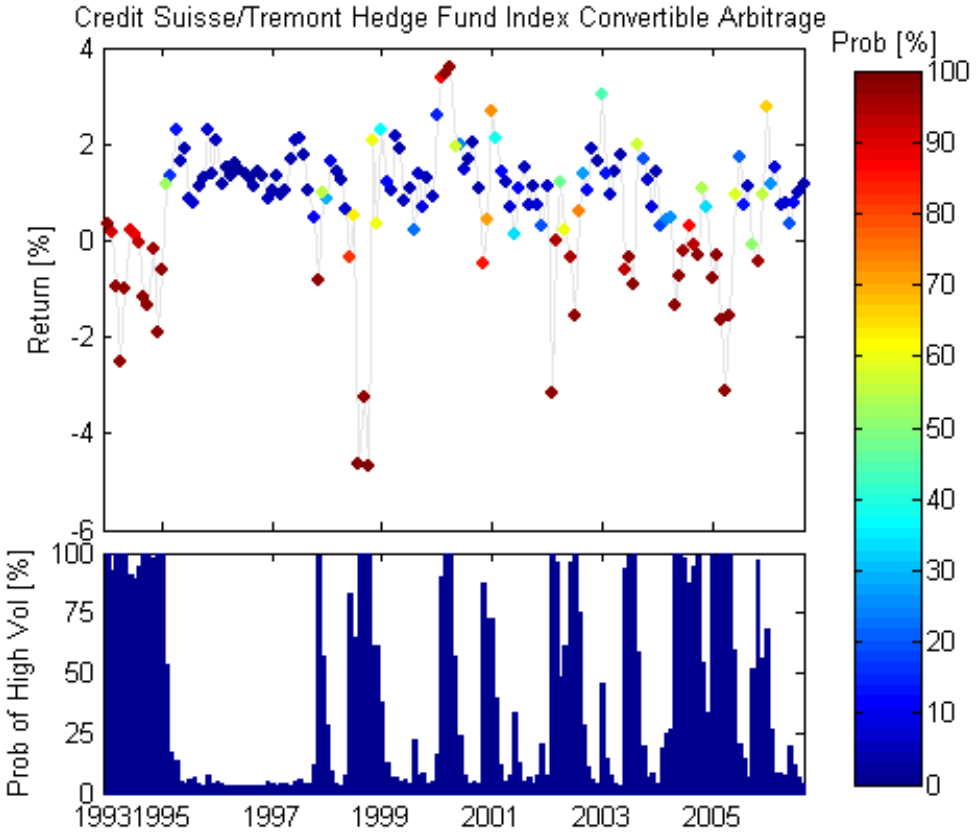
Regime-Switching Probability Estimates for CSFB/Tremont Fixed-Income Arbitrage Index

January 1994 to September 2006



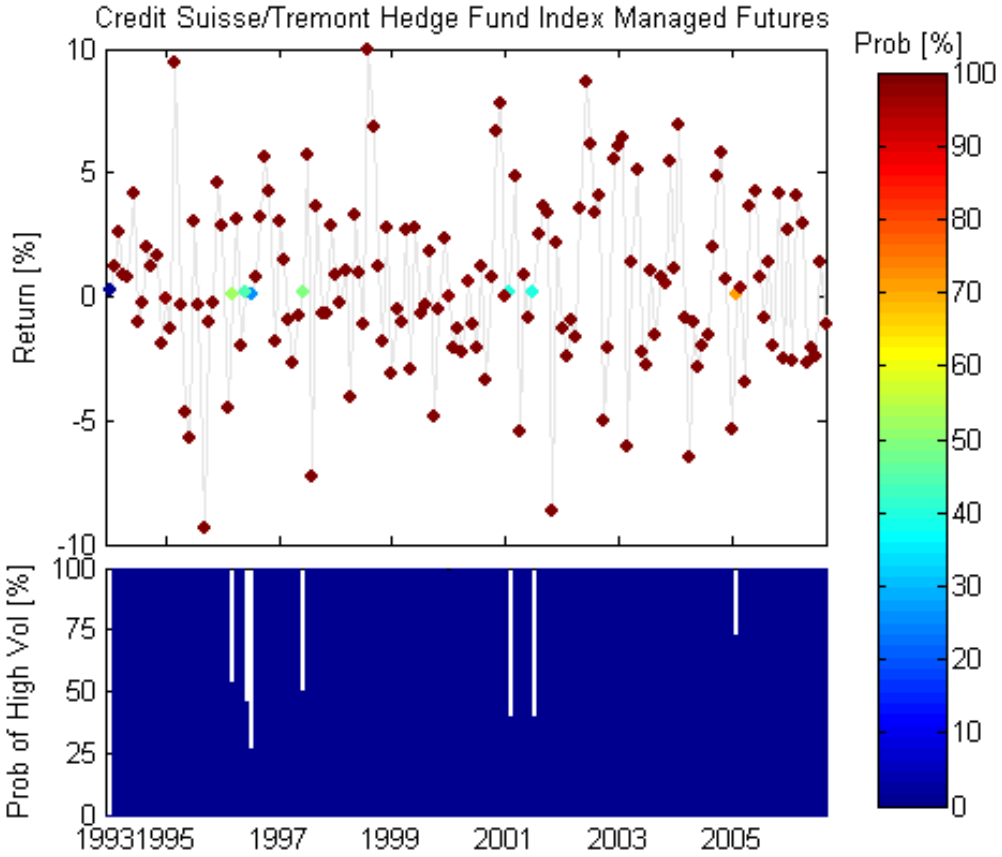
Regime-Switching Probability Estimates for CSFB/Tremont Convertible Arbitrage Index

January 1994 to September 2006



Regime-Switching Probability Estimates for CSFB/Tremont Managed Futures Index

January 1994 to September 2006



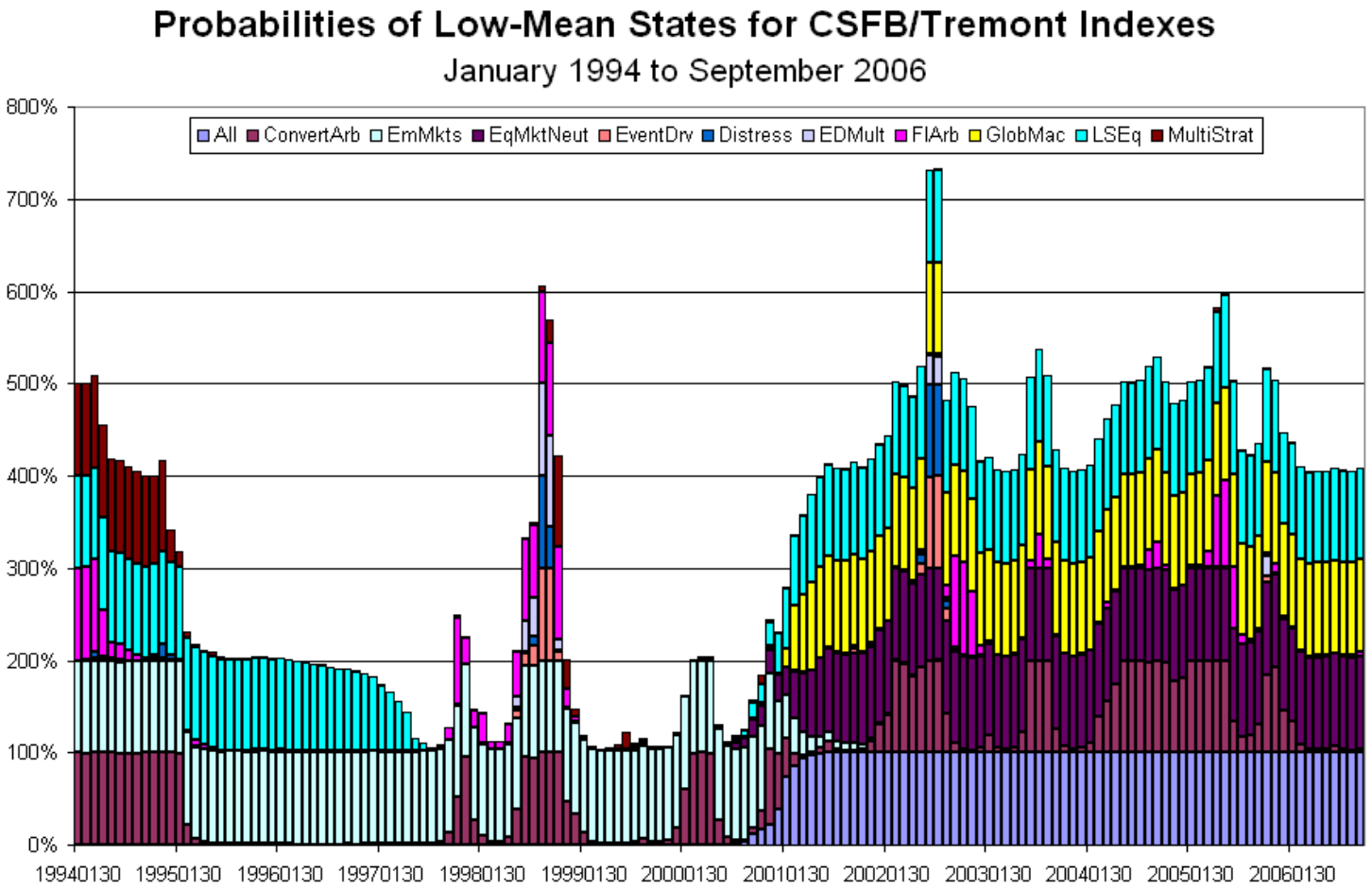
Risk Models

Aggregate Hedge-Fund Indexes:

- Estimate Parameters Via MLE
- Estimate Unconditional State Probabilities
- Aggregate Probabilities Across Indexes

$$\widehat{p}_{dt} \equiv \sum_{k=1}^{10} \text{Prob(Low-Mean State for Index } k)$$

Risk Models



Liquidity

Definition of Liquidity:

- Price, Time, and Size
- Many Hedge Funds Are Not "Liquid"
- Liquidity Risk Has Multiple Dimensions
  - Valuation, Correlation, Timing
- Nothing Wrong With Illiquidity, If Fully Disclosed
- Problems When Illiquidity Is Not Recognized
- Simple Indicator of Illiquidity:

$$\rho_1 \equiv \text{Corr}[R_t, R_{t-1}]$$

Summary Statistics for Various Monthly Indexes

Series	Period	T	Mean (%)	SD (%)	$\hat{\rho}_1$ (%)	$\hat{\rho}_2$ (%)	$\hat{\rho}_3$ (%)	$\hat{\beta}$	R^2 (%)
Ibbotson Small Company	192601–200112	912	1.35	8.63	15.6	1.7	−10.6	1.27	66.9
Ibbotson Long-Term Government Bonds	192601–200112	912	0.46	2.22	6.7	0.3	−8.3	0.07	2.8
Ibbotson Long-Term Corporate Bonds	192601–200112	912	0.49	1.96	15.6	0.3	−6.0	0.08	5.2
Ibbotson Large Company	192601–200112	912	1.03	5.57	9.8	−3.2	−10.7	1.00	100.0
AXP Extra Income Fund (INEAX)	198401–200112	216	0.67	2.04	35.4	13.1	2.5	0.21	20.7
Vanguard 500 Index Trust (VFINX)	197609–200112	304	1.16	4.36	−2.3	−6.8	−3.2	1.00	100.0
CSFB/Tremont Indices:									
Aggregate Hedge Fund Index	199401–200210	106	0.87	2.58	11.2	4.1	−0.4	0.31	24.9
Convertible Arbitrage	199401–200210	106	0.81	1.40	56.6	42.6	15.6	0.03	1.1
Dedicated Short Bias	199401–200210	106	0.22	5.29	7.8	−6.3	−5.0	−0.94	58.6
Emerging Markets	199401–200210	106	0.54	5.38	29.4	1.2	−2.1	0.62	24.0
Equity Market Neutral	199401–200210	106	0.89	0.92	29.4	18.1	8.4	0.10	21.1
Event Driven	199401–200210	106	0.83	1.81	34.8	14.7	3.8	0.23	30.2
Fixed Income Arbitrage	199401–200210	106	0.55	1.18	39.6	10.8	5.4	0.02	0.7
Global Macro	199401–200210	106	1.17	3.69	5.6	4.6	8.3	0.24	7.5
Long/Short	199401–200210	106	0.98	3.34	15.9	5.9	−4.6	0.48	36.7
Managed Futures	199401–200210	106	0.55	3.44	3.2	−6.3	0.7	−0.12	2.5

Summary Statistics for Individual Mutual Funds and Hedge Funds

Fund	Start Date	End Date	Sample Size	Mean (%)	SD (%)	ρ_1 (%)	ρ_2 (%)	ρ_3 (%)	$p(Q_{11})$ (%)
Mutual Funds									
Vanguard 500 Index	Oct-76	Jun-00	286	1.30	4.27	**-4.0**	-6.6	-4.9	**64.5**
Fidelity Magellan	Jan-67	Jun-00	402	1.73	6.23	**12.4**	-2.3	-0.4	**28.6**
Investment Company of America	Jan-63	Jun-00	450	1.17	4.01	**1.8**	-3.2	-4.5	**80.2**
Janus	Mar-70	Jun-00	364	1.52	4.75	**10.5**	0.0	-3.7	**58.1**
Fidelity Contrafund	May-67	Jun-00	397	1.29	4.97	**7.4**	-2.5	-6.8	**58.2**
Washington Mutual Investors	Jan-63	Jun-00	450	1.13	4.09	**-0.1**	-7.2	-2.6	**22.8**
Janus Worldwide	Jan-92	Jun-00	102	1.81	4.36	**11.4**	3.4	-3.8	**13.2**
Fidelity Growth and Income	Jan-86	Jun-00	174	1.54	4.13	**5.1**	-1.6	-8.2	**60.9**
American Century Ultra	Dec-81	Jun-00	223	1.72	7.11	**2.3**	3.4	1.4	**54.5**
Growth Fund of America	Jul-64	Jun-00	431	1.18	5.35	**8.5**	-2.7	-4.1	**45.4**
Hedge Funds									
Convertible/Option Arbitrage	May-92	Dec-00	104	1.63	0.97	**42.7**	29.0	21.4	**0.0**
Relative Value	Dec-92	Dec-00	97	0.66	0.21	**25.9**	19.2	-2.1	**4.5**
Mortgage-Backed Securities	Jan-93	Dec-00	96	1.33	0.79	**42.0**	22.1	16.7	**0.1**
High Yield Debt	Jun-94	Dec-00	79	1.30	0.87	**33.7**	21.8	13.1	**5.2**
Risk Arbitrage A	Jul-93	Dec-00	90	1.06	0.69	**-4.9**	-10.8	6.9	**30.6**
Long/Short Equities	Jul-89	Dec-00	138	1.18	0.83	**-20.2**	24.6	8.7	**0.1**
Multi-Strategy A	Jan-95	Dec-00	72	1.08	0.75	**48.9**	23.4	3.3	**0.3**
Risk Arbitrage B	Nov-94	Dec-00	74	0.90	0.77	**-4.9**	2.5	-8.3	**96.1**
Convertible Arbitrage A	Sep-92	Dec-00	100	1.38	1.60	**33.8**	30.8	7.9	**0.8**
Convertible Arbitrage B	Jul-94	Dec-00	78	0.78	0.62	**32.4**	9.7	-4.5	**23.4**
Multi-Strategy B	Jun-89	Dec-00	139	1.34	1.63	**49.0**	24.6	10.6	**0.0**
Fund of Funds	Oct-94	Dec-00	75	1.68	2.29	**29.7**	21.1	0.9	**23.4**

Liquidity

At Least Five Possible Sources of Serial Correlation:

1. Time-Varying Expected Returns
2. Inefficiencies
3. Nonsynchronous Trading
4. Illiquidity
5. Performance Smoothing

For Alternative Investments, (4) and (5) Most Relevant:

- (1) Is implausible over shorter horizons (monthly)
- (2) Unlikely for highly optimized strategies
- (3) Is related to (4)
- (4) is common among many hedge-fund strategies
- (5) may be an issue for some funds

Liquidity

Why Is Autocorrelation An Indicator?

- If this pattern exists and is strong, it can be exploited
  - Large positive return this month $\Rightarrow$ increase exposure
  - Large negative return this month $\Rightarrow$ decrease exposure
  - This leads to higher profits, so why not?
- Two reasons that hedge funds don't do this:
  1. They are dumb (possible, but unlikely)
  2. They can't (assets are too illiquid)
- Illiquid assets creates the **potential** for fraud

How? Return-Smoothing

Liquidity

What Is Return-Smoothing?

- Inappropriate valuation of illiquid fund assets
- In very good months, report less profits than actual
- In very bad months, report less losses than actual

What's the Harm? Isn't This Just "Conservative"?

- No, it's fraud (GAAP fair value measurement, FAS 157)
- Imagine potential investors drawn in by lower losses
- Imagine exiting investors that exit with lower gains
- Imagine investors going in/out and "timing" these cycles
- Smoother returns imply higher Sharpe ratios (moth-to-flame)

Liquidity

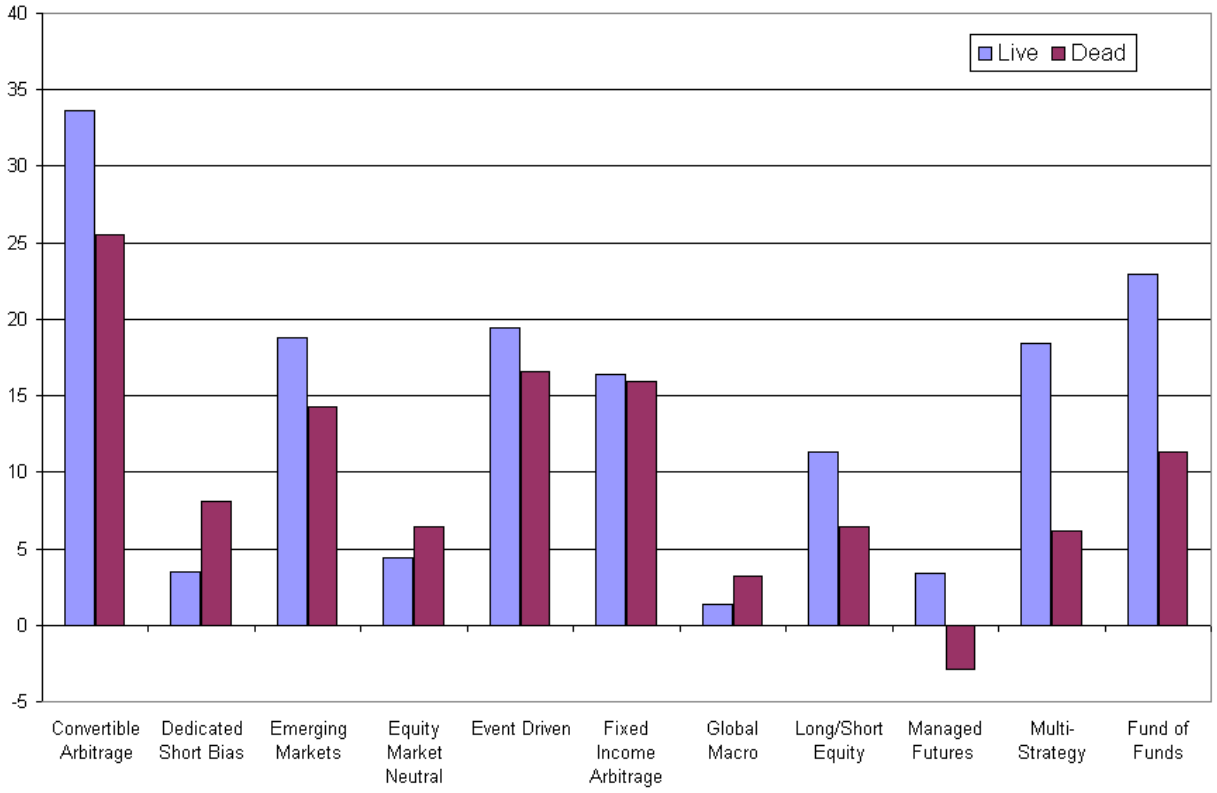
Smooth Returns Are Not Always Deliberate

- What is the monthly return of your house?
- Certain assets and strategies are known to be illiquid
- Smoothness is created by "three-quote rule" (averaging)
- For complex derivatives, mark-to-model is not unusual
- But these situations provide **opportunities** for abuse
- What to look for:
  - Extreme autocorrelation (more than 25%, less than –25%)
  - Mark-to-model instead of mark-to-market
  - No independent verification of valuations
  - Secrecy, lack of transparency

Liquidity

Average ρ_1 for Funds in the TASS Live and Graveyard Databases

February 1977 to August 2004



A Model of Smoothed Returns

- Suppose true returns are given by:

$$\begin{aligned} R_{it} &= \mu_i + \beta_i \Lambda_t + \epsilon_{it} \ , \quad \mathrm{E}[\Lambda_t] = \mathrm{E}[\epsilon_{it}] = 0 \\ \epsilon_{it} \ , \ \Lambda_t &\sim \mathrm{IID} \\ \mathrm{Var}[R_{it}] &\equiv \sigma_i^2 \end{aligned}$$

- Suppose observed returns are given by:

$$\begin{aligned} R_{it}^o &= \theta_0 \, R_{it} + \theta_1 \, R_{it-1} + \cdots + \theta_k \, R_{it-k} \\ \theta_j &\in [0,1] \ , \quad j = 1, \ldots, k \\ 1 &= \theta_0 + \theta_1 + \cdots + \theta_k \end{aligned}$$

Liquidity

- This model implies:

$$
\begin{array}{rcccl}
\mathrm{E}[R_{it}^o] & = & c_\mu\,\mu_i & = & \mu_i \\
\mathrm{Var}[R_{it}^o] & = & c_\sigma^2\,\sigma_i^2 & \leq & \sigma_i^2 \\
\mathrm{SR}_i^o & = & c_s\,\mathrm{SR}_i & \geq & \mathrm{SR}_i \\
\beta_i^o & = & c_\beta\,\beta_i & \leq & \beta_i
\end{array}
\qquad
\begin{array}{rcl}
c_\mu & \equiv & \theta_0 + \theta_1 + \cdots + \theta_k \\
c_\sigma^2 & \equiv & \theta_0^2 + \theta_1^2 + \cdots + \theta_k^2 \\
c_s & \equiv & \dfrac{1}{\sqrt{\theta_0^2 + \cdots + \theta_k^2}} \\
c_\beta & \equiv & \theta_0
\end{array}
$$

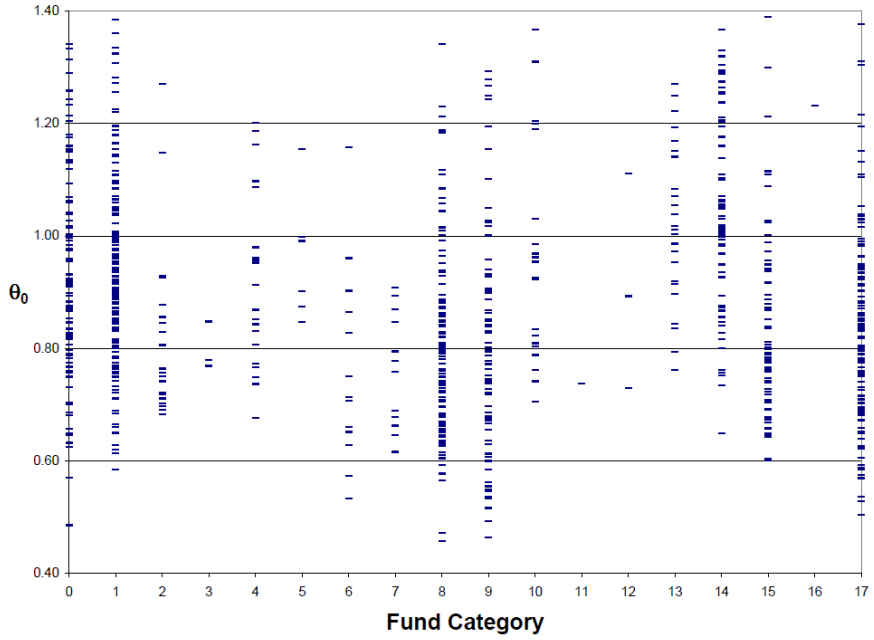
$$
\mathrm{Cov}[R_{it}^o, R_{it-m}^o] = \begin{cases} \left(\sum_{j=0}^{k-m} \theta_j \theta_{j+m}\right) \sigma_i^2 & \text{if } 0 \leq m \leq k \\ 0 & \text{if } m > k \end{cases}
$$

$$
\mathrm{Corr}[R_{it}^o, R_{it-m}^o] = \begin{cases} \dfrac{\sum_{j=0}^{k-m} \theta_j \theta_{j+m}}{\sum_{j=0}^{k} \theta_j^2} & \text{if } 0 \leq m \leq k \\ 0 & \text{if } m > k \end{cases}
$$

Liquidity

- Estimate MA(2) via maximum likelihood:

$$\begin{aligned} R_{it}^{o} &= \theta_0 R_{it} + \theta_1 R_{it-1} + \theta_2 R_{it-2} \\ R_{it} &\sim \text{IID } \mathcal{N}(\mu_i, \sigma_i^2) \\ \text{subjec to } 1 &= \theta_0 + \theta_1 + \theta_2 \end{aligned}$$



Summary of MA(2) Parameter Estimates For TASS Hedge Funds

Monthly Data, November 1977 to January 2001

Category	N	MA(2) with Constrained Sum							
		$\hat{\theta}_0$		$\hat{\theta}_1$		$\hat{\theta}_2$		$\hat{\xi}$	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Not Categorized	111	1.04	0.33	0.01	0.18	−0.05	0.23	1.27	1.06
US Equity Hedge	162	0.95	0.21	0.06	0.15	−0.01	0.15	1.00	0.54
European Equity Hedge	22	0.82	0.15	0.08	0.09	0.11	0.11	0.72	0.28
Asian Equity Hedge	5	0.94	0.30	0.05	0.19	0.01	0.11	1.00	0.71
Global Equity Hedge	27	0.91	0.14	0.11	0.10	−0.02	0.09	0.88	0.27
Dedicated Shortseller	7	1.03	0.20	0.03	0.12	−0.06	0.13	1.12	0.48
Fixed-Income Directional	13	0.76	0.17	0.15	0.10	0.08	0.12	0.67	0.27
Convertible Fund (Long Only)	15	0.84	0.35	0.18	0.08	−0.02	0.35	0.98	1.36
Event Driven	109	0.81	0.17	0.15	0.13	0.04	0.11	0.74	0.28
Non-Directional/Relative Value	85	0.82	0.24	0.09	0.25	0.09	0.14	0.82	0.62
Global Macro	24	0.95	0.18	0.08	0.11	−0.03	0.15	0.99	0.40
Global Opportunity	1	0.74	—	0.16	—	0.10	—	0.58	—
Natural Resources	3	0.91	0.19	0.02	0.11	0.07	0.09	0.87	0.34
Pure Leveraged Currency	26	1.10	0.34	0.03	0.13	−0.13	0.25	1.41	1.38
Pure Managed Futures	93	1.13	0.32	−0.05	0.22	−0.08	0.18	1.47	1.19
Pure Emerging Market	72	0.83	0.16	0.15	0.09	0.02	0.13	0.76	0.31
Pure Property	1	1.23	—	−0.31	—	0.07	—	1.62	—
Fund of Funds	132	0.85	0.21	0.13	0.13	0.03	0.13	0.81	0.50
All	908	0.92	0.26	0.08	0.17	0.00	0.17	0.98	0.76

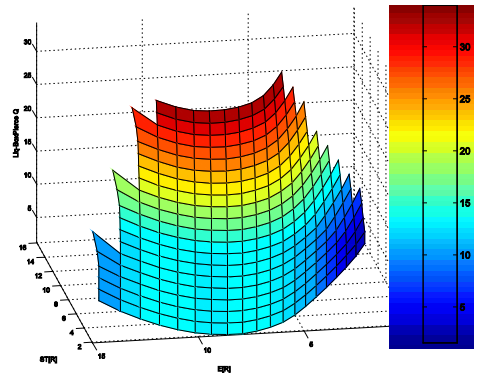
Means and standard deviations of maximum likelihood estimates of MA(2) smoothing process $R_t^o = \theta_0 R_t + \theta_1 R_{t-1} + \theta_2 R_{t-2}$, $\xi \equiv \theta_0^2 + \theta_1^2 + \theta_2^2$, for 908 hedge funds in the TASS combined database with at least five years of returns history during the period from November 1977 to January 2001.

Liquidity

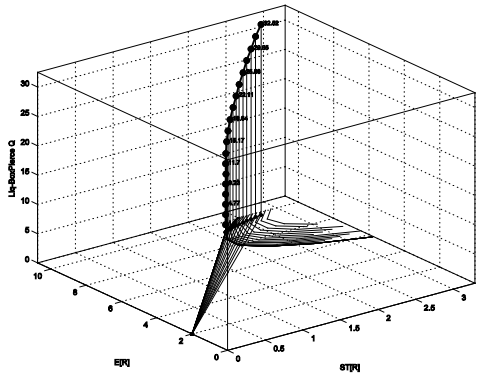
Managing Liquidity Exposure Explicitly

- Define a liquidity metric
- Construct mean-variance-liquidity-optimal portfolios
- Monitor changes in surface over time and market conditions
- See Lo, Petrov, Wierzbicki (2003) for details

$$\max_{\{\omega\}} \ \omega'\mu - \frac{\lambda}{2}\omega'\Sigma\omega + \phi\,\omega'\ell_t$$
$$\text{subject to} \quad 1 = \omega'\iota \ , \quad 0 \leq \omega$$



Mean-Variance-Liquidity Surface



Tangency Portfolio Trajectories

Hedge Funds and Systemic Risk

References

- Acharya, V. and M. Richardson, eds., 2009, *Restoring Financial Stability: How to Repair a Failed System*. New York: John Wiley & Sons.
- Billio, M., Getmansky, M., Lo, A. and L. Pelizzon, 2010, "Econometric Measures of Systemic Risk in the Finance and Insurance Sectors", SSRN No. 1571277.
- Chan, N., Getmansky, M., Haas, S. and A. Lo, 2007, "Systemic Risk and Hedge Funds", in M. Carey and R. Stulz, eds., *The Risks of Financial Institutions and the Financial Sector*. Chicago, IL: University of Chicago Press.

Hedge Funds and Systemic Risk

Lessons From August 1998:

- Liquidity and credit are critical to the macroeconomy
- Multiplier/accelerator effect of leverage
- Hedge funds are now important providers of liquidity
- Correlations can change quickly
- Nonlinearities in risk and expected return
- Systemic risk involves hedge funds

But No Direct Measures of Systemic Risk

Hedge Funds and Systemic Risk

Five Indirect Measures:

1. Liquidity Risk
2. Risk Models for Hedge Funds
3. Industry Dynamics
4. Hedge-Fund Liquidations
5. Network Models (preliminary)

For More Details, See:

- Chan, Getmansky, Haas, and Lo (2005)
- Getmansky, Lo, and Makarov (2005)
- Lo (2008)
- Billio, Getmansky, Lo, and Pelizzon (2010)

Early Warning Signs

Laboratory for Financial Engineering

Systemic Risk and Hedge Funds

Nicholas Chan, Mila Getmansky,
Shane M. Haas, and Andrew W. Lo

NBER Conference on the
Risks of Financial Institutions
October 22–23, 2004

Contributions

Laboratory for Financial Engineering

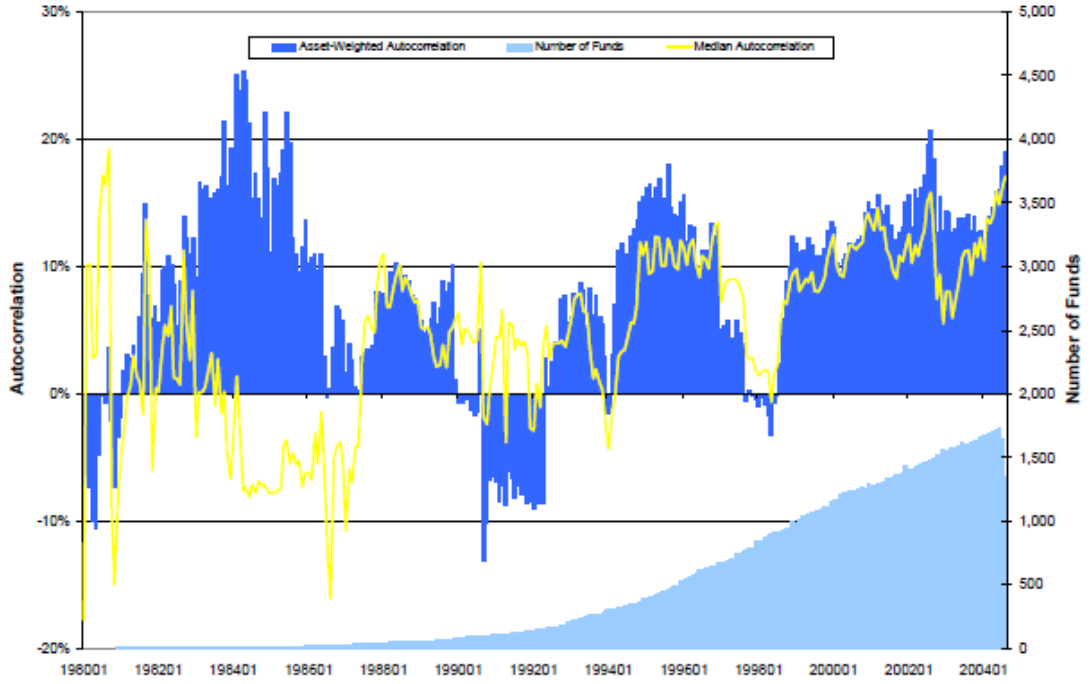
Two Themes: Liquidity and Nonlinearities

- Individual and Aggregate Measures of Illiquidity Exposure
- Aggregate Measures of Volatility and Distress in Hedge-Fund Sector
- Risk Models for Hedge Funds
- Hedge Funds and Banking Sector

Early Warning Signs

ρ^*_t Indicator

Laboratory for Financial Engineering



Individual Funds

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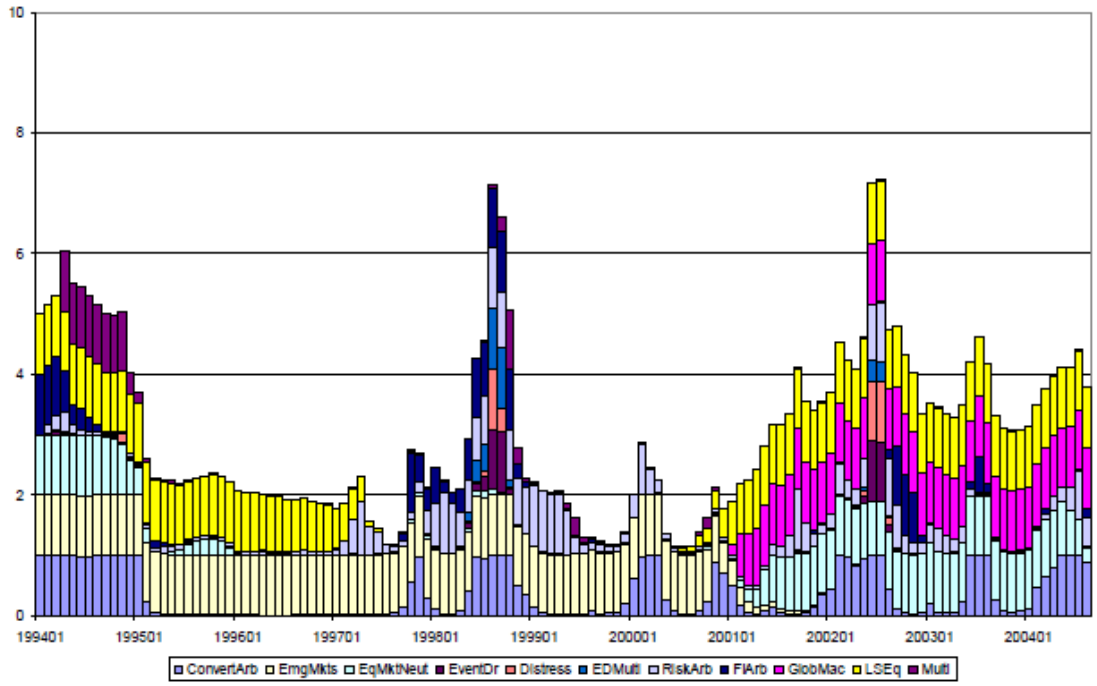
Early Warning Signs

HF Distress Indicator

Laboratory for Financial Engineering



Aggregate Indexes

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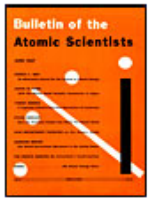
Early Warning Signs

Doomsday Clock

MITSloan MANAGEMENT — Laboratory for Financial Engineering



1947

1949

1988

1990

1991

1996

1998

2002

Conclusions

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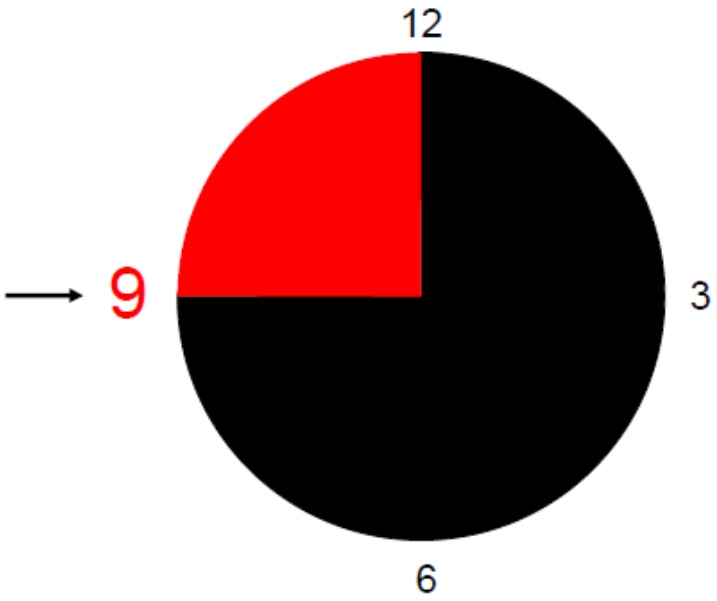
Early Warning Signs

Doomsday Clock

Laboratory for Financial Engineering



Conclusions

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Early Warning Signs

ECONOMIC VIEW

MARK GIMEIN

Is a Hedge Fund Shakeout Coming Soon? This Insider Thinks So

F all the sectors of the financial universe, the hedge fund world is probably the most secretive and almost certainly the most alluring. Open only to institutions and the wealthy, hedge funds offer sophisticated models of risk, access to the best financial minds and the chance for outsized returns. According to Hedge Advisors, hedge fund assets have topped a trillion dollars.

The downside, unfortunately, is that occasionally the industry may be subject to catastrophic and unexpected losses. In 1998, any top hedge fund managers lost their shirts. Long Term Capital Management came close to collapse. Just last month, investors were reminded of exactly this kind of possibility with the apparent failure of a $00 million Connecticut hedge fund managed by the Bayou Group.

Andrew W. Lo, a finance professor at the oan School of Management at the Massachusetts Institute of Technology, has been udying hedge fund failures and risks, and says that another hedge fund industry akeout is likely in the near future. Mr. Lo ns a company, AlphaSimplex, that manges a $400 million hedge fund — so he is not oking for a reason to say hedge funds are trouble. But that is exactly what he's saying, backing it up with powerful data and a uple of unexpected theories.

Mr. Lo has been working on the economs of hedge funds since the mid-1990's, but e started thinking seriously about how to measure risk across the industry in 1999, hen he was first approached by backers to tart his own hedge fund; it opened in 2003. le knew that sophisticated investors would ant lots of data about his fund's returns nd about the risk level he would assume, so e started looking carefully at the return ata provided by other funds.

Traditionally, economists have thought hat big up-and-down fluctuations in returns ndicated risky investments, so many hedge

Andrew W. Lo of M.I.T. says he has found warning signs for the hedge fund industry.

fund investors have hoped to see a pattern of smooth and even returns. But Mr. Lo quickly saw that lots of hedge funds were posting returns that were just too smooth to be realistic. Digging deeper, he found that funds with hard-to-appraise, illiquid investments — like real estate or esoteric interest rate swaps — showed returns that were particularly even. In those cases, he concluded, managers had no way to measure their fluctuations, and simply assumed that their value was going up steadily. The problem, unfortunately, is that those are exactly the kinds of investments that can be subject to big losses in a crisis. In 1998, investors retreated en masse from such investments.

Now, in a paper to be published by the University of Chicago, Mr. Lo, working with his graduate students, has come to a disturbing conclusion: that smooth returns, far from proving that hedge funds are safe, may be a warning sign for the industry. (The paper is at http://web.mit.edu/alo/www/Papers/systemic2.pdf.)

That doesn't necessarily hold true for every individual fund, but as Mr. Lo shows in his paper, measuring the smoothness of returns gives economists a good way to estimate the level of relatively illiquid investments in the hedge fund world. The approach lets economists measure industry-wide liquidity risks without knowing the details of the investments — information that hedge funds just don't give out.

By Mr. Lo's measures, hedge fund investments are less liquid now than they have been in 20 years. His work shows that the same pattern of investing preceded the 1998 global hedge fund meltdown and the 1987 stock market crash.

But that's not the only reason for worry. He says that crises like that of 1998 may be more predictable than was previously thought — and that another crisis is likely.

The 1998 panic is generally thought to have been set off by the Russian government's default on its debt. But Mr. Lo points out that only a minuscule proportion of the world's hedge fund investments were in Russian government bonds.

In his paper, he shows that the catastrophic losses of 1998 were preceded by a noticeable series of months of mediocre performance. Mr. Lo argues that while a hedge fund crisis appears to be sudden and to be caused by unforeseen events, the breakdown is only the late stage of the problem. As more hedge funds compete for the same slice of the pie, he says, their managers feel that they have no choice but to "leverage up," juicing their returns by borrowing more money to make bigger investments.

That, in turn, makes the investments more prone to a sudden credit crisis. Hedge funds that are highly leveraged are vulnerable to having their lenders — banks and big brokerage firms — cut off credit when they think that their money may be at risk. And Mr. Lo thinks that lenders would do exactly that in an industrywide downturn. That would force hedge funds to close out their positions at the worst possible time — the kind of cycle that brought down Long Term Capital Management.

Here again, his data suggests that the current situation is serious. His research indicates that the industry may have already entered a period of lower returns that is typical a prelude to crisis. He points to a downturn in April that hit virtually every category of hedge fund pursuing every kind of strategy.

"The concern that I and others have is that we're approaching the perfect financial storm where all the arrows line up in one direction," Mr. Lo said. The more money that is invested in hedge funds, he said, "the bigger the storm will be."

What might set off a crash is a matter of guesswork. Mr. Lo thinks that an oil-price increase to $100 a barrel, a level predicted by one Goldman Sachs analyst, could do it. Or , he said, a tightening of lending rules at Fannie Mae, the mortgage giant, could set off a "humongous unwinding" in credit markets. But Mr. Lo, who refers to some of his research as "measuring how strong the camel's back is and how much straw is already on it," thinks that the spark could be something much smaller.

ALREADY, his work has prompted hedge fund managers and investors to pay more attention to the hidden risks of funds that seem to be performing quite well. Clifford S. Asness, managing principal at AQR Capital Management, a large and successful hedge fund based in Greenwich, Conn., says Mr. Lo's work forces fund managers in general to confront the risks: "He demonstrates simple models that generally show a winning payoff but occasionally really die."

So what should be done? Mr. Lo sees no way to eliminate the cyclical nature of hedge fund investing, but he says we can learn from the mistakes of funds that fail. He advocates the creation of a financial equivalent of the teams at the National Transportation Safety Board that swoop in to investigate airplane crashes.

The nightmare script for Mr. Lo would be a series of collapses of highly leveraged hedge funds that bring down the major banks or brokerage firms that lend to them. That's a possibility that the entire hedge fund industry — secretive and fractious though it is — has a huge interest in avoiding.

THE NEW YORK TIMES, SUNDAY, SEPTEMBER 4, 2005

"The nightmare script for Mr. Lo would be a series of collapses of highly leveraged hedge funds that bring down the major banks or brokerage firms that lend to them."

Early Warning Signs

Some Experts Disagreed:

"In approaching its task, the Policy Group shared a broad consensus that the already low statistical probabilities of the occurrence of truly systemic financial shocks had **further declined over time**."

– CRMPG II, July 27, 2005, p. 1

Early Warning Signs

But CRMPG II Also Contained:

> …Recommendations 12, 21 and 22, which call for urgent industry-wide efforts (1) to cope with serious "back-office" and potential settlement problems in the credit default swap market and (2) to stop the practice whereby some market participants "assign" their side of a trade to another institution without the consent of the original counterparty to the trade. (CRMPG II, July 27, 2005, p. *iv*)

Early Warning Signs

Firms Represented in CRMPG II:

- Bear Stearns
- Citigroup
- Cleary Gottlieb
- Deutsche Bank
- GMAM
- Goldman Sachs
- HSBC
- JPMorgan Chase
- Merrill Lynch
- Morgan Stanley
- Lehman Brothers
- TIAA CREF
- Tudor Investments

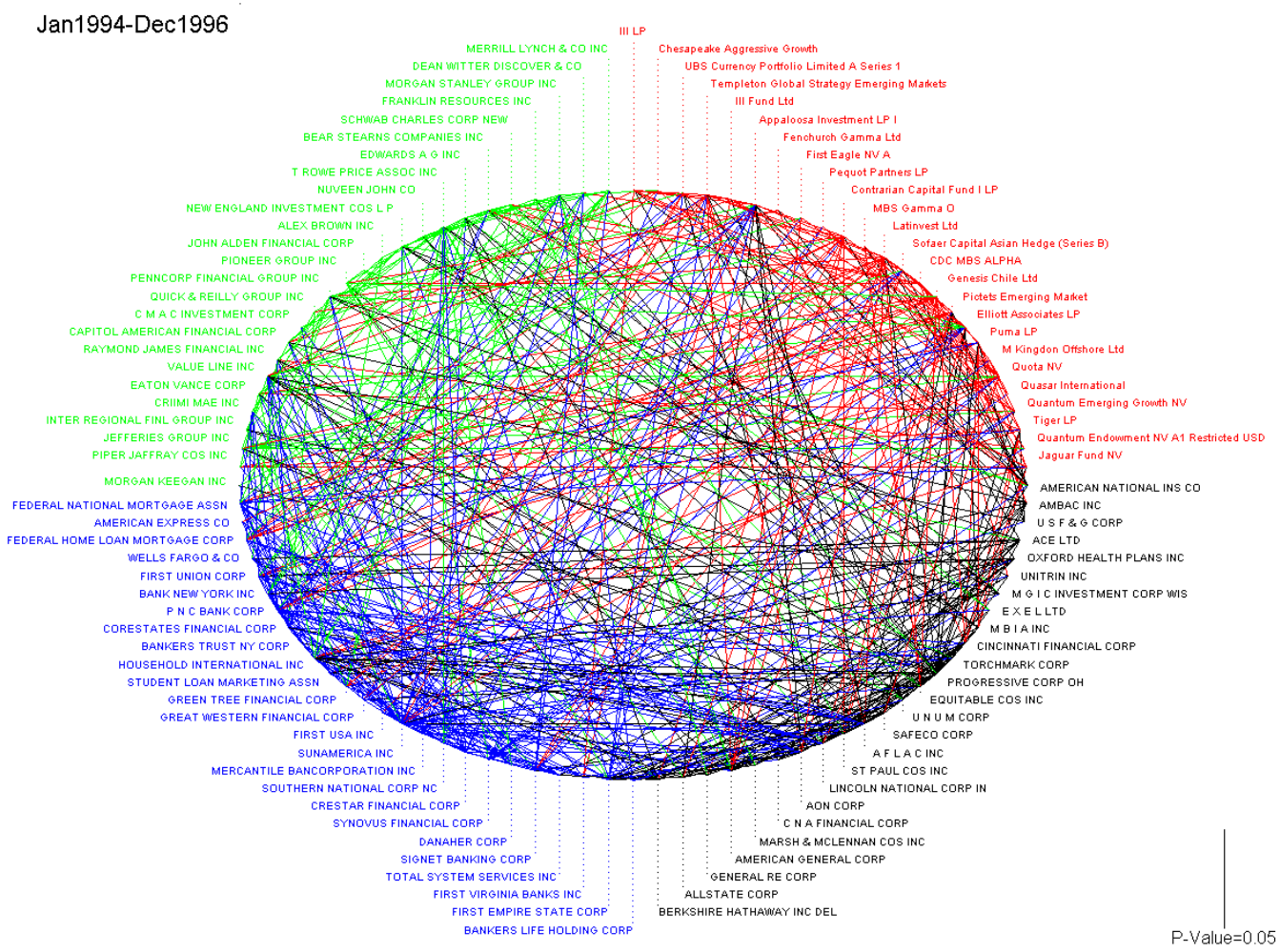
Granger Causality Networks (Billio et al. 2010) NBER

Granger Causality Is A Statistical Relationship

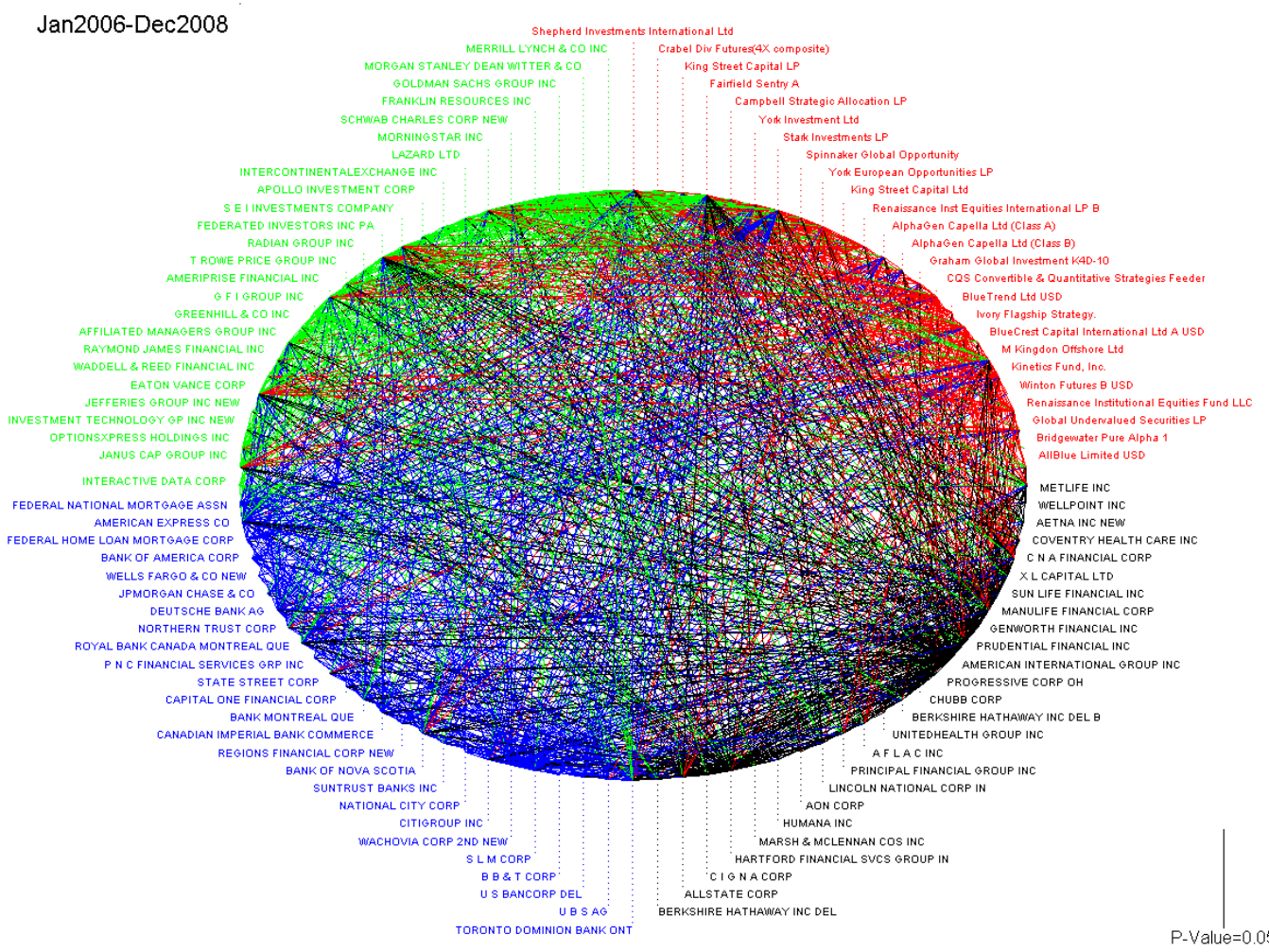
$$X_t = \sum_{j=1}^{m} a_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + \epsilon_t,$$
$$Y_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + \eta_t,$$

- $Y \Rightarrow_G X$ if $\{b_j\}$ is different from 0
- $X \Rightarrow_G Y$ if $\{d_j\}$ is different from 0
- If both $\{b_j\}$ and $\{d_j\}$ are different from 0, feedback relation
- Consider causality among the monthly returns of hedge funds, publicly traded banks, brokers, and insurance companies

Granger Causality Networks

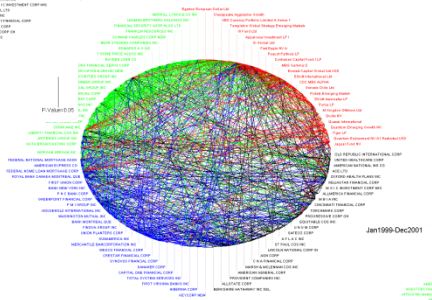


Granger Causality Networks

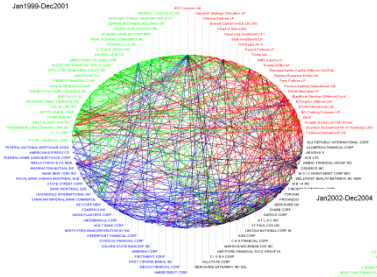


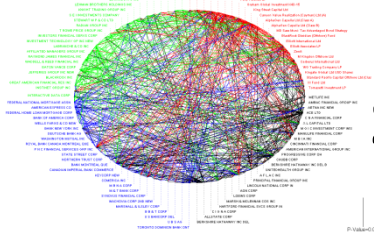
Granger Causality Networks

LTCM 1998

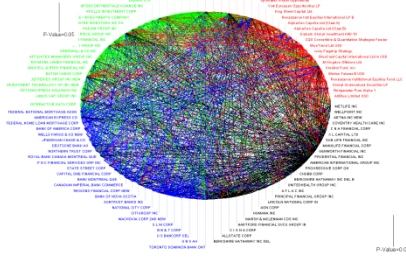


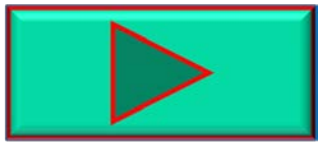
Internet Bubble Crash





Financial Crisis of 2007-2009





Granger Causality Networks

In	
PRINCIPAL FINANCIAL GROUP INC	45
BERKSHIRE HATHAWAY INC DEL	28
INSTINET GROUP INC	24
Cerberus International Ltd	21
BERKSHIRE HATHAWAY INC DEL B	21
M Kingdon Offshore Ltd	19
Perry Partners LP	17
LABRANCHE & CO INC	17
KEYCORP NEW	15
Sagamore Hill Ltd	14
EDWARDS A G INC	14
JEFFERIES GROUP INC NEW	13
WADDELL & REED FINANCIAL INC	13
BANK MONTREAL QUE	13
AMERITRADE HOLDING CORP NEW	12
INVESTORS FINANCIAL SERVS CORP	12
STEWART W P & CO LTD	12
TORONTO DOMINION BANK ONT	12
MANULIFE FINANCIAL CORP	11
Elliott International Ltd	10

Out	
WELLS FARGO & CO NEW	26
PROGRESSIVE CORP OH	24
BANK OF AMERICA CORP	20
CITIGROUP INC	19
STEWART W P & CO LTD	18
FEDERAL NATIONAL MORTGAGE ASSN	17
U B S AG	16
UNITEDHEALTH GROUP INC	16
INVESTMENT TECHNOLOGY GP INC NEW	15
LEHMAN BROTHERS HOLDINGS INC	14
T ROWE PRICE GROUP INC	14
EATON VANCE CORP	14
AMERICAN EXPRESS CO	14
M B I A INC	14
JEFFERIES GROUP INC NEW	13
M B N A CORP	13
Graham Global Investment K4D-15	12
RAYMOND JAMES FINANCIAL INC	12
WACHOVIA CORP 2ND NEW	12
AMBAC FINANCIAL GROUP INC	12

In+Out	
PRINCIPAL FINANCIAL GROUP INC	51
STEWART W P & CO LTD	30
INSTINET GROUP INC	29
BERKSHIRE HATHAWAY INC DEL	29
WELLS FARGO & CO NEW	28
PROGRESSIVE CORP OH	27
JEFFERIES GROUP INC NEW	26
BERKSHIRE HATHAWAY INC DEL B	26
U B S AG	25
Cerberus International Ltd	23
M Kingdon Offshore Ltd	23
T ROWE PRICE GROUP INC	23
LABRANCHE & CO INC	22
M B N A CORP	21
Graham Global Investment K4D-10	20
AMERITRADE HOLDING CORP NEW	20
EATON VANCE CORP	20
CITIGROUP INC	20
BANK OF AMERICA CORP	20
TORONTO DOMINION BANK ONT	20

In from Other	
PRINCIPAL FINANCIAL GROUP INC	41
BERKSHIRE HATHAWAY INC DEL	25
INSTINET GROUP INC	20
BERKSHIRE HATHAWAY INC DEL B	20
M Kingdon Offshore Ltd	18
Cerberus International Ltd	17
LABRANCHE & CO INC	16
Perry Partners LP	13
WADDELL & REED FINANCIAL INC	13
KEYCORP NEW	13
EDWARDS A G INC	12
STEWART W P & CO LTD	12
BANK MONTREAL QUE	12
AMERITRADE HOLDING CORP NEW	11
INVESTORS FINANCIAL SERVS CORP	11
JEFFERIES GROUP INC NEW	11
Sagamore Hill Ltd	10
TORONTO DOMINION BANK ONT	10
MANULIFE FINANCIAL CORP	10
Elliott International Ltd	9

Out to Other	
WELLS FARGO & CO NEW	23
PROGRESSIVE CORP OH	20
BANK OF AMERICA CORP	17
STEWART W P & CO LTD	16
UNITEDHEALTH GROUP INC	15
INVESTMENT TECHNOLOGY GP INC NEW	14
CITIGROUP INC	14
U B S AG	14
FEDERAL NATIONAL MORTGAGE ASSN	12
AMERICAN EXPRESS CO	12
AMBAC FINANCIAL GROUP INC	12
Kingate Global Ltd USD Shares	11
T ROWE PRICE GROUP INC	11
JEFFERIES GROUP INC NEW	11
X L CAPITAL LTD	11
M B N A CORP	10
M B I A INC	10
Graham Global Investment K4D-10	9
AMERICAN INTERNATIONAL GROUP INC	9
ACE LTD	9

In+Out Other	
PRINCIPAL FINANCIAL GROUP INC	45
STEWART W P & CO LTD	28
BERKSHIRE HATHAWAY INC DEL	26
WELLS FARGO & CO NEW	25
INSTINET GROUP INC	23
U B S AG	23
BERKSHIRE HATHAWAY INC DEL B	23
M Kingdon Offshore Ltd	22
JEFFERIES GROUP INC NEW	22
PROGRESSIVE CORP OH	22
LABRANCHE & CO INC	20
T ROWE PRICE GROUP INC	19
Cerberus International Ltd	18
INVESTMENT TECHNOLOGY GP INC NEW	18
BANK OF AMERICA CORP	17
KEYCORP NEW	17
EDWARDS A G INC	16
UNITEDHEALTH GROUP INC	16
X L CAPITAL LTD	16
Graham Global Investment K4D-10	15

Closeness	
WELLS FARGO & CO NEW	1.74
PROGRESSIVE CORP OH	1.76
BANK OF AMERICA CORP	1.80
CITIGROUP INC	1.81
STEWART W P & CO LTD	1.82
FEDERAL NATIONAL MORTGAGE ASSN	1.83
U B S AG	1.84
UNITEDHEALTH GROUP INC	1.84
INVESTMENT TECHNOLOGY GP INC NEW	1.85
LEHMAN BROTHERS HOLDINGS INC	1.86
T ROWE PRICE GROUP INC	1.86
EATON VANCE CORP	1.86
AMERICAN EXPRESS CO	1.86
M B I A INC	1.86
JEFFERIES GROUP INC NEW	1.87
M B N A CORP	1.87
Graham Global Investment K4D-15	1.88
RAYMOND JAMES FINANCIAL INC	1.88
WACHOVIA CORP 2ND NEW	1.88
AMBAC FINANCIAL GROUP INC	1.88

Eigenvector Centrality	
PROGRESSIVE CORP OH	0.31
WELLS FARGO & CO NEW	0.31
BANK OF AMERICA CORP	0.24
CITIGROUP INC	0.22
STEWART W P & CO LTD	0.21
UNITEDHEALTH GROUP INC	0.19
FEDERAL NATIONAL MORTGAGE ASSN	0.19
INVESTMENT TECHNOLOGY GP INC NEW	0.18
AMBAC FINANCIAL GROUP INC	0.16
M B N A CORP	0.16
T ROWE PRICE GROUP INC	0.15
X L CAPITAL LTD	0.15
U B S AG	0.14
Kingate Global Ltd USD Shares	0.14
AMERICAN EXPRESS CO	0.14
BlackRock Obsidian (Offshore) Fund	0.14
LEHMAN BROTHERS HOLDINGS INC	0.14
Crabel Div Futures(4X composite)	0.13
WASHINGTON MUTUAL INC	0.13
M B I A INC	0.12

August 1998, August 2007, May 2010, ...

References

- Khandani, A. and A. Lo, 2007, "What Happened To The Quants In August 2007?", *Journal of Investment Management* 5, 29–78.
- Khandani, A. and A. Lo, 2010, "What Happened To The Quants In August 2007?: Evidence from Factors and Transactions Data", to appear in *Journal of Financial Markets*.
- NANEX, 2010, "Analysis of the Flash Crash", http://www.nanex.net/20100506/FlashCrashAnalysis_CompleteText.html.

The Quant Meltdown of August 2007

Quantitative Equity Funds Hit Hard In August 2007

- Specifically, August 7–9, and massive reversal on August 10
- Some of the most consistently profitable funds lost too
- Seemed to affect only quants
- No real market news

What Is The Future of Quant?

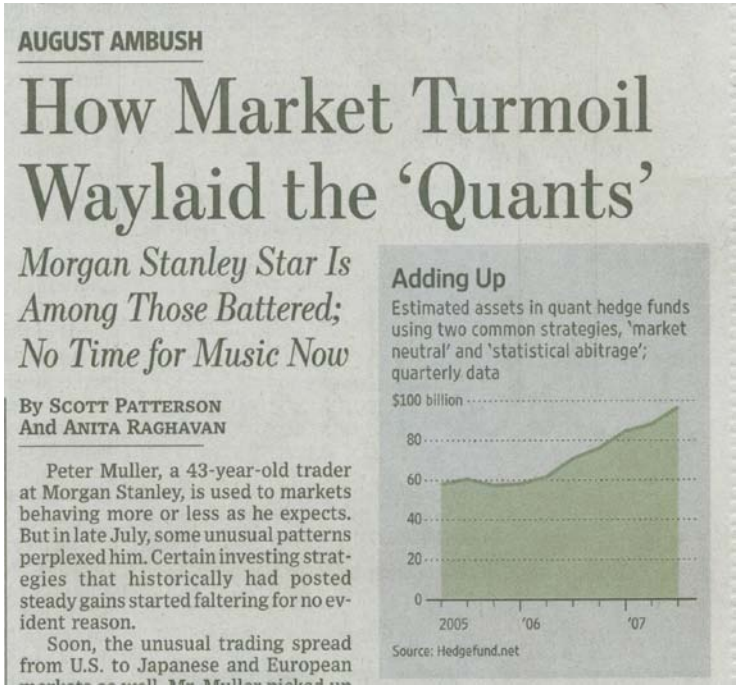
- Is "Quant Dead"?
- Can "it" happen again?
- What can be done about it?

But Lack of Transparency Is Problematic!

- Khandani and Lo (2007, 2010)

Wall Street Journal

September 7, 2007



AUGUST AMBUSH

How Market Turmoil Waylaid the 'Quants'

Morgan Stanley Star Is Among Those Battered; No Time for Music Now

By Scott Patterson And Anita Raghavan

Peter Muller, a 43-year-old trader at Morgan Stanley, is used to markets behaving more or less as he expects. But in late July, some unusual patterns perplexed him. Certain investing strategies that historically had posted steady gains started faltering for no evident reason.

Soon, the unusual trading spread from U.S. to Japanese and European

Adding Up

Estimated assets in quant hedge funds using two common strategies, 'market neutral' and 'statistical abitrage'; quarterly data

$100 billion
80
60
40
20
0
2005
'06
'07

Source: Hedgefund.net

A New Microscope

Use Strategy As Research Tool

- Lehmann (1990) and Lo and MacKinlay (1990)
- Basic mean-reversion strategy:

$$\omega_{it} = -\frac{1}{N}(R_{it-k} - R_{mt-k}) \quad , \quad R_{mt-k} \equiv \frac{1}{N}\sum_{i=1}^{N} R_{it-k}$$

$$\sum_{i=1}^{N} \omega_{it} = 0 \quad \text{Market Neutral}$$

$$\mathrm{I}_t \equiv \frac{1}{2}\sum_{i=1}^{N} |\omega_{it}| \quad \text{Gross Long or Short Market Value}$$

$$R_{pt} \equiv \sum_{i=1}^{n} \omega_{it} R_{it}/\mathrm{I}_t \quad \text{Unleveraged Return}$$

A New Microscope

Use Strategy As Research Tool

- Linearity allows strategy to be analyzed explicitly:

$$\begin{aligned}
\text{Profit } \pi_t(k) &= \sum_{i=1}^{n} \omega_{it}(k) R_{it} \\
\mathrm{E}[\pi_t(k)] &= \frac{\iota' \mathbf{\Gamma}_k \iota}{n^2} - \frac{1}{n}\mathrm{tr}(\mathbf{\Gamma}_k) - \frac{1}{n}\sum_{i=1}^{n}(\mu_i - \mu_m)^2 \\
&= \frac{1}{n^2}\left[\iota' \mathbf{\Gamma}_k \iota - \mathrm{tr}(\mathbf{\Gamma}_k)\right] - \left(\frac{n-1}{n^2}\right) \cdot \mathrm{tr}(\mathbf{\Gamma}_k) - \\
&\qquad \frac{1}{n}\sum_{i=1}^{n}(\mu_i - \mu_m)^2
\end{aligned}$$

A New Microscope

Simulated Historical Performance of Contrarian Strategy

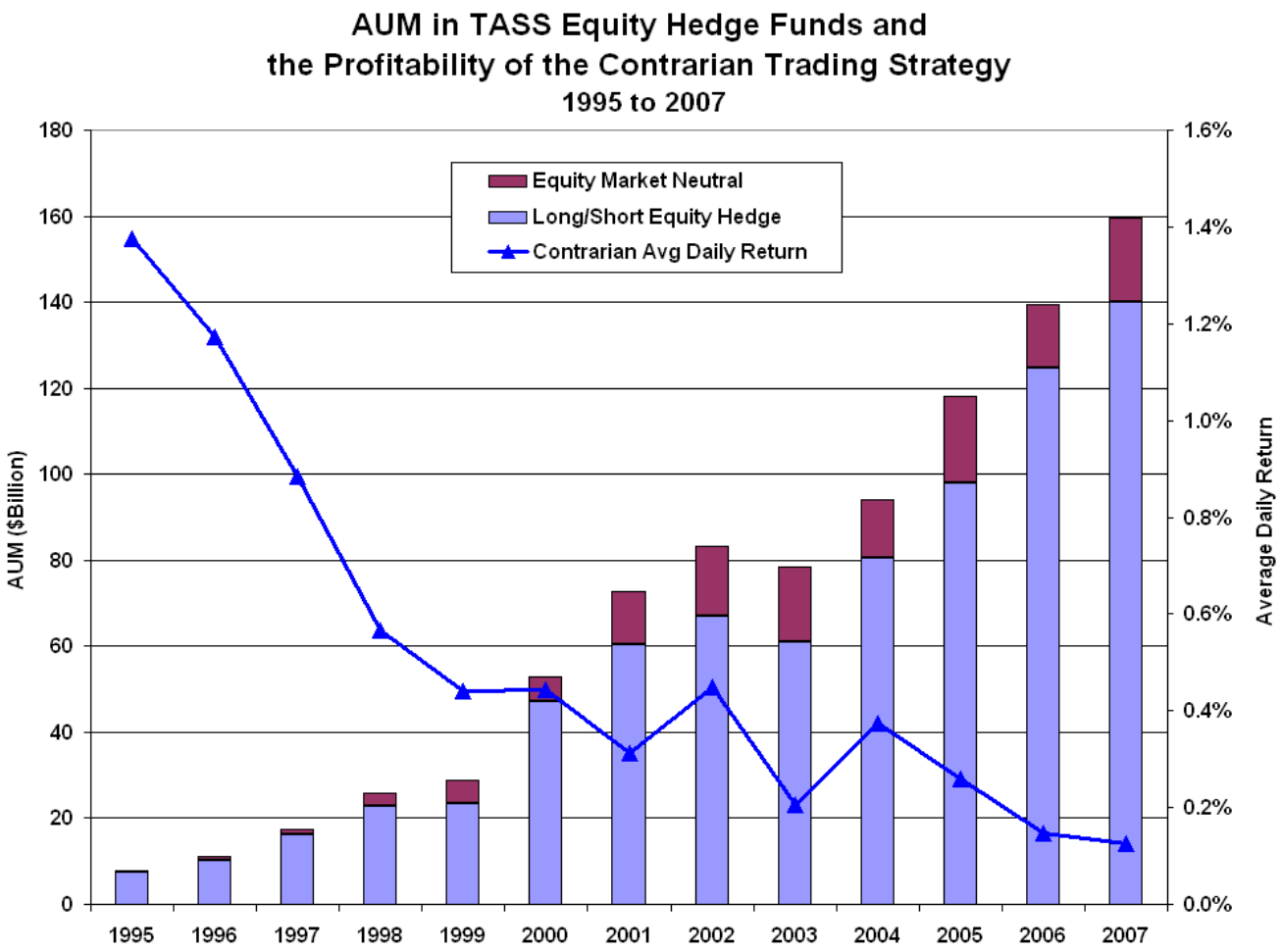
Year	Market Capitalization Deciles										All
	Smallest	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Largest	
	Average Daily Returns										
1995	3.57%	2.75%	1.94%	1.62%	1.07%	0.61%	0.21%	-0.01%	-0.02%	0.04%	1.38%
1996	3.58%	2.47%	1.82%	1.34%	0.84%	0.52%	0.19%	-0.11%	-0.04%	0.02%	1.17%
1997	2.83%	1.94%	1.34%	1.02%	0.62%	0.28%	0.04%	-0.12%	0.06%	0.14%	0.88%
1998	2.38%	1.45%	1.11%	0.62%	0.29%	0.03%	-0.04%	-0.12%	0.03%	0.10%	0.57%
1999	2.56%	1.41%	0.82%	0.38%	-0.01%	-0.11%	-0.21%	-0.35%	-0.01%	0.06%	0.44%
2000	2.58%	1.59%	0.92%	0.14%	0.03%	-0.02%	-0.14%	0.16%	0.00%	0.03%	0.44%
2001	2.15%	1.25%	0.57%	0.24%	-0.01%	0.06%	0.13%	-0.10%	-0.11%	-0.11%	0.31%
2002	1.67%	0.85%	0.53%	0.29%	0.28%	0.26%	0.28%	0.20%	0.11%	0.09%	0.45%
2003	1.00%	0.26%	-0.07%	0.04%	0.11%	0.20%	0.18%	0.15%	0.04%	0.05%	0.21%
2004	1.17%	0.48%	0.31%	0.38%	0.25%	0.29%	0.22%	0.15%	0.05%	-0.01%	0.37%
2005	1.05%	0.39%	0.13%	0.11%	0.09%	0.11%	0.05%	0.08%	0.01%	0.02%	0.26%
2006	0.86%	0.26%	0.11%	0.06%	0.05%	-0.02%	-0.02%	0.05%	0.06%	0.00%	0.15%
2007	0.57%	0.09%	0.08%	0.18%	0.16%	-0.08%	0.04%	-0.04%	0.00%	-0.04%	0.13%

A New Microscope

Simulated Historical Performance of Contrarian Strategy

Year	Market Capitalization Deciles										All
	Smallest	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Largest	
	Standard Deviation of Daily Returns										
1995	0.92%	0.88%	0.81%	0.82%	0.78%	0.77%	0.73%	0.67%	0.63%	0.65%	0.40%
1996	1.07%	1.00%	0.79%	0.81%	0.88%	0.84%	0.90%	0.90%	0.83%	0.73%	0.48%
1997	1.04%	0.98%	0.96%	0.96%	1.12%	1.00%	0.91%	0.99%	0.98%	0.77%	0.68%
1998	1.59%	1.67%	1.23%	1.22%	1.57%	1.25%	1.29%	1.43%	1.08%	1.00%	0.84%
1999	1.66%	1.82%	1.44%	1.44%	1.79%	1.57%	1.71%	1.70%	1.57%	1.07%	1.02%
2000	1.57%	1.69%	2.06%	1.89%	1.76%	2.15%	2.18%	2.29%	2.44%	2.56%	1.68%
2001	1.33%	1.26%	1.46%	1.62%	1.65%	1.64%	1.83%	1.91%	2.28%	2.29%	1.43%
2002	1.17%	0.89%	1.14%	1.07%	1.25%	1.11%	1.30%	1.42%	1.50%	1.50%	0.98%
2003	1.11%	0.81%	0.95%	0.89%	0.86%	0.81%	0.77%	0.76%	0.75%	0.56%	0.54%
2004	1.35%	1.01%	0.87%	0.76%	0.76%	0.78%	0.80%	0.74%	0.69%	0.57%	0.53%
2005	1.35%	0.80%	0.89%	0.70%	0.77%	0.77%	0.65%	0.73%	0.57%	0.56%	0.46%
2006	1.07%	0.90%	0.83%	0.84%	0.70%	1.07%	0.68%	0.68%	0.64%	0.61%	0.52%
2007	0.96%	1.02%	1.00%	0.99%	1.06%	1.44%	1.00%	0.87%	0.67%	0.56%	0.72%

Total Assets, Expected Returns, and Leverage



A New Microscope

Basic Leverage Calculations

- Regulation T leverage of 2:1 implies

$$\$100\text{MM of Capital} \;\Rightarrow\; \text{Leverage} = \frac{|100| + |-100|}{100} = 2:1$$

- More leverage is available:

$$\$100\text{MM of Capital} \;\Rightarrow\; \text{Leverage} = \frac{|500| + |-500|}{100} = 10:1$$

- Leverage magnifies risk and return:

$$\theta:1 \;\Rightarrow\; \text{Leveraged Return} \equiv \frac{\theta}{2} R_{pt}$$

Total Assets, Expected Returns, and Leverage

How Much Leverage Needed To Get 1998 Expected Return Level?

- In 2007, use 2006 multiplier of 4
- 8:1 leverage
- Compute leveraged returns
- How did the contrarian strategy perform during August 2007?
- Recall that for 8:1 leverage:
  - $E[R_{pt}] = 4 \times 0.15\% = 0.60\%$
  - $SD[R_{pt}] = 4 \times 0.52\% = 2.08\%$

$\Rightarrow$ 2007 Daily Mean: **0.60%**

$\Rightarrow$ 2007 Daily SD: **2.08%**

Required Leverage Ratios For Contrarian Strategy To Yield 1998 Level of Average Daily Return

Year	Average Daily Return	Return Multiplier	Required Leverage Ratio
1998	0.57%	1.00	2.00
1999	0.44%	1.28	2.57
2000	0.44%	1.28	2.56
2001	0.31%	1.81	3.63
2002	0.45%	1.26	2.52
2003	0.21%	2.77	5.53
2004	0.37%	1.52	3.04
2005	0.26%	2.20	4.40
2006	0.15%	3.88	7.76
2007	0.13%	4.48	8.96

What Happened In August 2007?

Daily Returns of the Contrarian Strategy In August 2007

Date	Deciles by Market Capitalization										All
	Smallest	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Largest	
7/30/2007	-0.28%	0.08%	7.85%	-1.43%	0.29%	0.91%	1.04%	1.51%	2.05%	0.71%	1.77%
7/31/2007	0.77%	4.41%	1.12%	2.20%	-2.53%	0.09%	-3.19%	1.94%	-1.23%	0.22%	1.46%
8/1/2007	6.10%	1.78%	-5.55%	1.39%	3.79%	-3.52%	-2.83%	-2.52%	-8.06%	-0.90%	0.43%
8/2/2007	3.54%	-3.04%	-0.46%	-2.68%	-3.77%	-10.79%	8.63%	6.12%	-2.97%	-0.77%	-1.22%
8/3/2007	-3.79%	-2.49%	-3.12%	0.24%	3.52%	0.05%	-2.49%	-4.35%	-2.29%	-2.74%	-0.10%
8/6/2007	-3.33%	-7.06%	-1.57%	-4.12%	5.47%	-5.47%	-4.75%	-2.86%	1.06%	3.08%	2.01%
8/7/2007	3.00%	1.03%	-6.55%	-11.65%	-6.01%	-2.79%	1.42%	-4.08%	-6.86%	-2.67%	-4.64%
8/8/2007	3.52%	-5.30%	-10.36%	-14.58%	-17.07%	-8.65%	-8.94%	-13.85%	-5.06%	-5.91%	-11.33%
8/9/2007	3.66%	-7.42%	-15.46%	-11.08%	-12.72%	-15.78%	-13.06%	-17.33%	-10.32%	-5.22%	-11.43%
8/10/2007	-1.32%	14.62%	24.32%	31.58%	35.08%	30.67%	30.07%	26.79%	18.73%	9.55%	23.67%
8/13/2007	5.42%	-1.24%	-2.53%	-4.26%	-6.20%	-0.88%	-5.15%	-8.04%	-8.58%	-4.99%	-3.05%
8/14/2007	4.65%	3.64%	-1.02%	1.35%	2.23%	-1.12%	2.74%	-1.16%	0.66%	0.67%	0.33%
8/15/2007	3.52%	4.74%	-2.42%	-2.33%	-0.69%	-3.89%	-0.97%	-5.36%	-2.29%	-4.73%	-1.53%
8/16/2007	-5.03%	-2.16%	0.59%	-2.36%	-2.39%	-3.95%	-6.94%	-5.08%	1.08%	-7.31%	-3.24%
8/17/2007	14.30%	9.94%	0.41%	5.04%	5.32%	-2.07%	0.47%	-1.56%	1.24%	0.44%	1.53%
8/20/2007	15.02%	7.02%	1.42%	5.40%	2.03%	1.74%	4.88%	2.22%	1.57%	4.67%	4.58%
8/21/2007	4.98%	0.43%	0.02%	-1.80%	0.09%	-2.54%	-0.33%	-0.20%	0.74%	0.43%	0.24%
8/22/2007	-3.39%	-1.23%	-2.07%	-2.05%	-0.67%	-3.31%	-0.74%	-2.26%	1.57%	0.37%	-1.51%
8/23/2007	-0.14%	2.79%	2.79%	-0.64%	1.51%	4.15%	1.04%	-1.33%	1.28%	1.23%	1.31%
8/24/2007	2.47%	-1.13%	-0.26%	0.92%	3.70%	-0.23%	-0.29%	0.37%	-1.42%	2.43%	1.73%
8/27/2007	4.38%	2.80%	0.46%	0.78%	5.01%	-0.63%	1.58%	2.85%	2.84%	0.10%	2.99%
8/28/2007	1.64%	1.26%	0.34%	-2.45%	-2.56%	-1.99%	-1.33%	-1.77%	-1.88%	0.99%	-3.04%
8/29/2007	5.79%	0.31%	5.07%	8.32%	7.75%	-2.14%	5.67%	6.39%	3.63%	3.94%	7.06%
8/30/2007	4.27%	0.16%	2.46%	1.61%	3.55%	0.41%	-0.11%	-0.16%	0.47%	-0.19%	2.01%
8/31/2007	6.75%	3.86%	3.80%	-2.21%	0.21%	2.08%	-0.32%	-2.68%	0.02%	0.58%	1.46%

What Happened In August 2007?

Daily Returns of Various Indexes In August 2007

Date	S&P 500	S&P Small Cap 600	MSCI Emerging Markets	MSCI World ex. US	Lehman Aggregate US Gov. Index	Lehman US Universal Corp. High-Yield Index	Goldman Sachs Commodity Index	Trade Weighted USD Index	CBOE Volatility Index (VIX) Change
7/30/2007	1.03%	0.94%	0.87%	0.14%	-0.04%	0.18%	0.11%	-0.12%	-3.30
7/31/2007	-1.26%	-0.88%	1.67%	1.36%	0.17%	0.61%	1.18%	-0.10%	2.65
8/1/2007	0.73%	0.19%	-3.42%	-1.70%	0.04%	-0.15%	-1.34%	0.13%	0.15
8/2/2007	0.46%	0.98%	0.61%	0.62%	0.04%	0.53%	0.00%	-0.20%	-2.45
8/3/2007	-2.65%	-3.48%	-0.05%	-0.37%	0.29%	0.08%	-1.10%	-0.66%	3.94
8/6/2007	2.42%	1.35%	-1.99%	-0.57%	-0.14%	-0.29%	-2.76%	0.10%	-2.56
8/7/2007	**0.62%**	**0.71%**	**0.45%**	**0.56%**	**-0.04%**	**0.38%**	**0.34%**	**0.28%**	**-1.04**
8/8/2007	**1.44%**	**1.52%**	**2.83%**	**1.88%**	**-0.48%**	**0.84%**	**-0.20%**	**-0.17%**	**-0.11**
8/9/2007	**-2.95%**	**-1.38%**	**-1.28%**	**-1.52%**	**0.31%**	**-0.07%**	**-0.37%**	**0.54%**	**5.03**
8/10/2007	**0.04%**	**1.01%**	**-3.30%**	**-2.85%**	**0.07%**	**-0.29%**	**-0.03%**	**-0.12%**	**1.82**
8/13/2007	-0.03%	-0.84%	1.01%	1.08%	0.04%	0.34%	0.27%	0.46%	-1.73
8/14/2007	-1.81%	-1.87%	-1.42%	-1.10%	0.23%	-0.10%	0.35%	0.54%	1.11
8/15/2007	-1.36%	-1.45%	-2.39%	-1.52%	0.15%	-0.56%	0.80%	0.41%	2.99
8/16/2007	0.33%	1.70%	-5.63%	-2.91%	0.58%	-0.59%	-3.01%	-0.11%	0.16
8/17/2007	2.46%	2.30%	0.12%	0.96%	-0.28%	0.24%	1.49%	-0.37%	-0.84
8/20/2007	-0.03%	0.30%	3.78%	1.23%	0.23%	0.24%	-1.65%	-0.03%	-3.66
8/21/2007	0.11%	0.21%	-0.18%	0.61%	0.24%	0.19%	-1.14%	0.11%	-1.08
8/22/2007	1.18%	1.19%	2.58%	1.27%	-0.16%	0.37%	0.04%	-0.30%	-2.36
8/23/2007	-0.11%	-1.16%	1.76%	1.16%	-0.01%	0.22%	0.96%	-0.13%	-0.27
8/24/2007	1.16%	1.44%	0.44%	0.51%	-0.10%	0.04%	1.10%	-0.59%	-1.90
8/27/2007	-0.85%	-1.07%	1.90%	0.29%	0.23%	0.17%	0.28%	0.09%	2.00
8/28/2007	-2.34%	-2.70%	-0.85%	-1.26%	0.34%	-0.07%	-0.17%	0.02%	3.58
8/29/2007	2.22%	2.28%	-0.23%	0.04%	-0.09%	-0.06%	1.40%	-0.07%	-2.49
8/30/2007	-0.41%	-0.38%	1.31%	0.80%	0.29%	0.06%	0.15%	0.12%	1.25
8/31/2007	1.12%	1.28%	2.39%	1.58%	-0.16%	0.01%	0.48%	0.00%	-1.68

Comparing August 2007 To August 1998

Daily Returns of the Contrarian Strategy In August and September 1998

Date	Deciles by Market Capitalization										All
	Smallest	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Largest	
8/3/1998	3.35%	1.75%	1.68%	0.15%	3.25%	-0.33%	0.40%	0.06%	0.62%	0.16%	1.01%
8/4/1998	-0.29%	2.16%	1.64%	-1.35%	-1.18%	-0.51%	-0.82%	-0.07%	-1.22%	-0.16%	-0.18%
8/5/1998	2.75%	1.93%	0.68%	2.60%	2.04%	0.93%	-0.57%	0.38%	-0.59%	2.56%	1.27%
8/6/1998	2.25%	1.68%	2.01%	0.36%	0.17%	-0.33%	-1.35%	0.15%	0.85%	1.34%	0.66%
8/7/1998	3.05%	2.99%	0.79%	0.26%	-0.23%	0.03%	0.12%	0.39%	2.93%	-0.10%	0.67%
8/10/1998	3.48%	1.69%	1.53%	0.91%	0.48%	2.23%	1.03%	-0.23%	0.68%	0.27%	1.27%
8/11/1998	2.34%	1.72%	0.81%	-0.24%	0.60%	1.18%	-0.36%	0.79%	-0.29%	-0.14%	0.59%
8/12/1998	4.83%	2.88%	2.71%	1.31%	0.96%	0.58%	2.01%	0.93%	1.00%	0.68%	2.04%
8/13/1998	3.74%	2.24%	0.88%	2.72%	0.37%	0.39%	1.03%	0.48%	-0.11%	0.04%	1.33%
8/14/1998	2.25%	1.64%	3.57%	1.42%	-0.46%	-0.05%	0.66%	-0.07%	0.77%	-0.42%	0.94%
8/17/1998	**2.46%**	**2.48%**	**1.81%**	**0.11%**	**-0.32%**	**1.66%**	**-0.01%**	**-0.80%**	**0.11%**	**0.49%**	**0.96%**
8/18/1998	4.31%	1.85%	1.75%	3.86%	0.35%	-0.16%	-2.12%	0.03%	0.29%	0.12%	0.87%
8/19/1998	2.60%	2.15%	1.16%	0.45%	-0.65%	-0.36%	0.34%	-0.80%	0.06%	-0.13%	0.63%
8/20/1998	1.60%	3.04%	1.49%	0.42%	-0.64%	0.55%	0.87%	-0.61%	-0.55%	-1.47%	0.46%
8/21/1998	**2.26%**	**4.06%**	**2.18%**	**1.79%**	**1.03%**	**-0.06%**	**-0.28%**	**-0.51%**	**0.06%**	**-0.36%**	**1.04%**
8/24/1998	5.35%	1.84%	4.13%	0.63%	-0.83%	0.13%	-1.57%	-1.02%	-0.68%	0.73%	0.90%
8/25/1998	2.05%	2.19%	1.76%	0.85%	-0.45%	-0.34%	0.91%	-1.46%	-0.48%	-0.56%	0.36%
8/26/1998	4.02%	1.39%	1.78%	0.81%	-0.31%	0.06%	-0.43%	1.03%	-0.65%	-0.26%	0.61%
8/27/1998	1.69%	1.15%	0.24%	-1.16%	-2.02%	-0.47%	-1.54%	-1.91%	-0.63%	-2.20%	-0.78%
8/28/1998	2.52%	2.29%	1.33%	1.35%	0.11%	1.12%	-1.29%	-1.32%	-1.18%	-0.36%	0.39%
8/31/1998	3.31%	1.79%	0.51%	-0.36%	-3.44%	-1.97%	-3.08%	-4.47%	-2.73%	-2.82%	-1.62%
9/1/1998	4.96%	4.42%	6.04%	4.67%	9.06%	6.68%	6.71%	6.67%	4.90%	6.10%	6.59%
9/2/1998	4.43%	2.74%	1.90%	0.82%	-1.33%	0.25%	0.86%	-0.39%	0.45%	0.33%	0.63%
9/3/1998	**3.89%**	**3.78%**	**2.08%**	**2.09%**	**0.23%**	**-0.03%**	**0.79%**	**0.15%**	**0.51%**	**0.76%**	**1.41%**
9/4/1998	5.10%	3.95%	2.09%	0.75%	-0.33%	-0.84%	-1.33%	-1.61%	-1.15%	-3.68%	0.26%

Comparing August 2007 To August 1998

Daily Returns of the Contrarian Strategy In August and September 1998

Date	Deciles by Market Capitalization										All
	Smallest	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Largest	
9/8/1998	3.53%	3.40%	3.82%	0.57%	0.60%	0.82%	1.35%	1.05%	0.97%	3.73%	2.08%
9/9/1998	1.99%	3.62%	1.38%	1.15%	1.12%	1.66%	1.70%	2.10%	2.32%	2.92%	2.42%
9/10/1998	4.26%	2.68%	0.08%	2.05%	0.96%	-0.27%	0.64%	-0.86%	-0.67%	-2.16%	0.29%
9/11/1998	3.34%	3.17%	2.15%	0.77%	0.20%	0.50%	-0.95%	1.28%	-0.18%	0.15%	1.24%
9/14/1998	3.53%	3.58%	1.54%	0.83%	-0.20%	-0.42%	-0.47%	-0.50%	0.02%	-0.23%	0.33%
9/15/1998	3.62%	2.36%	1.34%	0.77%	-0.17%	-0.98%	-0.52%	-1.15%	-0.95%	-0.63%	0.14%
9/16/1998	2.71%	3.33%	0.89%	1.48%	0.58%	0.83%	0.00%	0.05%	1.53%	-0.04%	1.01%
9/17/1998	3.70%	2.24%	1.54%	1.56%	-0.95%	0.23%	1.10%	-0.40%	-0.86%	0.38%	0.79%
9/18/1998	4.01%	3.94%	2.67%	1.27%	2.55%	1.20%	-1.17%	-1.41%	-0.51%	-0.45%	1.07%
9/21/1998	3.22%	1.28%	1.86%	-0.61%	-0.87%	-0.09%	-2.22%	1.08%	-0.47%	-0.32%	0.19%
9/22/1998	3.26%	2.15%	1.68%	1.76%	-0.21%	-0.16%	-0.62%	-2.06%	-1.46%	0.16%	0.42%
9/23/1998	4.24%	2.16%	0.78%	-1.66%	-0.34%	-2.33%	-3.08%	-3.27%	-0.60%	-0.42%	-0.71%
9/24/1998	**2.54%**	**1.47%**	**3.13%**	**1.60%**	**0.63%**	**-0.38%**	**-0.06%**	**-0.27%**	**0.59%**	**1.63%**	**1.21%**
9/25/1998	2.28%	3.27%	0.16%	0.86%	0.28%	-0.90%	-0.66%	0.67%	1.16%	0.36%	0.61%
9/28/1998	4.24%	1.24%	1.81%	2.64%	0.52%	-1.30%	0.47%	-1.58%	-0.59%	0.16%	0.60%
9/29/1998	2.75%	1.48%	-0.07%	0.81%	-0.83%	-1.61%	-1.58%	-0.83%	-1.19%	-0.83%	-0.29%
9/30/1998	2.98%	0.41%	0.33%	-0.96%	0.01%	-1.00%	-1.78%	-0.41%	-0.10%	-0.74%	-0.33%

The Unwind Hypothesis

What Happened?

- Losses due to rapid and large unwind of quant fund (market-neutral)
- Liquidation is likely forced because of firesale prices (sub-prime?)
- Initial losses caused other funds to reduce risk and de-leverage
- De-leveraging caused further losses across broader set of equity funds
- Friday rebound consistent with liquidity trade, not informed trade
- Rebound due to quant funds, long/short, 130/30, long-only funds

Lessons

- "Quant" is not the issue; liquidity and credit are the issues
- Long/short equity space is more crowded now than in 1998
- Hedge funds provide more significant amounts of liquidity today
- Hedge funds can withdraw liquidity suddenly, unlike banks
- Financial markets are more highly connected $\Rightarrow$ **new betas**

Factor-Based Strategies

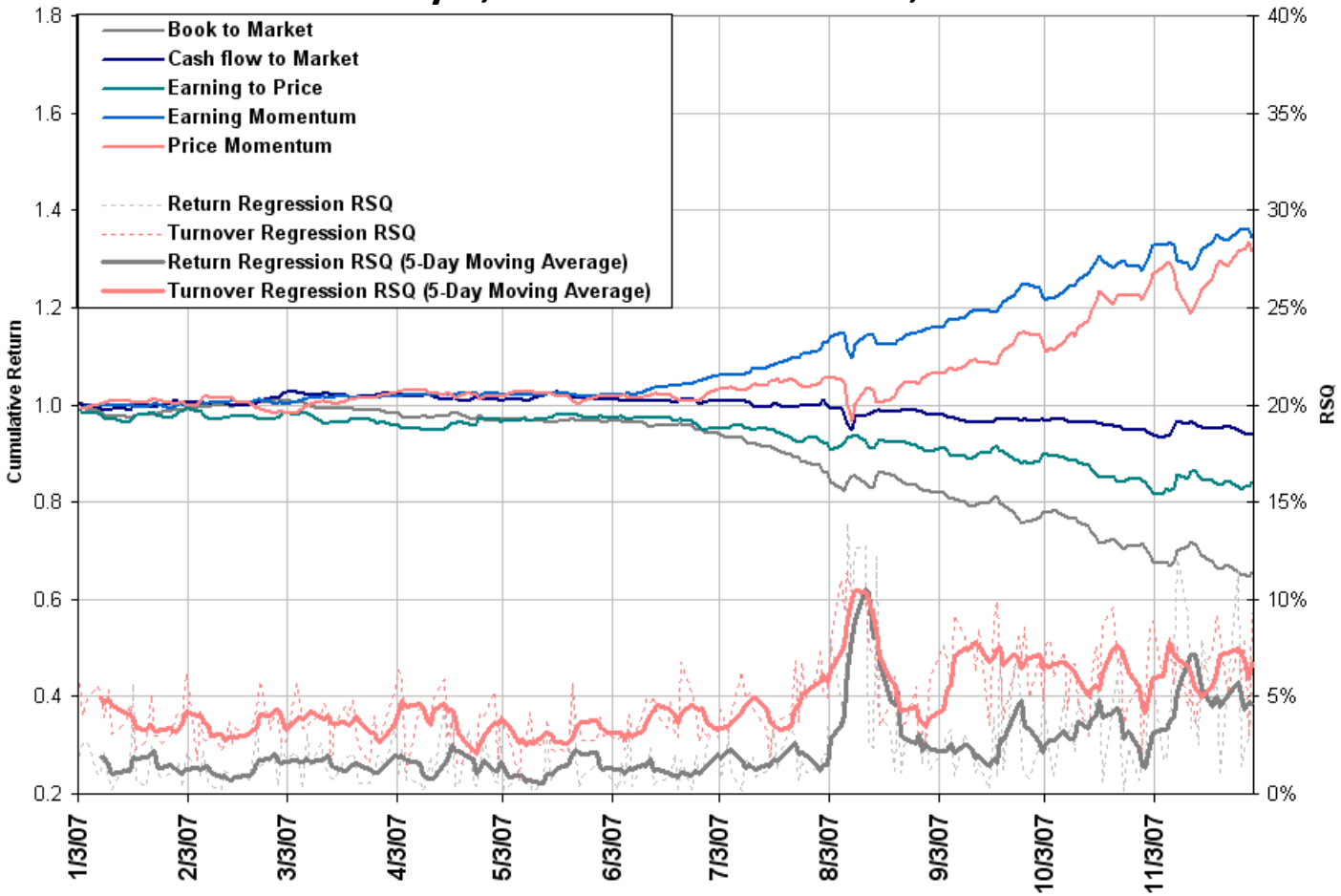
Construct Five Long/Short Factor Portfolios

- Book-to-Market
- Earnings-to-Price
- Cashflow-to-Price
- Price Momentum
- Earnings Momentum
- Rank S&P 1500 stocks monthly
- Invest $1 long in decile 10 (highest), $1 short in decile 1 (lowest)
- Equal-weighting within deciles
- Simulate daily holding-period returns

Factor-Based Strategies

Cumulative Returns of Factor-Based Portfolios

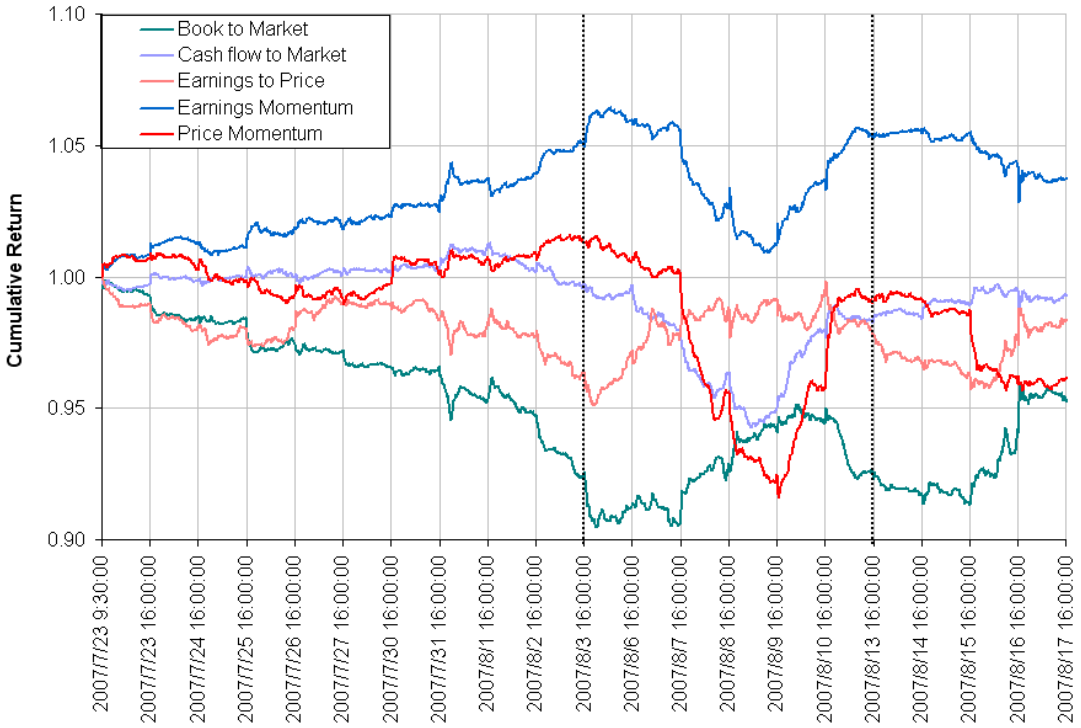
January 3, 2007 to December 31, 2007



Factor-Based Strategies

Using Tick Data, Construct Long/Short Factor Portfolios

- Same five factors
- Compute 5-minute returns from 9:30am to 4:00pm (no overnight returns)
- Simulate intra-day performance of five long/short portfolios

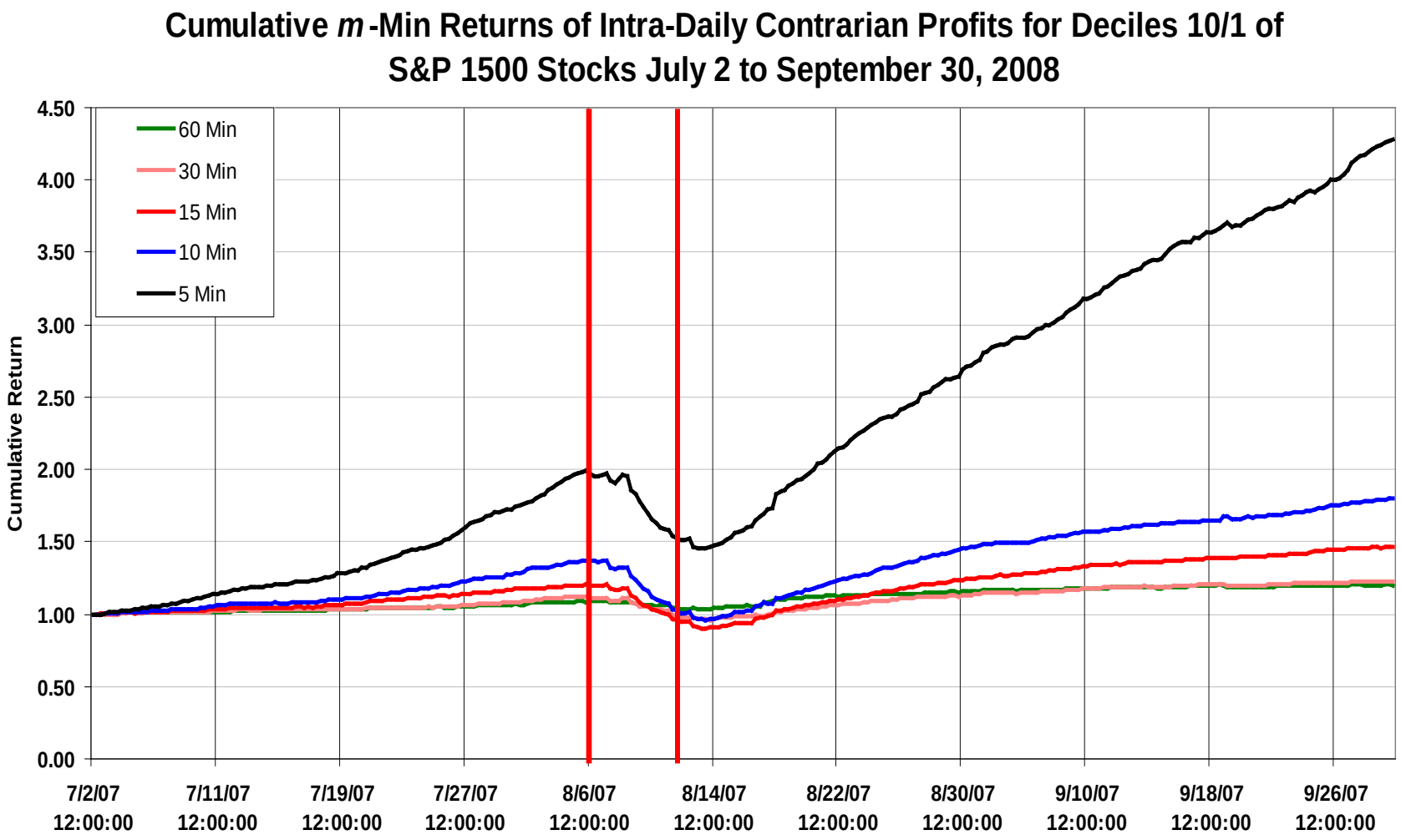


Proxies for Market-Making Profits

What Happened To Market-Makers During August 2007?

- Simulate simpler contrarian strategy using TAQ data
  - Sort stocks based on previous *m*-minute returns
  - Put $1 long in decile 1 (losers) and $1 short in decile 10 (winners)
  - Rebalance every m minutes
  - Cumulate profits
- Profitability of contrarian strategy should proxy for market-making P&L
- Let *m* vary to measure the value of liquidity provision vs. horizons
- Greater immediacy $\Rightarrow$ larger profits on average
- Positive profits suggest the presence of discretionary liquidity providers
- Negative profits suggest the absence of discretionary liquidity providers
- Given positive bid/offer spreads, on average, profits should be positive

Proxies for Market-Making Profits



August 2007: A Preview of May 2010?

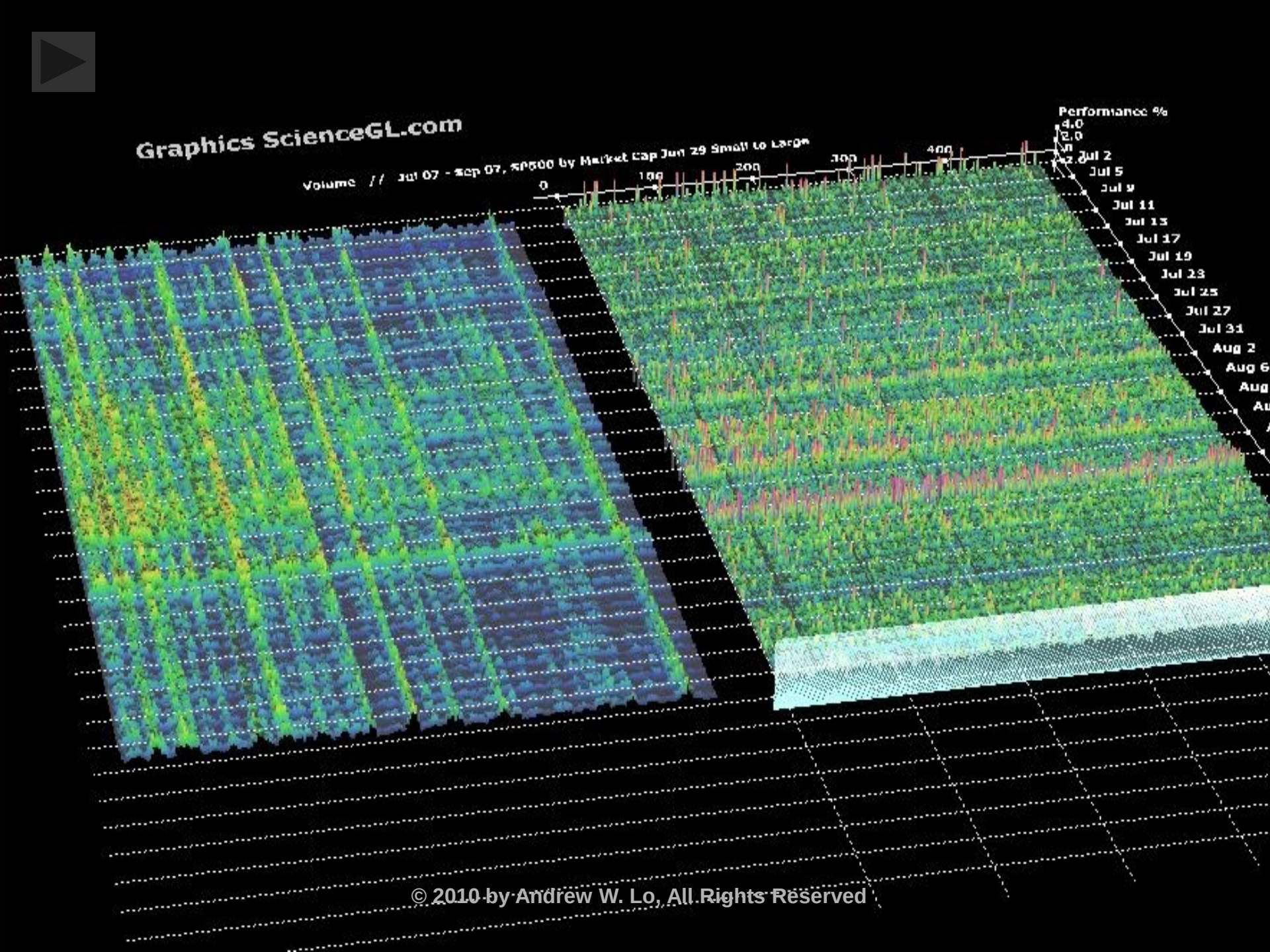
Profitability of Intra-Daily and Daily Strategies Over Various Holding Period, August 1–15, 2007

Panel A: High-Frequency Contrarian Strategy

	Average Return (bps)				
Date	5 Minutes	10 Minutes	15 Minutes	30 Minutes	60 Minutes
8/1/2007	5.06	6.81	5.15	8.02	7.37
8/2/2007	6.74	6.97	8.47	9.48	9.02
8/3/2007	4.28	2.93	1.77	1.47	-0.62
8/6/2007	-1.30	-2.57	-3.57	-8.75	-5.30
8/7/2007	-1.12	-6.32	-10.14	-14.55	-15.43
8/8/2007	-18.69	-31.60	-40.99	-56.82	-62.49
8/9/2007	-9.82	-16.86	-20.87	-27.65	-26.06
8/10/2007	-4.38	-11.41	-16.25	-25.15	-42.97
8/13/2007	-4.90	-10.29	-15.17	-23.18	-28.69
8/14/2007	5.39	7.72	8.30	10.12	10.28
8/15/2007	6.79	8.96	9.63	8.46	8.35
July Sigma	1.58	1.96	2.15	2.58	3.53

Panel B: Daily Contrarian Strategy

	Return (%)				
Portfolio Construction Date	Held 1 Day	Held 2 Days	Held 3 Days	Held 4 Days	Held 5 Days
8/1/2007	0.14%	-1.03%	-2.69%	-2.57%	-0.34%
8/2/2007	-0.76%	-1.62%	-2.57%	-2.63%	-2.79%
8/3/2007	-0.30%	-0.57%	0.65%	0.29%	2.04%
8/6/2007	-1.47%	-1.79%	-1.75%	1.24%	3.44%
8/7/2007	-2.88%	-4.49%	1.38%	4.00%	4.52%
8/8/2007	-3.99%	3.79%	7.81%	8.31%	8.20%
8/9/2007	6.85%	10.12%	9.83%	9.47%	8.96%
8/10/2007	-1.46%	-1.71%	-1.48%	-1.84%	-1.49%
8/13/2007	0.19%	0.82%	3.79%	4.61%	3.77%
8/14/2007	-0.95%	-0.83%	0.22%	0.34%	0.56%
8/15/2007	-1.34%	-0.58%	0.31%	0.76%	1.69%
January to July 2007	0.36%	0.49%	0.59%	0.66%	0.69%
2007 Sigma	0.8%	1.1%	1.2%	1.5%	1.5%



Summary and Conclusions

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Topics for Future Research

- Time-varying parameters of hedge-fund returns
- Dynamic correlations, rare events, tail risk
- Funding risk, leverage, and market dislocation
- Hedge funds and the macroeconomy
- Welfare implications of hedge funds (how much is too much liquidity?)
- Industrial organization of the hedge-fund industry
- Incentive contracts and risk-taking

Current Trends In The Industry

- Hedge-fund industry has already changed dramatically
- Assets are near all-time highs again, and growing
- Registration is almost certain (majority already registered)
- Will likely have to provide more disclosure to regulators
  - Leverage, positions, counterparties, etc.
- Financial Stability Oversight Council will have access
- Office of Financial Research (Treasury) will manage data
- If Volcker Rule passes, more hedge funds will be created!
- Traditional businesses will move closer to hedge funds
- Market gyrations will create more opportunities and risks
- Hedge funds will continue to be at the leading/bleeding edge

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