Adaptive Markets: Financial Evolution at the Speed of Thought

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National Bank of Belgium and 11 Universities
Finance Seminar
November 29, 2017
1. DELIVERY OF MANUSCRIPT

You agree to deliver the complete manuscript ready for copyediting, including a preface, other front matter, and back matter, together with camera-ready copy for all illustrations, maps, charts, drawings, or other material (except index) to be included in the Work, not later than April 15, 2008, or a later date designated in writing by the Press (the “Delivery Date”), time of delivery being of the essence. The final manuscript submitted to the Press will consist of no more than 80,000 words in length (including text, notes, and bibliography), 20 illustrations, and 10 color plates, and we reserve the right to reject the manuscript if the manuscript exceeds this limit.
In a fashion analogous to Theorem 6.5.1, the behavior of \( Q_t \) under a non-dependent and stationary Gaussian alternative may now be derived in several steps using Lemma 6.3.1, and Theorem 6.3.2.

**Theorem 6.3.3.** Let \( \{Z_t\} \) be a non-dependent stationary Gaussian stochastic process with autocovariance function \( \gamma \) such that

\[
\gamma = \begin{cases} 
\gamma(t), & \text{for } t \in [1, 1] \\
\gamma(t), & \text{for } t \in [0, 1]
\end{cases}
\]

where \( \gamma(t) \) is a slowly varying function at infinity. Then as \( n \to \infty \), we have:

(a) \[
\max_{t \in [0, 1]} \frac{n}{a} \sum_{i=1}^{n} (X_{t+i} - \bar{X}) \Rightarrow \max_{t \in [0, 1]} \mathbb{E}[W_t(t) + \sigma_t^2].
\]

(b) \[
\min_{t \in [0, 1]} \frac{n}{a} \sum_{i=1}^{n} (X_{t+i} - \bar{X}) \Rightarrow \min_{t \in [0, 1]} \mathbb{E}[W_t(t) + \sigma_t^2].
\]

(c) \[
\frac{1}{\sqrt{n}} \frac{1}{\sigma_t} \sum_{i=1}^{n} Q_{X_{t+i}} \Rightarrow \mathbb{E}[M_t - \gamma] = \mathbb{E}[0].
\]

(d) \[
\alpha_t = \frac{1}{\sqrt{n}} \frac{1}{\sigma_t} \sum_{i=1}^{n} Q_{X_{t+i}} \Rightarrow \begin{cases} 
\mathbb{E}[M_t - \gamma] & \text{for } t \in [1, 1] \\
0 & \text{for } t \in [0, 1]
\end{cases}
\]

(e) \[
\frac{1}{\sqrt{n}} \frac{1}{\sigma_t} \sum_{i=1}^{n} Q_{X_{t+i}} \Rightarrow \begin{cases} 
\mathbb{E}[M_t - \gamma] & \text{for } t \in [1, 1] \\
0 & \text{for } t \in [0, 1]
\end{cases}
\]

where \( \gamma(t) \) is defined in (6.3.6), \( \alpha_t \) is defined in Theorem 6.3.2, and \( W_t(t) = W_t(t) - t W_t(1) \).

Theorem 6.3.3 shows that the modified rescaled range test is consistent against a class of non-dependent stationary Gaussian alternatives. In the presence of positive strong dependence, the R/S statistic diverges in probability to infinity; in the presence of negative strong dependence, it converges in probability to zero. In either case, it is consistent with both null hypotheses. For all stationary Gaussian stochastic processes satisfying (6.3.6), a broad set of alternatives that includes all fractionally-different Gaussian ARMA(p, d, q) models with \( d \leq 1 \).

From (a) and (b) of Theorem 6.3.3 it is apparent that the normalized population rescaled R/S and \( Q_{X_{t+i}} \) converges to zero in probability. Therefore,
Markets are efficient

People behave irrationally
Personal Journey

- Efficient Markets
  Rational Expectations
- Behavioral Finance
  Psychology
- Artificial Intelligence
  Bounded Rationality
- Cognitive Neurosciences
- Evolutionary Biology
  Ecology
- Adaptive Markets
  Hypothesis
Summary

- Traditional investment framework is flawed
- Not wrong, but incomplete (physics envy)
- Stable environment $\Rightarrow$ stable investment policies (EMH)
- Dynamic environment $\Rightarrow$ dynamic investment policies (AMH)
- The current environment is highly dynamic
- We must adapt to changing market conditions
- “it’s the economy, stupid”
- The Adaptive Markets Hypothesis provides a framework for investing, risk management, financial regulation, and more
The Traditional Investment Paradigm

In the beginning...

\[ R_{it} = \alpha_i + \beta_i F_t + \epsilon_{it} \]

Implications:
- Correlation matters; diversification
- Benchmarks, performance attribution
- Passive investing
- Indexation, hedging, portable alpha
- Risk budgeting
- Framework for fiduciary duties
The Traditional Investment Paradigm

But This Framework Requires Several Key Assumptions:

- Relationship is linear
- Relationship is static across time and circumstances
- Parameters can be accurately estimated
- Investors behave rationally
- Markets are stationary (static probability laws)
- Markets are efficient

What If Some of These Assumptions Don’t Hold?
The Traditional Investment Paradigm

Cumulative Return of S&P 500 (log scale)
January 1926 to December 2015

But Do They Still Hold Today??

Assumptions Used To Hold

Source: CRSP and author’s calculations.
The Traditional Investment Paradigm

Nikkei 225 (log scale)
May 16, 1950 to May 13, 2016
Have Alternatives Become Irrelevant?

Hedge funds
Going nowhere fast

Hedge funds have had another lousy year, to cap a disappointing decade
Dec 22nd 2012 | From the print edition

'An industry in crisis': Hedge funds bleed $100 billion in 2016

Jeff Cox | @JeffCoxCNBCcom
Friday, 13 Jan 2017 | 2:02 PM ET
Have Alternatives Become Irrelevant?

A YEAR ago hedge-fund managers were hailed as smarter than lawyers, with a 20% annualized return, despite being in a bear market. Hedge funds have struggled to do well recently, and some have even returned negative returns. A number of hedge fund managers have been accused of mismanagement and fraud.

A hedge fund is a private investment fund that raises money from investors and uses this money to trade in financial markets. Hedge funds are usually structured as limited partnerships, with the managers being general partners and the investors being limited partners. They are usually managed by a single manager or a group of managers and are typically open to a limited number of investors.

Hedge funds are often seen as a way for investors to generate high returns through the use of leverage, derivatives, and other strategies. However, the performance of hedge funds can be highly volatile, and investors in these funds can lose significant amounts of money if the manager is unable to generate positive returns.

There are several different types of hedge funds, including event-driven, distressed, relative value, and quantitative. Event-driven funds focus on taking advantage of specific events, such as mergers and acquisitions, while distressed funds invest in companies that are in financial trouble. Relative value funds seek to generate capital gains by exploiting relative pricing discrepancies, and quantitative funds use computer programs to identify opportunities in the market.

Hedge funds are typically designed for high net-worth individuals and institutional investors, and they are usually not available to the general public. They are typically managed by a single manager or a group of managers and are typically open to a limited number of investors.

Hedge funds are often used by institutional investors, such as pension funds and endowments, as a way to invest in a diversified mix of assets. They can also be used by high net-worth individuals as a way to generate capital gains and keep pace with inflation.

Despite their potential for high returns, hedge funds are often criticized for their high fees and poor performance. They are also subject to frequent changes in management, which can make it difficult for investors to determine the true performance of a fund.

In recent years, the popularity of hedge funds has declined, as investors have become more aware of the risks associated with investing in these funds. As a result, some investors are turning to other types of investments, such as mutual funds and exchange-traded funds, as a way to generate returns and diversify their portfolios.
“News of my death is greatly exaggerated...”

Source: www.barclayhedge.com
## Pre- and Post-Crisis Hedge Fund Performance

<table>
<thead>
<tr>
<th>Category</th>
<th># Fund-Months</th>
<th>Ann. Mean (%)</th>
<th>Ann. SD (%)</th>
<th>Sharpe Ratio</th>
<th>Sortino Ratio</th>
<th>Skew.</th>
<th>Kurt.</th>
<th>MaxDD (%)</th>
<th>Corr. to S&amp;P 500 (%)</th>
<th>$\rho_2$ (%)</th>
<th>Box-Q(3) p-value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convertible Arbitrage</td>
<td>7,827</td>
<td>8.1</td>
<td>4.3</td>
<td>0.95</td>
<td>1.53</td>
<td>-1.25</td>
<td>8.63</td>
<td>-8.70</td>
<td>42.9</td>
<td>45.9</td>
<td>0.0</td>
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<tr>
<td>Dedicated Short Bias</td>
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<td>0.59</td>
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<td>-1.61</td>
<td>10.51</td>
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<td>1.82</td>
<td>2.05</td>
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<td>-2.21</td>
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<tr>
<td>Event Driven</td>
<td>18,565</td>
<td>9.4</td>
<td>5.2</td>
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<td>1.55</td>
<td>-2.02</td>
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<td>0.46</td>
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<tr>
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<td>16.7</td>
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<td>0.0</td>
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<td><strong>All Single Manager Funds</strong></td>
<td><strong>163,702</strong></td>
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<td><strong>0.72</strong></td>
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<td><strong>-0.26</strong></td>
<td><strong>5.46</strong></td>
<td><strong>-10.95</strong></td>
<td><strong>65.2</strong></td>
<td><strong>19.2</strong></td>
<td><strong>13.1</strong></td>
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</table>

### January 2010 to December 2014

<table>
<thead>
<tr>
<th>Category</th>
<th># Fund-Months</th>
<th>Ann. Mean (%)</th>
<th>Ann. SD (%)</th>
<th>Sharpe Ratio</th>
<th>Sortino Ratio</th>
<th>Skew.</th>
<th>Kurt.</th>
<th>MaxDD (%)</th>
<th>Corr. to S&amp;P 500 (%)</th>
<th>$\rho_2$ (%)</th>
<th>Box-Q(3) p-value (%)</th>
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<tbody>
<tr>
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<td>63.6</td>
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<tr>
<td>Dedicated Short Bias</td>
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<tr>
<td>Emerging Markets</td>
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<td>8.5</td>
<td>0.00</td>
<td>0.06</td>
<td>-0.67</td>
<td>3.84</td>
<td>-16.10</td>
<td>38.4</td>
<td>7.9</td>
<td>41.9</td>
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<tr>
<td>Equity Market Neutral</td>
<td>8,930</td>
<td>3.9</td>
<td>2.4</td>
<td>1.59</td>
<td>2.97</td>
<td>-0.69</td>
<td>4.00</td>
<td>-13.35</td>
<td>81.6</td>
<td>22.4</td>
<td>25.1</td>
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<tr>
<td>Event Driven</td>
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<td>77.4</td>
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<td>20.2</td>
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<td>Fixed Income Arbitrage</td>
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<td>-1.03</td>
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<tr>
<td>Global Macro</td>
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<td>1.46</td>
<td>3.29</td>
<td>0.12</td>
<td>3.54</td>
<td>-2.03</td>
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<td>9.7</td>
<td>68.7</td>
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<tr>
<td>Long/Short Equity Hedge</td>
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<tr>
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<td>-14.48</td>
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<td>-12.4</td>
<td>78.4</td>
</tr>
<tr>
<td>Multi-Strategy</td>
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<td>2.5</td>
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<td>4.06</td>
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<td>-3.20</td>
<td>80.9</td>
<td>16.3</td>
<td>23.2</td>
</tr>
<tr>
<td>Fund of Funds</td>
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<td>3.5</td>
<td>0.46</td>
<td>0.78</td>
<td>-0.55</td>
<td>2.73</td>
<td>-7.42</td>
<td>72.3</td>
<td>13.6</td>
<td>59.1</td>
</tr>
<tr>
<td><strong>All Single Manager Funds</strong></td>
<td><strong>233,194</strong></td>
<td><strong>4.2</strong></td>
<td><strong>4.2</strong></td>
<td><strong>1.00</strong></td>
<td><strong>1.84</strong></td>
<td><strong>-0.39</strong></td>
<td><strong>3.63</strong></td>
<td><strong>-6.36</strong></td>
<td><strong>85.3</strong></td>
<td><strong>11.7</strong></td>
<td><strong>46.8</strong></td>
</tr>
</tbody>
</table>

Source: Getmansky, Lee, Lo (2015, Table 14)
Hedge-Fund Strategy Life Cycle

Unique → Novel → Popular → Common
The Adaptive Markets Hypothesis

“Nothing makes sense in biology except in the light of evolution,” Dobzhansky (1973)


1. Individuals act in their own self-interest
2. Individuals make mistakes ("satisfice")
3. Individuals learn and adapt (heuristics)
4. Competition drives adaptation and innovation
5. Evolution determines market dynamics
What Do Investors Want?
Risk Perception and Adaptive Behavior

The Effects of Automobile Safety Regulation

Sam Peltzman
University of Chicago

Technological studies imply that annual highway deaths would be 20 percent greater without legally mandated installation of various safety devices on automobiles. However, this literature ignores offsetting effects of nonregulatory demand for safety and driver response to the devices. This article indicates that these offsets are virtually complete, so that regulation has not decreased highway deaths. Time-series (but not cross-section) data imply some saving of auto occupants’ lives at the expense of more pedestrian deaths and more nonfatal accidents, a pattern consistent with optimal driver response to regulation.

Automobile Safety Regulation and the Incentive to Drive Recklessly: Evidence from NASCAR

Russell S. Sobel* and Todd M. Nesbit†

When safety regulation makes automobiles safer, drivers may drive more recklessly, partially or completely offsetting effects on the overall level of safety. Evidence of these offsetting effects has been hard to find, however, primarily because of the aggregate nature of accident data. In this paper we explore how changes in the safety of automobiles used in the National Association for Stock Car Auto Racing (NASCAR) has altered the incentive of drivers to drive recklessly. This unique data set allows more accurate and objective measurement of the necessary variables to test for these effects at a microlevel. Our results strongly support the presence of these offsetting behavioral effects.

Implications for the Current Ecosystem
A New Investment Paradigm Is Emerging

<table>
<thead>
<tr>
<th>Efficient Markets</th>
<th>Adaptive Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Long-only constraint</td>
<td>▪ Long/short strategies</td>
</tr>
<tr>
<td>▪ Diversify across stocks and bonds</td>
<td>▪ Diversify across more asset classes and strategies</td>
</tr>
<tr>
<td>▪ Market-cap-weighted indexes</td>
<td>▪ Passive transparent indexes</td>
</tr>
<tr>
<td>▪ Manage risk via asset allocation</td>
<td>▪ Manage risk via active volatility scaling algorithms</td>
</tr>
<tr>
<td>▪ Alpha vs. market beta</td>
<td>▪ Alphas $\Rightarrow$ multiple betas</td>
</tr>
<tr>
<td>▪ Markets are efficient</td>
<td>▪ Markets are adaptive</td>
</tr>
<tr>
<td>▪ Equities in the long run</td>
<td>▪ “In the long run we’re all dead,” but make sure the short run doesn’t kill you first</td>
</tr>
</tbody>
</table>
A New Investment Paradigm Is Emerging

**Efficient Markets**
- Long-only constraint
- Diversify across stocks and bonds
- Market-cap-weighted indexes
- Manage risk via asset allocation
- Alpha vs. market beta
- Markets are efficient
- Equities in the long run

**Adaptive Markets**
- Long/short strategies
- Diversify across more asset classes and strategies
- Passive transparent indexes
- Manage risk via active volatility scaling algorithms
- Alphas $\Rightarrow$ multiple betas
- Markets are adaptive
- “In the long run we’re all dead,” but make sure the short run doesn’t kill you first
What Is An Index??

- Market-cap-weighted portfolio?

Jack Bogle (1997) on the Origins of the Vanguard Index Trust:

The basic ideas go back a few years earlier. In 1969–1971, Wells Fargo Bank had worked from academic models to develop the principles and techniques leading to index investing. John A. McQuown and William L. Fouse pioneered the effort, which led to the construction of a $6 million index account for the pension fund of Samsonite Corporation. With a strategy based on an equal-weighted index of New York Stock Exchange equities, its execution was described as “a nightmare”. The strategy was abandoned in 1976, replaced with a market-weighted strategy using the Standard & Poor's 500 Composite Stock Price Index. The first such models were accounts run by Wells Fargo for its own pension fund and for Illinois Bell.
What Is An Index??

- Market-cap weighting requires little trading
- “Buy-and-hold” portfolio
- What if trading were cheaper, faster, and automatable?

**Index**

An index is any portfolio strategy satisfying three properties: (1) it is completely transparent; (2) it is investable; and (3) it is totally systematic.
What Is An Index??

Value-weighted average?  Yes
Equal-weighted average?  Yes
Target-date fund?  Yes
FHFA House Price Index?  Yes
Hedge Fund Index?  Yes
Trend-following futures?  Yes
Risk-managed large-cap core?  Yes
What Is An Index??
What Is An Index??

- Active
- Passive

- Alpha
- Risk Control

- Hedge Fund
- Index Fund
The Opportunity: Precision Indexes

- Instead of the DowJones30®, FTSE100®, or S&P500®, imagine investing in the:
  - RichardZeckhauser30®, ArnieWood100®, or LarrySummers500®

- Imagine if such portfolios took into account income, expenses, age, health, taxes, and behavior

- Imagine if such portfolios were automated

- We have the hardware and software; we need the algorithms
“Artificial intelligence and active management are not at odds with indexation, but instead imply a more sophisticated set of indexes and portfolio management policies for the typical investor, something each of us can look forward to, perhaps within the next decade.”

– Andrew W. Lo, *Journal of Indexes* Q2, 2001
So What’s Missing?

…Not Artificial Intelligence

Artificial Humanity

- We need an algorithm for investor behavior so we can counterbalance our least productive actions (e.g., loss aversion, overconfidence, overreaction, etc.)
Artificial vs. Natural Intelligence

- Expert systems vs. machine-learning techniques
- Expensive storage → small data, complex code
- Cheap storage → big data, simple code
- This is closer to natural intelligence! Narrative vs. facts
Friend or Foe?
Friend or Foe?

- Gender and sex orientation (4)
- Race/ethnicity (4)
- Age (4)
- Current home state (50)
- Religious affiliation (4)
- Political party (3)
- Economic status (3)
- Education (3)

345,600 Possible Types!

But Beware of Learning With Sparse Data
Evolution at the Speed of Thought

Aron Lee Ralston, 4/26/03
A blond three-year-old boy in a red polo shirt comes running across a sunlit hardwood floor in what I somehow know is my future home. By the same intuitive perception, I know the boy is my own. I bend to scoop him into my left arm, using my handless right arm to balance him, and we laugh together as I swing him up to my shoulder... Then, with a shock, the vision blinks out. I'm back in the canyon, echoes of his joyful sounds resonating in my mind, creating a subconscious reassurance that somehow I will survive this entrapment. Despite having already come to accept that I will die where I stand before help arrives, now I believe I will live.

That belief, that boy, changes everything for me.

– Aron Lee Ralston (2005)
Evolution at the Speed of Thought

We Need New Narratives In Finance!
Conclusion

“It Takes A Theory To Beat A Theory”

- Standard paradigm is not wrong, just incomplete
- Human behavior has been stable for 60,000 years
- Our environment has changed rapidly
- The mismatch can create challenges
- Evolution determines dynamics
- Competition, selection, innovation

How Adaptive Are You?
Thank You!

For more on Adaptive Markets:

- [http://alo.mit.edu](http://alo.mit.edu) (website)
- [@AndrewWLo](https://twitter.com/AndrewWLo) (Twitter)
Additional References

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