Special Topics in Financial Engineering

Statistical Arbitrage

MGMT MFE 431 - Section 3

Professor Olivier Ledoit

University of California Los Angeles
Anderson School of Management
Master of Financial Engineering

Fall 2019

Contact Details

- Office: Entrepreneurs Hall, C5.20
- Office Phone: ext. 5-2873 = (310) 825-2873
- Mobile: (424) 431-5931 …Don't call me!
- E-mail: **olivier.ledoit@anderson.ucla.edu**
- More solid: **olivier.ledoit@econ.uzh.edu**
- Office Hours:
  - Tue 11:20am-11:50pm
  - Thu 11:20am-11:50am

General Information

- Worth 4 units
- 10 lectures of 2h50 each
- 3-hour in-class final exam
- 3 problem sets in groups
- Grade:
  - 10% participation
  - 40% final exam
  - 50% problem sets (16.67% each)

Current Positions

- Visiting Professor of Finance, UCLA Anderson School of Management
- Senior Research Associate, Department of Economics, University of Zurich, Switzerland
- Partner, AlphaCrest Capital Management, New York

Past Experience

- 1999-2008: Managing Director, Global Statistical Arbitrage Group, Equity Proprietary Trading Division, Credit Suisse, London
- 1995-1998: Assistant Professor of Finance (tenure-track), UCLA Anderson School of Management
- Published 20+ articles in top-ranked peer-reviewed academic research journals

Areas of Interest

- Probability theory
- Statistics
- Econometrics
- Finance
- Asset pricing theory
- Monetary Economics

One of my Latest Papers

Moving on to (A.12), let $\Delta \equiv \max_{m \in S} |m|$ and note that $|z_j| \leq 2$. Therefore, for any $\tau_1, \tau_2 \in [0, +\infty)$,

$$\begin{aligned}
|h_{m,z_j}(\tau_1) - h_{m,z_j}(\tau_2)| &= |\tau_1 - \tau_2| \left| \frac{1 - d - d\, z_j\, m}{(\tau_1 [1 - d - d\, z_j\, m] - z_j)\,(\tau_2 [1 - d - d\, z_j\, m] - z_j)} \right| \\
&= |\tau_1 - \tau_2| \frac{|1 - d - d\, z_j\, m|}{|\tau_1 [1 - d - d\, z_j\, m] - z_j|\, |\tau_2 [1 - d - d\, z_j\, m] - z_j|} \\
&= |\tau_1 - \tau_2| \frac{|1 - d - d\, z_j\, m|}{|\tau_1 [1 - d - d\, z_j\, m] - z_j|\, |\tau_2 [1 - d - d\, z_j\, m] - z_j|} \\
&\leq |\tau_1 - \tau_2|\, (1 + d + 2\, d\, \Delta)\ ,
\end{aligned}$$

implying that we may choose $d_1 \equiv (1 + d + 2\, d\, \Delta)$.

Recall that convergence in distribution of $\widehat{G}_n$ to G is equivalent to convergence to zero of the bounded-Lipschitz metric between $\widehat{G}_n$ and G; for example, see Pollard (1984, Chapter IV, Example 22). Furthermore, since $\widehat{G}_n$ and G put all their mass on $[0, \infty)$, it is sufficient to start all integrals at $\tau = 0$ rather than at $\tau = -\infty$. Therefore,

$$\begin{aligned}
\int_{-\infty}^{+\infty} \frac{d\widehat{G}_n(\tau)}{\tau [1 - d - d\, z_j\, m] - z_j} &= \int_0^{+\infty} \frac{1}{\tau [1 - d - d\, z_j\, m] - z_j}\, d\widehat{G}_n(\tau) \\
&= \int_0^{\infty} h_{m,z_j}(\tau)\, d\widehat{G}_n(\tau) \\
&\to \int_0^{\infty} h_{m,z_j}(\tau)\, dG(\tau) \\
&= \int_0^{+\infty} \frac{1}{\tau [1 - d - d\, z_j\, m] - z_j}\, dG(\tau) \\
&= \int_{-\infty}^{+\infty} \frac{1}{\tau [1 - d - d\, z_j\, m] - z_j}\, dG(\tau) \quad \text{uniformly in } m \in S\ ,
\end{aligned}$$

Education

- 1995: Finance PhD, MIT Sloan School of Management, Advisor: Andrew Lo
- 1992: MSc in Statistics & Economics, ENSAE, Paris, France
- 1990: BSc in Applied Mathematics, Ecole Polytechnique, Paris, France

Journal Officiel de la République

Arrêté du 20 août 1987 portant nomination des élèves admis en 1987 à l'Ecole polytechnique

NOR : *DEFA8701646A*

Par arrêté du ministre de la défense en date du 20 août 1987 :

I. – Sont nommés élèves français de l'Ecole polytechnique à la suite du concours d'admission organisé conformément au décret nº 71-708 du 25 août 1971 modifié (titre Ier) et à l'arrêté du 25 juillet 1973 modifié :

Option M'

1 Laruelle (Claude).
2 de Vigouroux d'Arvieu (Alexis).
3 Ledoit (Olivier).
4 Schmitt (Alain).
5 Huve (Pierre).
6 Roussel (Jean-François).
7 Chassagne (Olivier).
45 Blary (Benoît).
46 Macchi (Denis).
47 Arlès (Olivier).
48 Mehadhebi (Karim).
49 Kammerer (Clotilde).
50 Leroy (Xavier).
51 Daulmerie (Christophe).
52 Fabiani (Patrick).

MIT Graduation Day

Academic Research

Olivier Ledoit

FOLLOW

Senior Research Associate, Department of Economics, University of Zurich
Verified email at econ.uzh.ch - Homepage

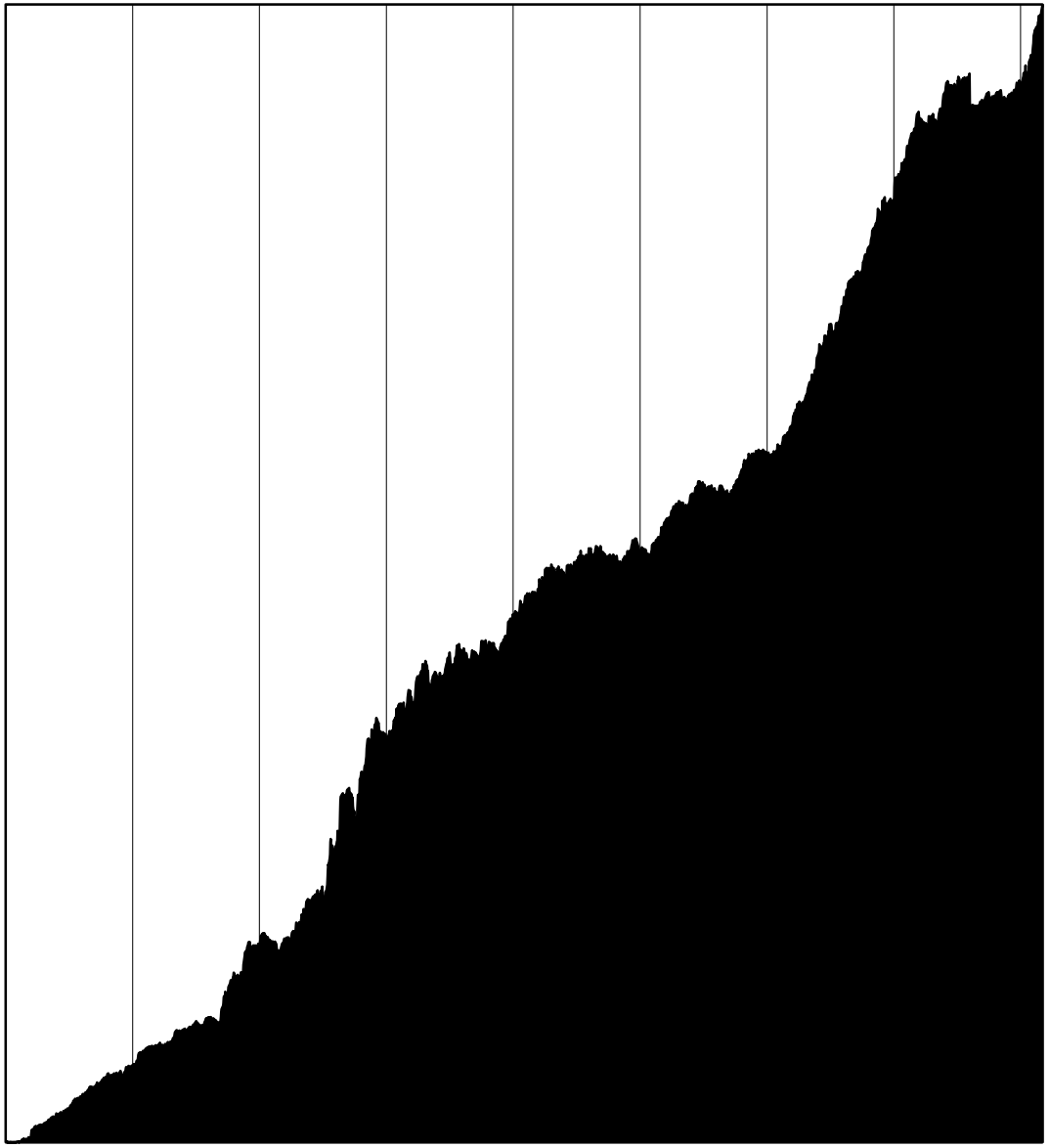
Finance Economics Statistics Probability Financial Econometrics

TITLE	CITED BY	YEAR
A well-conditioned estimator for large-dimensional covariance matrices O Ledoit, M Wolf Journal of multivariate analysis 88 (2), 365-411	1742	2004
Improved estimation of the covariance matrix of stock returns with an application to portfolio selection O Ledoit, M Wolf Journal of empirical finance 10 (5), 603-621	1333	2003
Honey, I shrunk the sample covariance matrix O Ledoit, M Wolf The Journal of Portfolio Management 30 (4), 110-119	914	2004
Robust performance hypothesis testing with the Sharpe ratio O Ledoit, M Wolf Journal of Empirical Finance 15 (5), 850-859	597	2008
Gain, loss, and asset pricing AE Bernardo, O Ledoit Journal of political economy 108 (1), 144-172	481	2000

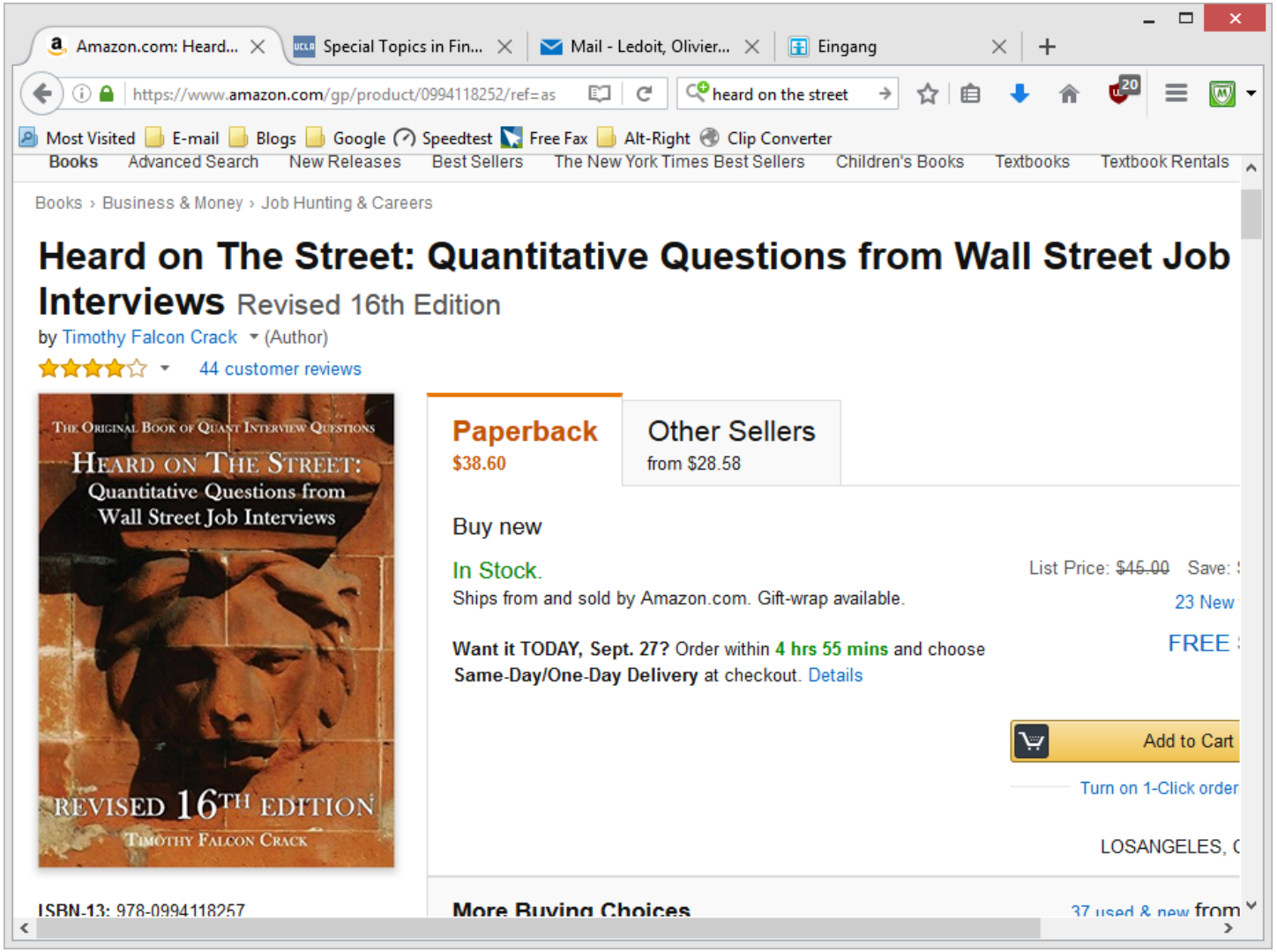
Used Everywhere

- Radar detection
- Speech recognition
- Brain/Computer Interface
- Improving mobile phone reception
- Decoding the human genome
- Finding a cure for cancer
- Saving the planet from Global Warming

Why I Retired Early



Holy Grail For Anyone Who Wants A Quant Job At Goldman Sachs



Statistical Arbitrage

- Equity Long-Short Market Neutral
- Systematic: No Human Overlay
- Medium Frequency: Turn portfolio around in 1 week to 1 month

High Frequency

- Orders must travel to the Stock Exchange in less than 10 milliseconds
- Flat position overnight
- Make money every day
- Technological horse race
- Low capacity

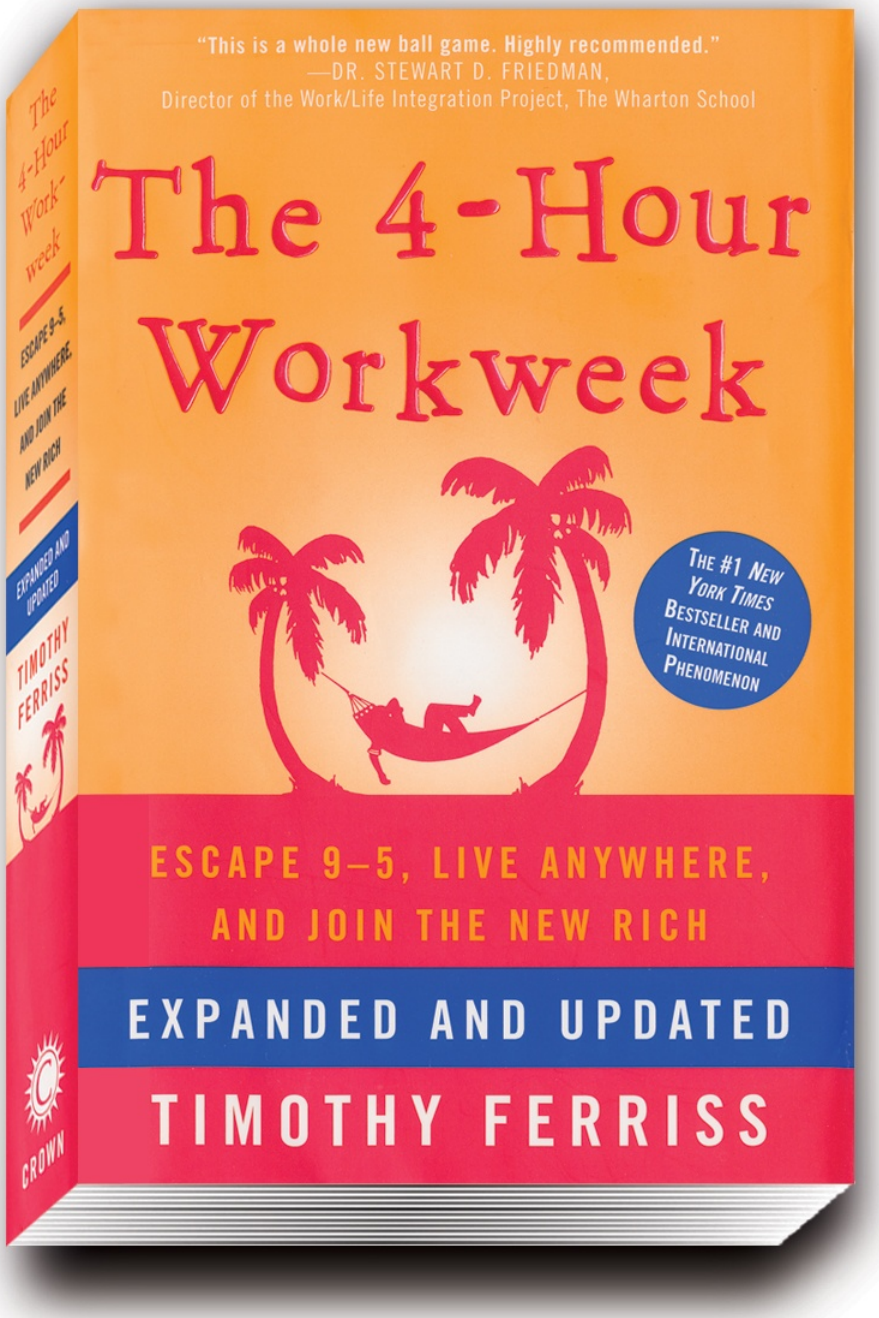
Low Frequency

- Quantitative Asset Management (Jason Hsu)
- Sharpe Ratio < 0.7
- More emphasis on asset gathering, distribution, marketing
- Lower fees

Medium Frequency

- Golden outlet: work in a hedge fund

- Other possibilities:
  - Work for Investment Bank outside the US (Volcker rule)
  - Work inside traditional asset management company
  - Work from home


"This is a whole new ball game. Highly recommended."
—DR. STEWART D. FRIEDMAN,
Director of the Work/Life Integration Project, The Wharton School
The 4-Hour Workweek
ESCAPE 9–5, LIVE ANYWHERE, AND JOIN THE NEW RICH
THE #1 NEW YORK TIMES BESTSELLER AND INTERNATIONAL PHENOMENON
EXPANDED AND UPDATED
TIMOTHY FERRISS
CROWN

Stat Arb

- Realized *(not backtested)* Sharpe Ratio > 2
- Make profit over any 6-months period
- Leverage: for $1M capital, go $2M long and $2M short
- Scalable up to $250M capacity
- Globally (developed equity markets only)
- Long-term sustainable through research

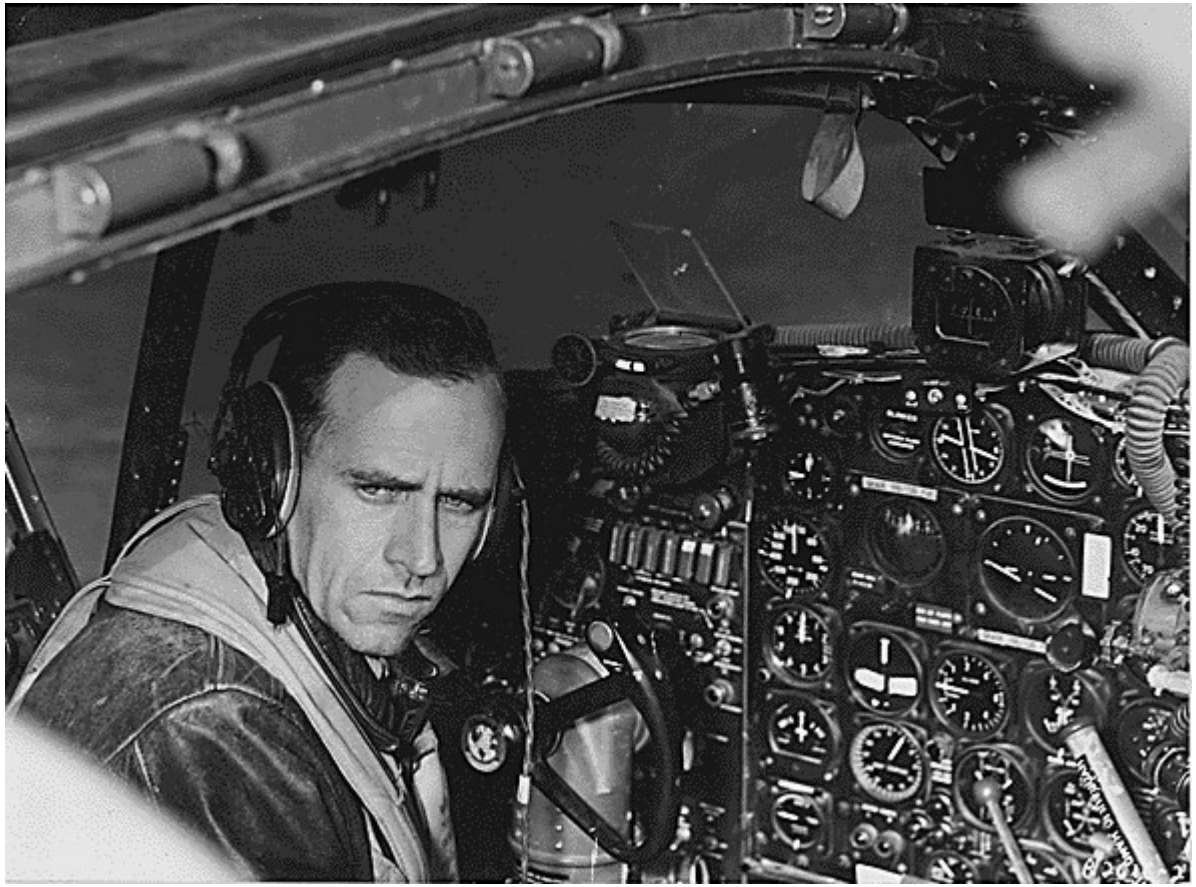
What does it take to succeed?

- Managing complexity
- 10,000+ lines of code, 100's of databases

- Must retain intellectual control at all times
- Need to "feel" the model and the markets
- Box is black to others, transparent to you

- Like piloting an airplane

Managing Complexity



Qualities

- High IQ
- Work > 60 hours/week

- Passionate about beating the market

DISCIPLINED

EMPIRICAL

PARANOID

Market Efficiency

- Need to reinvent 30% of your business every year just to stand still
- One new market anomaly published every day on Financial Economics Network
- In 10 years @ CS, I released one new version every 2 weeks
- Like fixing an airplane as you're flying it
- I won't give you a fish, I'll teach you how to fish

What this Class Is About

- Teaching you simple Stat Arb model
- Building Blocks
- Design Principles
- Homework:
  - You'll walk away with code you can improve
  - Europe (hardest but juiciest)
  - Jan 1998 – Dec2002 (save recent past as out-of-sample period)

Basic Structure

- One program to load data into memory
- Create the alphas
- Rebalance the portfolio
- Run historical backtest simulation
- Generate current trade

- Processes to update databases
- Auditing programs

Categories of Alpha

- Short-term momentum
- Short-term reversion
- Long-term momentum
- Long-term reversion

Main Components

- Alphas
- Risk model (covariance matrix)
- T-cost model
- Optimizer

What is an Alpha?

- α is a matrix of dimension $T \times n$
  - T = number of days in the backtest
  - n = number of stocks in your universe

- $\alpha_{t,i}$ = alpha of stock i on day t

Example: Momentum Alpha

- $p_{t,i}$ = price of stock *i* on day *t*
  Adjusted for stock splits, dividends, etc

- $m_{t,i} = \left(p_{t-21,i} / p_{t-252,i} \right) - 1$

- In Stat Arb we do not sort into quintiles!

Step 1: Demean

$$x_{t,i} = m_{t,i} - \left(m_{t,1} + \ldots + m_{t,n}\right) / n$$

Step 2: Standardize

$$y_{t,i} = \frac{x_{t,i}}{\sqrt{\sum_{j=1}^{n} x_{t,j}^2 /(n-1)}}$$

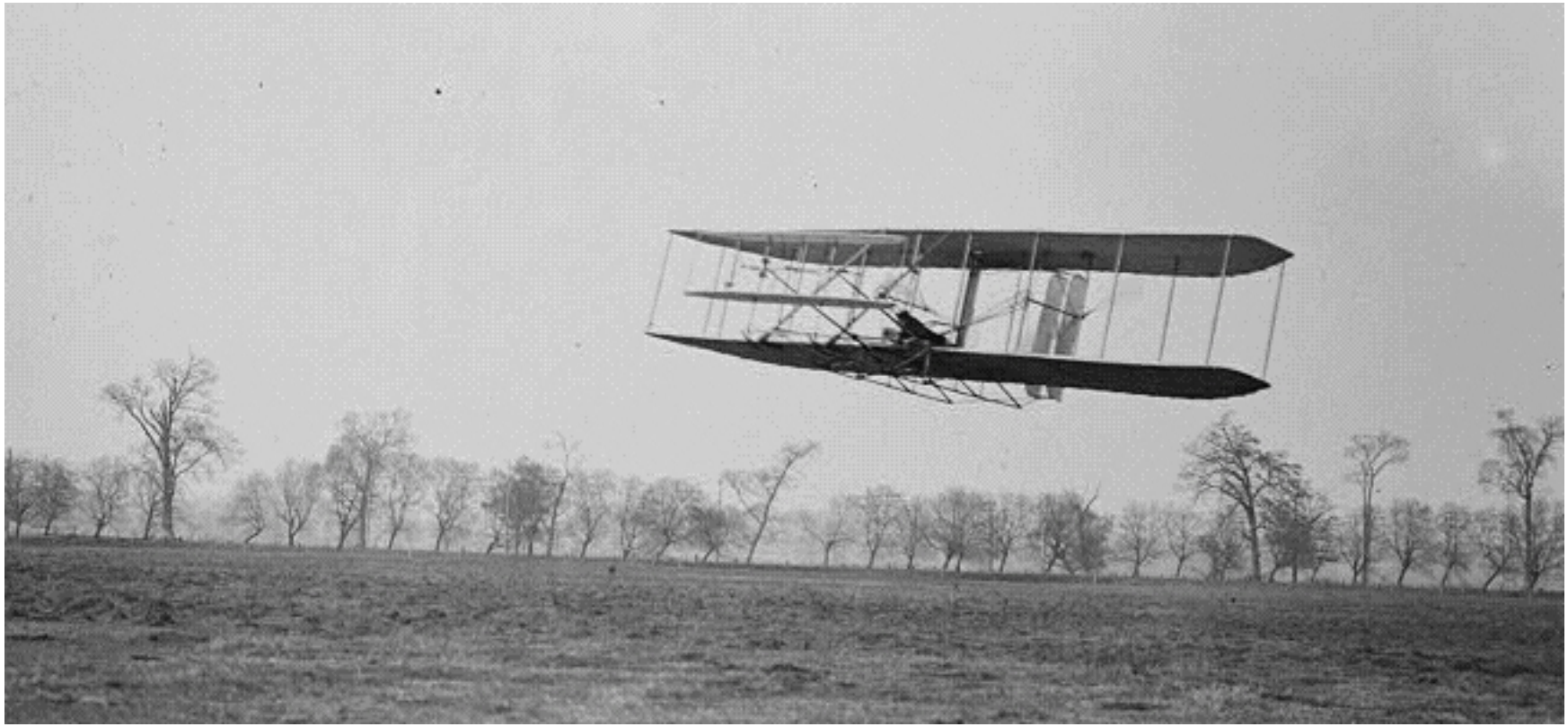
Step 3: Windsorize

- $\alpha_{t,i} = y_{t,i}$ if $|y_{t,i}| \leq 3$
- $\alpha_{t,i} = 3$ if $y_{t,i} > 3$
- $\alpha_{t,i} = -3$ if $y_{t,i} < -3$

How to Use Alphas

- Expected return on stock *i* on day *t* is linear function of $\alpha_{t,i}$ with positive slope
- On day *t* you maximize exposure to the vector $(\alpha_{t,1}, \ldots, \alpha_{t,n})$
- If today is day *T* (last day of your historical database) then you trade to maximize exposure to $(\alpha_{T,1}, \ldots, \alpha_{T,n})$
- Matrix α could be composite of many signals

Wright Brothers



Boeing 747

HSBC Hedge Fund Report

Hedge Weekly N°28

Investment Funds Performance Review

HSBC Alternative Investment Group

Week of Monday 04 Jul to Friday 08 Jul 2016

HSBC

Alternative Investment Products are:

NOT A DEPOSIT OR OTHER OBLIGATION OF THE BANK OR ANY OF ITS AFFILIATES	NOT FDIC INSURED	NOT INSURED BY ANY FEDERAL GOVERNMENT AGENCY OF THE UNITED STATES	NOT GUARANTEED BY THE BANK OR ANY OF ITS AFFILIATES	SUBJECT TO INVESTMENT RISK, INCLUDING POSSIBLE LOSS OF PRINCIPAL INVESTED

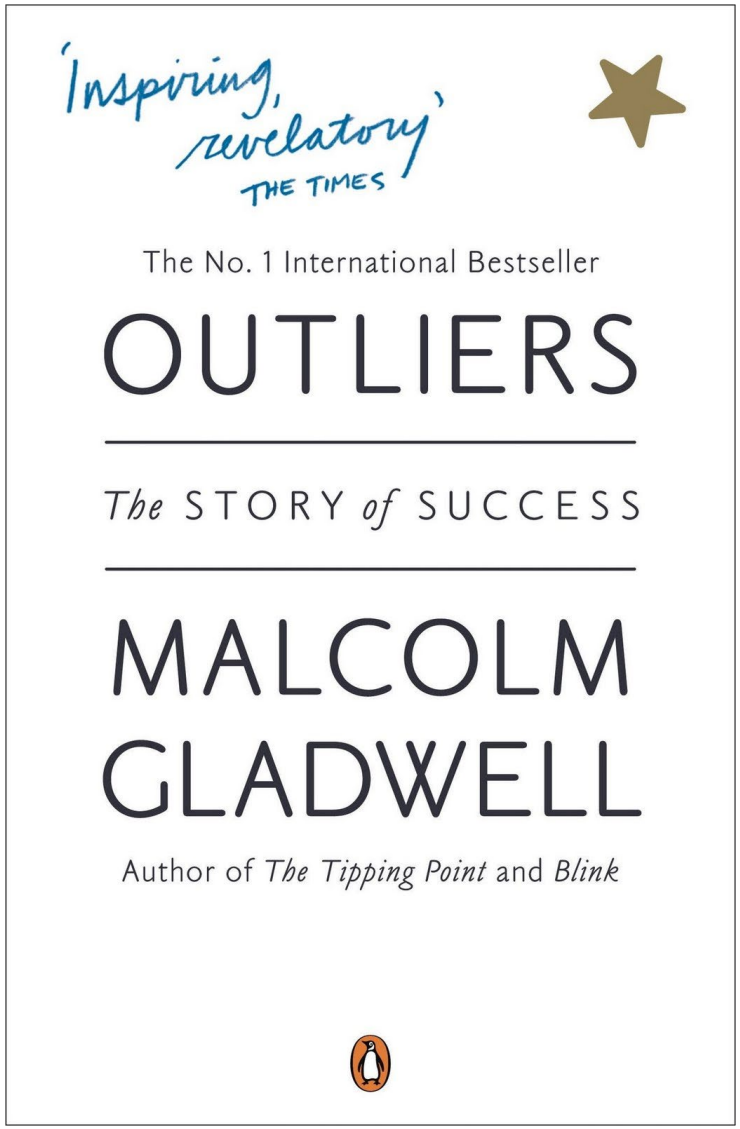
Equity Market Neutral Funds

TWO SIGMA ABSOLUTE RETURN CAYMAN FUND LTD *Two Sigma Advisers, LP*	31 Oct 11	M	$1'066M Apr 16	1,472.64	30 Jun 16	(4.45%)	(0.70%)	14.99%	10.09%	11.25%	4.03%	1.23%	8.64%	5.43%	(4.45%) May 16 - Jun 16
Multi-Strategy															
Ytd Avg. 2016 0.60%															
Multi-Strategy/Asia							Ytd Avg. 2016 (0.10%)								
LIM ASIA MULTI-STRATEGY FUND CLASS A *George W. Long*	31 Dec 95	Q	$975M May 16	39.53	24 Jun 16	(1.10%)	(0.10%)	1.77%	4.12%	5.63%	3.57%	-0.23%	6.94%	5.59%	(15.79%) Feb 08 - Nov 08
Multi-Strategy/Global							Ytd Avg. 2016 1.30%								
HUDSON BAY INTERNATIONAL FUND LTD *Hudson Bay Capital Management LP*	31 May 06	Q	$2'222M May 16	230.12	31 May 16	0.50%	1.30%	-1.91%	-2.08%	7.9%	11.37%	4.31%	8.68%	4.92%	(6.11%) Feb 14 - Nov 15
Statistical Arbitrage															
Ytd Avg. 2016 (2.74%)															
Statistical Arbitrage/Global							Ytd Avg. 2016 (2.74%)								
A.R.T. INTERNATIONAL INVESTOR (BVI) Ltd *Aaron Sosnick*	28 Feb 07	Q	$849M May 16	242.31	30 Jun 16	(2.29%)	(1.27%)	3.11%	9.83%	4.91%	5.67%	7.88%	9.94%	7.19%	(10.48%) Jul 07 - Aug 07
GSA INTERNATIONAL FUND - CLASS A *David Khabie-Zeitoune*	28 Feb 05	Q	$803M May 16	282.21	30 Jun 16	(0.97%)	(4.22%)	11.41%	12.14%	13.28%	3.64%	15.2%	9.58%	4.41%	(11.91%) Jun 08 - Sep 08

GSA Capital International Fund

- Manager: Jonathan Hiscock
- Inception Date: February 28, 2005
- Assets under Management: $803M
- Return in 2015: +11.41%; 2013: +12.14%
- Annual Return since Inception: +9.58%
- Annual Volatility: +4.41%
- Max Drawdown: -11.91% (Jun-Sep 2008)

10,000-Hour Rule



Toolkit

- Linear Algebra
- Statistics
- Economics
- Finance
- Optimization
- Programming

Required Readings for Next Week

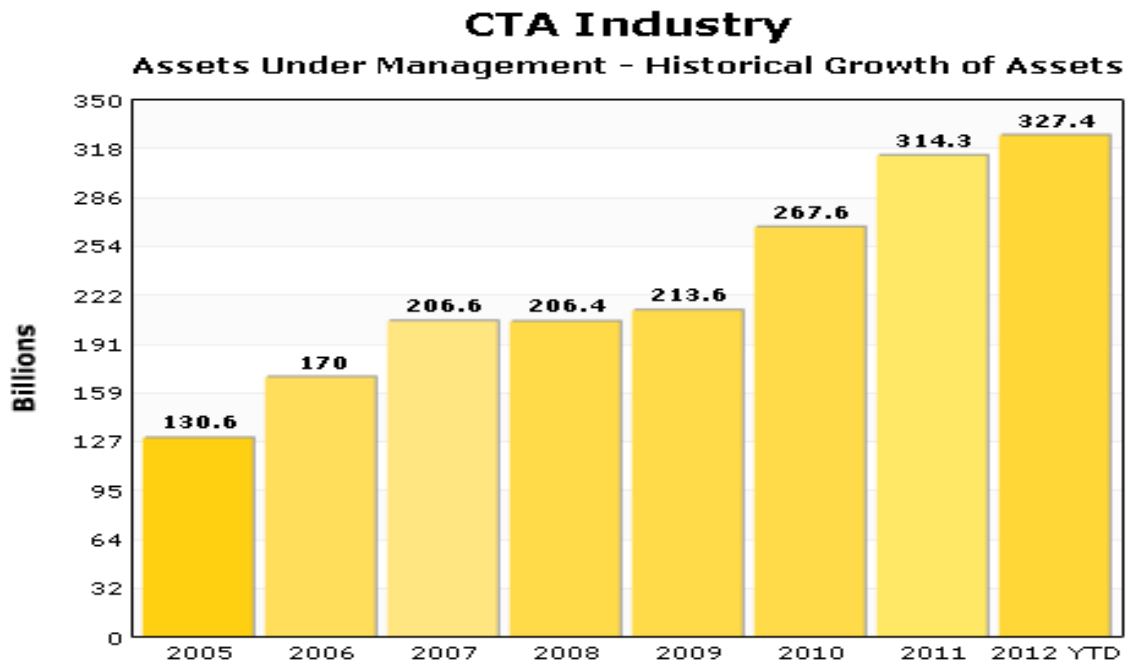
- Quantitative Trading (2009), by Ernest P. Chan:
  - How Will Transaction Costs Affect the Strategy? pp.22-23
  - Minimizing Transaction Costs, pp.87-88
- VWAP Strategies (2002), by Ananth Madhavan
  Only 7 pages!
- Execution Costs (2008), by Robert Almgren in the Encyclopedia of Quantitative Finance
  Only 5 pages!

Additional Readings

- Transactions costs and investment style, Keim and Madhavan (1997)
- Direct Estimation of Equity Market Impact, Almgren et al. (2005)
- Quantitative Trading, Ernest P. Chan (2009) “Transaction Costs”, pp. 60-65

Other Applications

- Volatility Harvesting
- Systematic Merger Arbitrage
- Index Rebalancing
- CTA:



Let’s Have Fun!