

# Overfitting and pseudo-analysis

Quantitative Strategies  
Global Markets Research  
EMEA

Tony Morris

8<sup>th</sup> May 2014

See Appendix A-1 for analyst certification, important disclosures, and the status of non-U.S. analysts

# Bailey et al. accuse finance quants of charlatanism

A recent paper argues that many quant strategies are false and a result of data-snooping

## Pseudo-Mathematics and Financial Charlatanism: The Effects of Backtest Overfitting on Out-of-Sample Performance

David H. Bailey, Jonathan M. Borwein, Marcos López de Prado, and Qiji Jim Zhu

Another thing I must point out is that you cannot prove a vague theory wrong. [...] Also, if the process of computing the consequences is indefinite, then with a little skill any experimental result can be made to look like the expected consequences.

—Richard Feynman [1964]

### Introduction

A *backtest* is a historical simulation of an algorithmic investment strategy. Among other things, it computes the series of profits and losses that such strategy would have generated had that algorithm been run over that time period. Popular performance statistics, such as the *Sharpe ratio* or the *Information ratio*, are used to quantify the backtested strategy's return on risk. Investors typically study those backtest statistics and then allocate capital to the best performing scheme.

Regarding the measured performance of a backtested strategy, we have to distinguish between two very different readings: *in-sample* (IS) and *out-of-sample* (OOS). The IS performance is the one simulated over the sample used in the design of the strategy (also known as "learning period" or

"training set" in the machine-learning literature). The OOS performance is simulated over a sample not used in the design of the strategy (a.k.a. "testing set"). A backtest is *realistic* when the IS performance is consistent with the OOS performance.

When an investor receives a promising backtest from a researcher or portfolio manager, one of her key problems is to assess how realistic that simulation is. This is because, given any financial series, it is relatively simple to *overfit* an investment strategy so that it performs well IS.

Overfitting is a concept borrowed from machine learning and denotes the situation when a model targets particular observations rather than a general structure. For example, a researcher could design a trading system based on some parameters that target the removal of specific recommendations that she knows led to losses IS (a practice known as "data snooping"). After a few iterations, the researcher will come up with "optimal parameters", which profit from features that are present in that particular sample but may well be rare in the population.

Recent computational advances allow invest-

SMART MONEY

April 16, 2014 9:28 am

### When use of pseudo-maths adds up to fraud

By Stephen Foley

Many models tweak strategy to fit data or are just statistical flukes

An academic journal called the Notices of the American Mathematical Society may seem an unlikely periodical to have exposed fraud on a massive scale. The investigation, published in the current edition, is certainly not going to sit among the nominees for next year's Pulitzer prizes. But a quartet of mathematicians have just published a piercing article in the public interest and in the nick of time.

In their paper, entitled *Pseudo-Mathematics and Financial Charlatanism*, they make the case that the vast majority of claims being made for quantitative investment strategies are false.\*



By calling it fraud, the academics command attention, and investors would be wise to beware. With interest rates about to turn, and a stock market bull run ageing fast, there have never been such temptations to eschew traditional bond and equity investing and to follow the siren sales patter of those who claim to see patterns in the historical data.

The (unnamed) targets of the mathematicians' ire range from individual technical analysts who identify buy and sell signals in a stock chart, all the way up to managed futures funds holding billions of dollars of clients assets.

There will be many offenders, too, among investment

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*Pseudo-Mathematics and Financial Charlatanism: The Effects of Backtest Overfitting on Out-of-Sample Performance*, AMS, Bailey et al



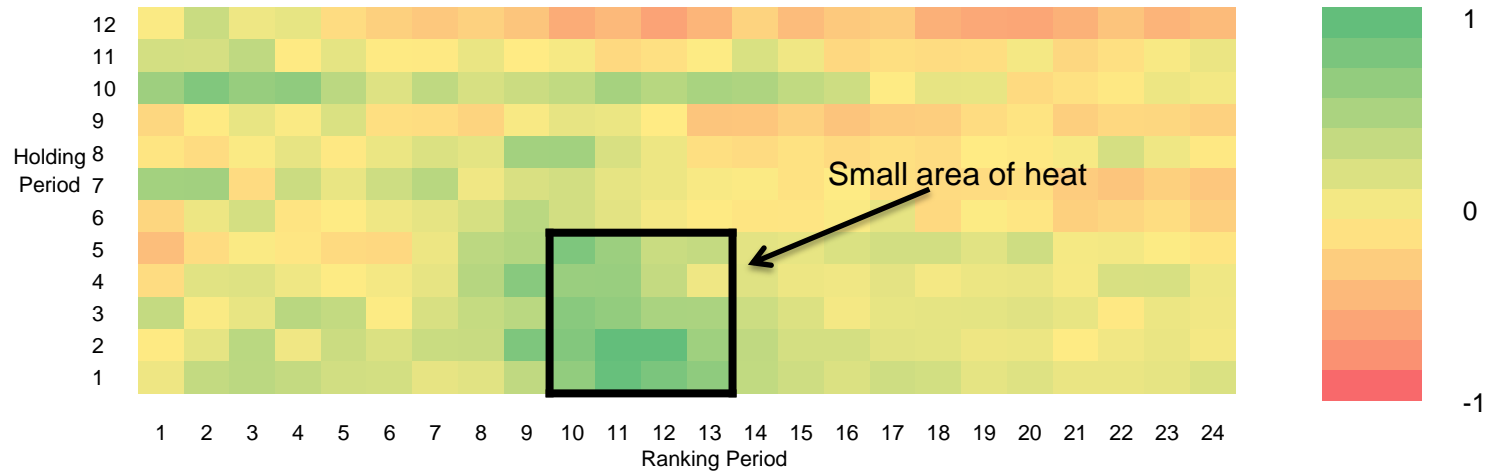
## Two answers, two questions

- Yes, they have a point.
- But this is an older and bigger problem than they seem to realise.
- Would you be able to tell if you were doing “pseudo-analysis”?
  - If yes, how much would you care?
- What should we do about this?

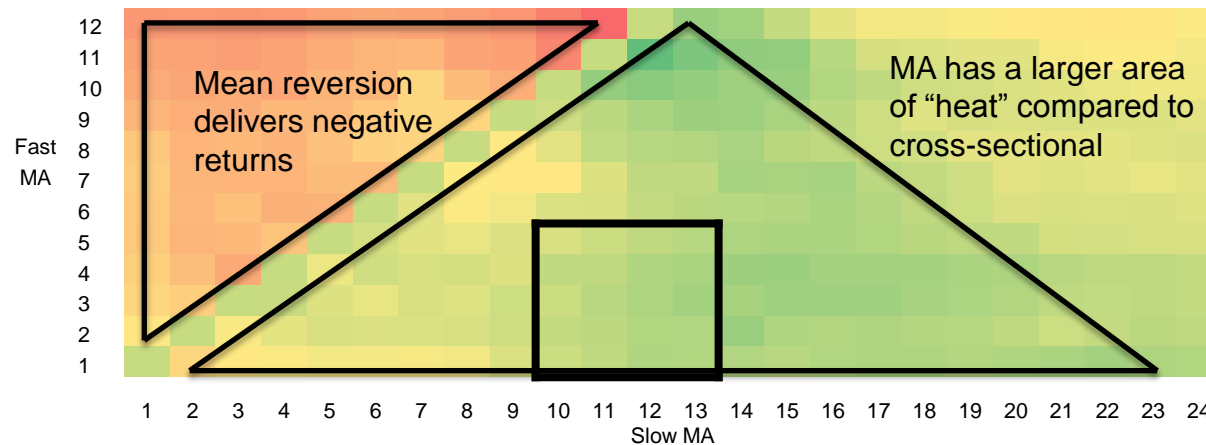
**Yes, they have a point**

# Parameter optimisation can lead to fragile strategies

## Parameter choice is important for cross sectional momentum



## Moving average (MA) momentum looks more robust

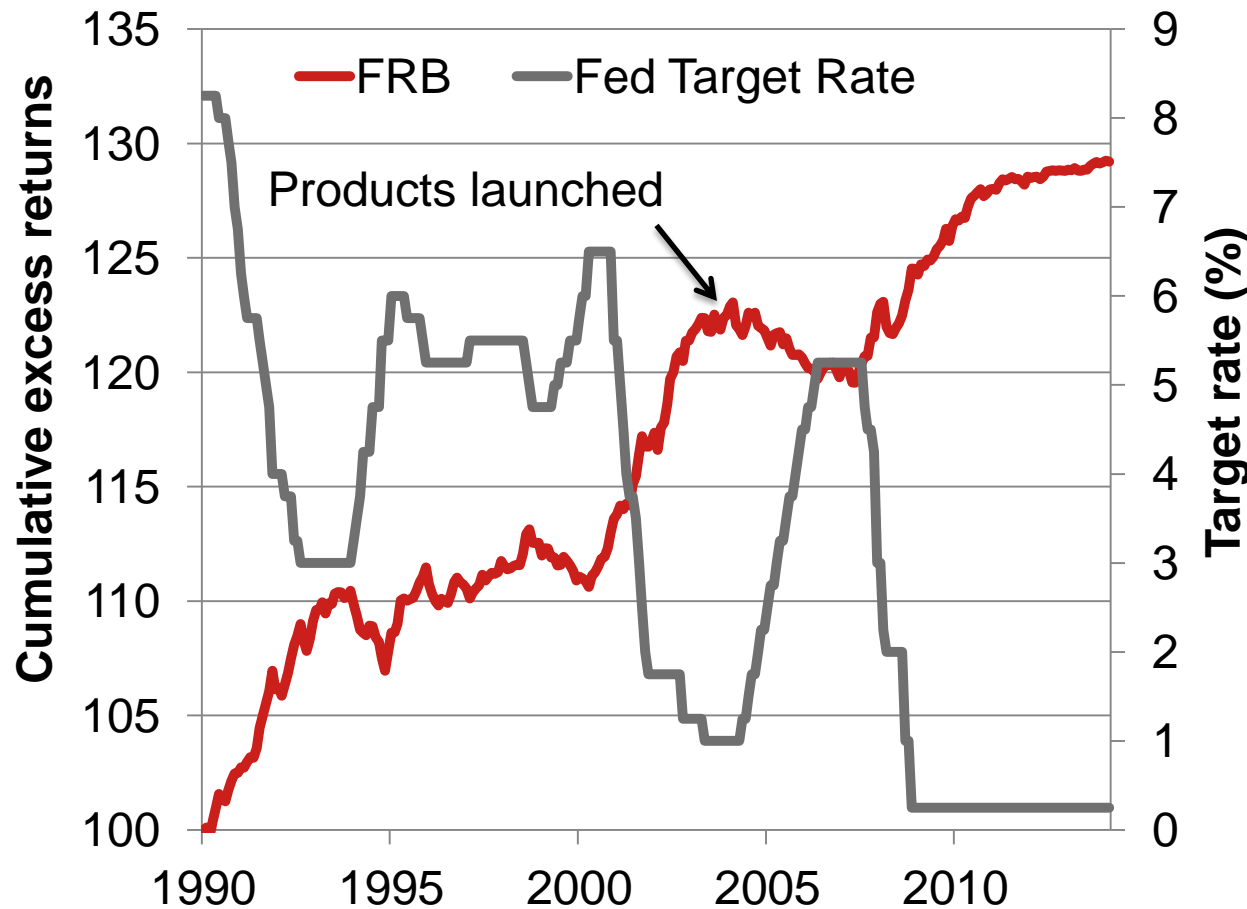


# Forward Rate Bias

FRB strategies (including 50x leveraged and managed versions) were introduced to much fanfare in 2003/4

FRB did not perform well after launch and the outlook is bleak

Problems?



- Backtest inappropriate
- Long-only has limits
- Alpha capability of manager has limits

**An old and big problem**

## It's not just finance, it's business and academia in general

- Pharmaceuticals - Only a quarter of 67 seminal studies could be reproduced.
- Medicine – Paper which uncovered genetic variants associated with longevity retracted after technical errors admitted.
- Psychology – 9 separate experiments have not managed to reproduce the results of a 1998 study which showed that thinking about a professor prior to an intelligence test leads to higher scores than imagining a football hooligan.
- Academia – “Why Most Published Research Findings Are False” Ioannidis (2005).

*Open access, freely available online*

### Essay

## Why Most Published Research Findings Are False

John P. A. Ioannidis

### Summary

There is increasing concern that most current published research findings are false. The probability that a research claim is true may depend on study power and bias, the number of other studies on the

factors that influence this problem and some corollaries thereof.

### Modeling the Framework for False Positive Findings

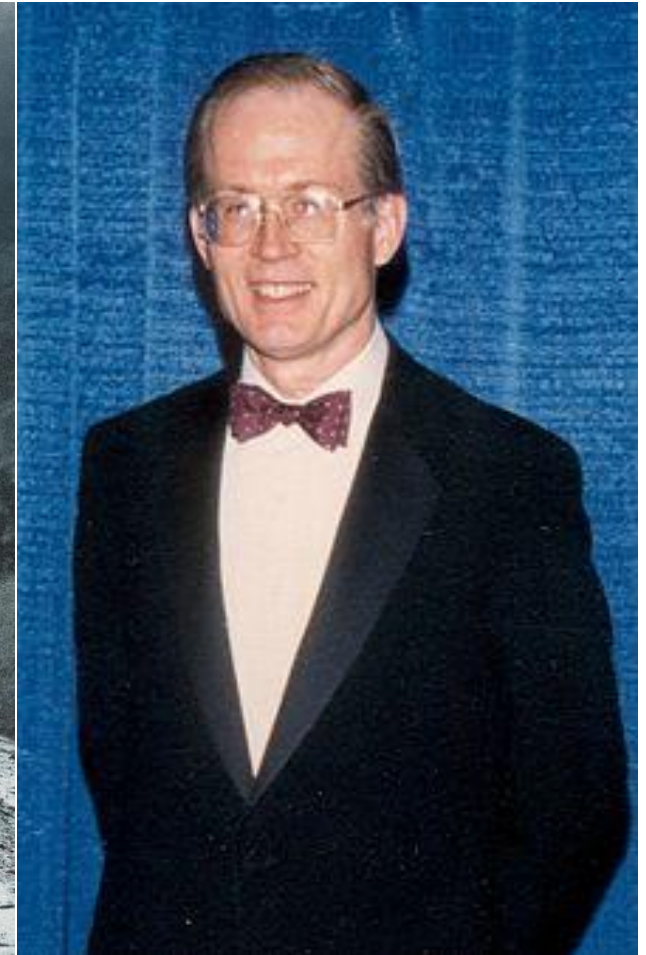
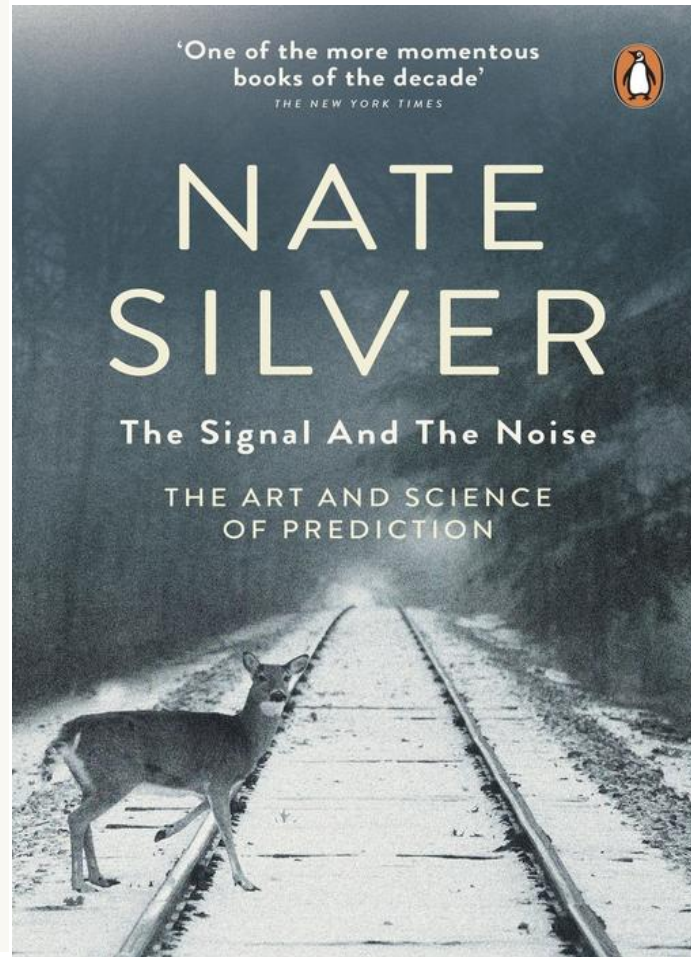
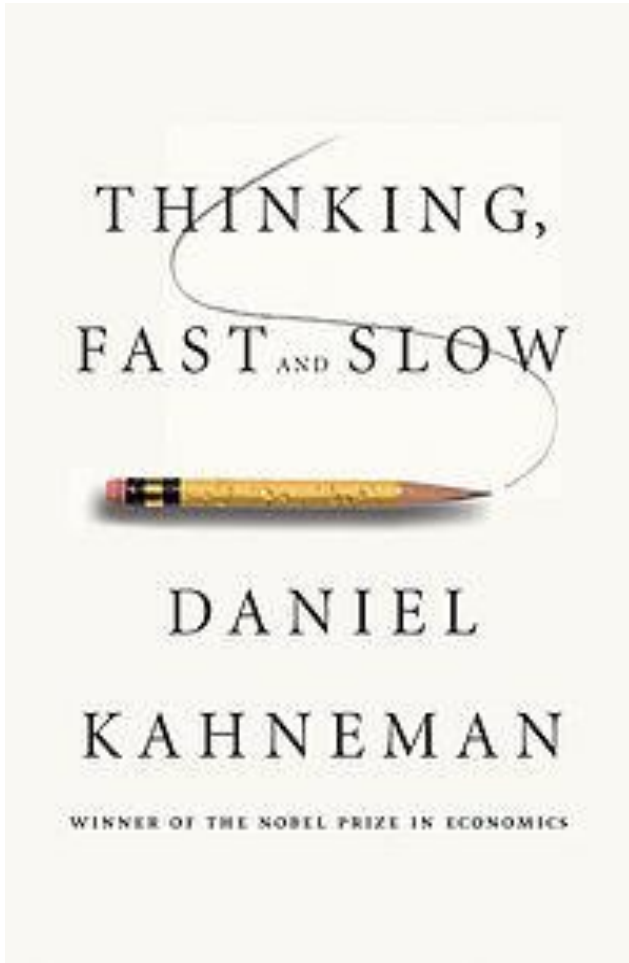
Several methodologists have pointed out [9–11] that the high

is characteristic of the field and can vary a lot depending on whether the field targets highly likely relationships or searches for only one or a few true relationships among thousands and millions of hypotheses that may be postulated. Let us also consider,

field. In this framework, a research finding is less likely to be true when the studies conducted in a field are smaller; when effect sizes are smaller; when there is a greater number and lesser preselection of tested relationships; where there is greater flexibility in designs, definitions, outcomes, and analytical modes; when there is greater financial and other interest and prejudice; and when more teams are involved in a scientific field in chase of statistical significance.



Who else has looked at overfitting?



### Adding sample length and simplifying models won't solve everything

- Kahneman:
  - When confronted by data that threaten a view we need to be true, we:
    - Turn our brains off, embrace “the illusion of validity and skill”
    - Embrace the “law of small numbers” and “the halo effect”
    - Surround ourselves with like-minded believers (attend a quant conference?)
    - Embrace certainty and avoid doubt.
- Black:
  - Expected returns are unknowable, historical estimates are noisy
  - Volatilities change over time
  - No conventional econometric model can distinguish between my beliefs and theirs
  - Beware “rules of thumb”

## Commonly held long-only return assumptions

Asset class	Assumed return (10-15 year horizon)	Risk premia over cash**
Equities	Inflation* + 525bp	725bp
Duration	Inflation* + 200bp	400bp
Credit	Inflation* + 275bp	475bp
Commodities	Inflation* + 150bp	350bp
FX	Not considered to be an asset class	?

\* Inflation assumed to be 225bp

\*\* Cash assumed to be 25bp

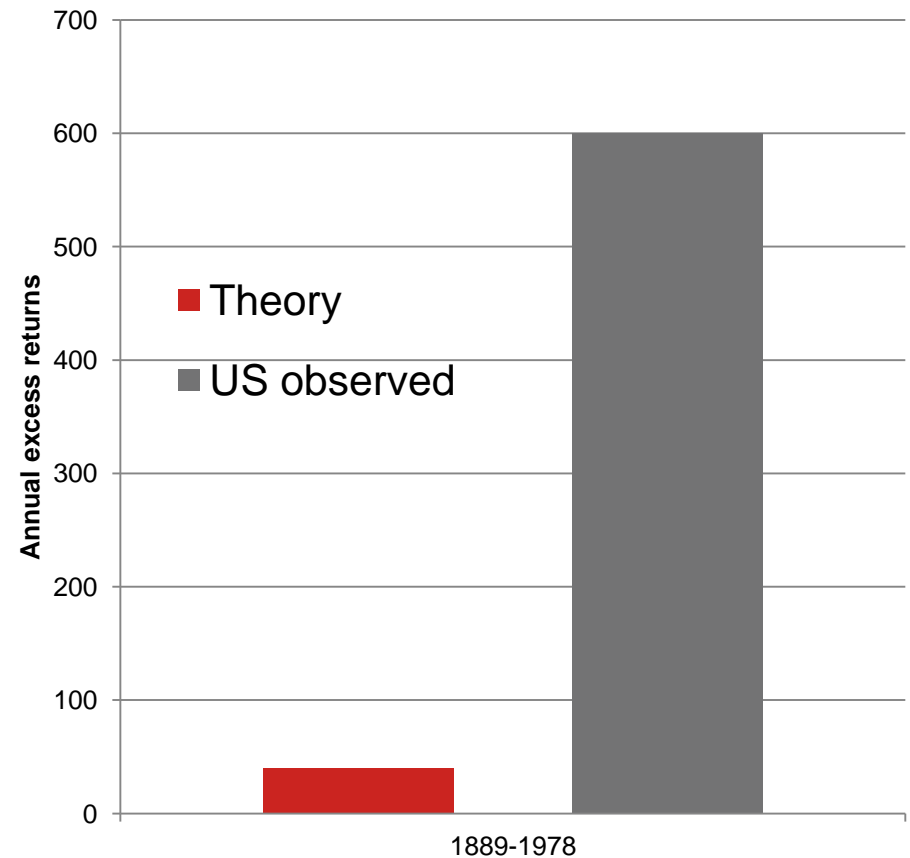
# A theoretical problem—the equity risk premium puzzle

Mehra – Prescott showed standard models could justify only 40bps

## Theory suggests a lower return for equities

In addition, the economies are constructed to display equilibrium consumption growth rates with the same mean, variance and serial correlation as those observed for the U.S. economy in the 1889–1978 period. We find that for such economies, the average real annual yield on equity is a maximum of four-tenths of a percent higher than that on short-term debt, in sharp contrast to the six percent premium observed. Our results are robust to non-stationarities in the means and variances of the economies' growth processes.

## Historical US equity returns exceed the theoretical value



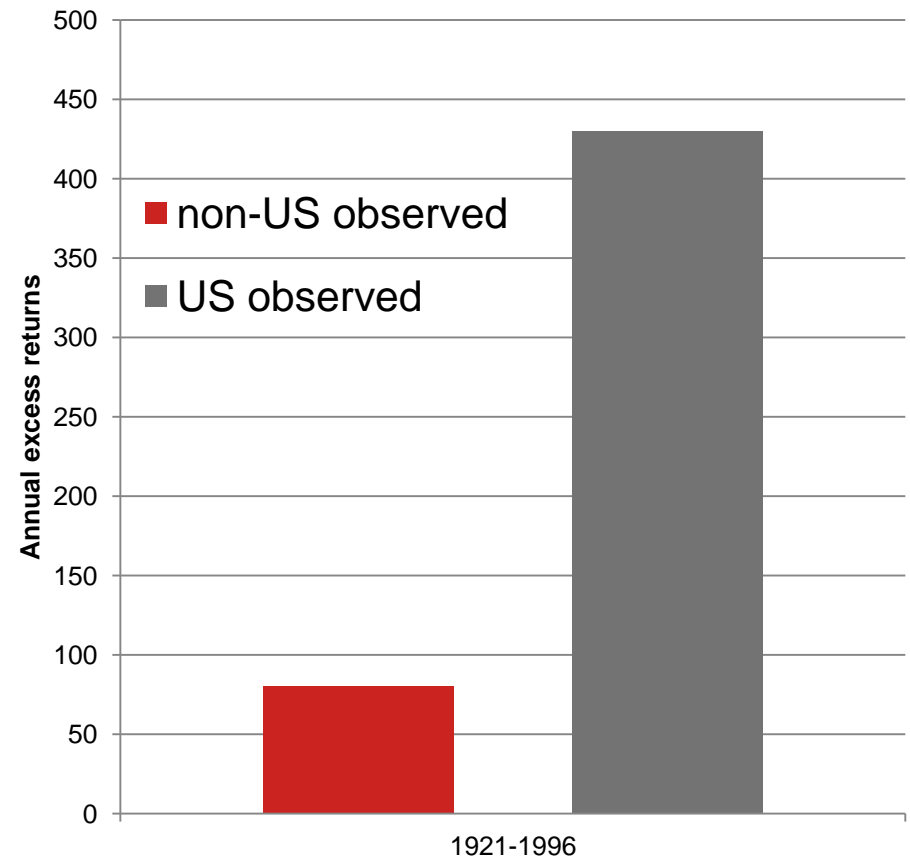
# An empirical problem—survivorship bias

## Is the American past the world future? Non-US history shows an equity risk premium around 80bps

### Global market excess returns are much closer to the theory

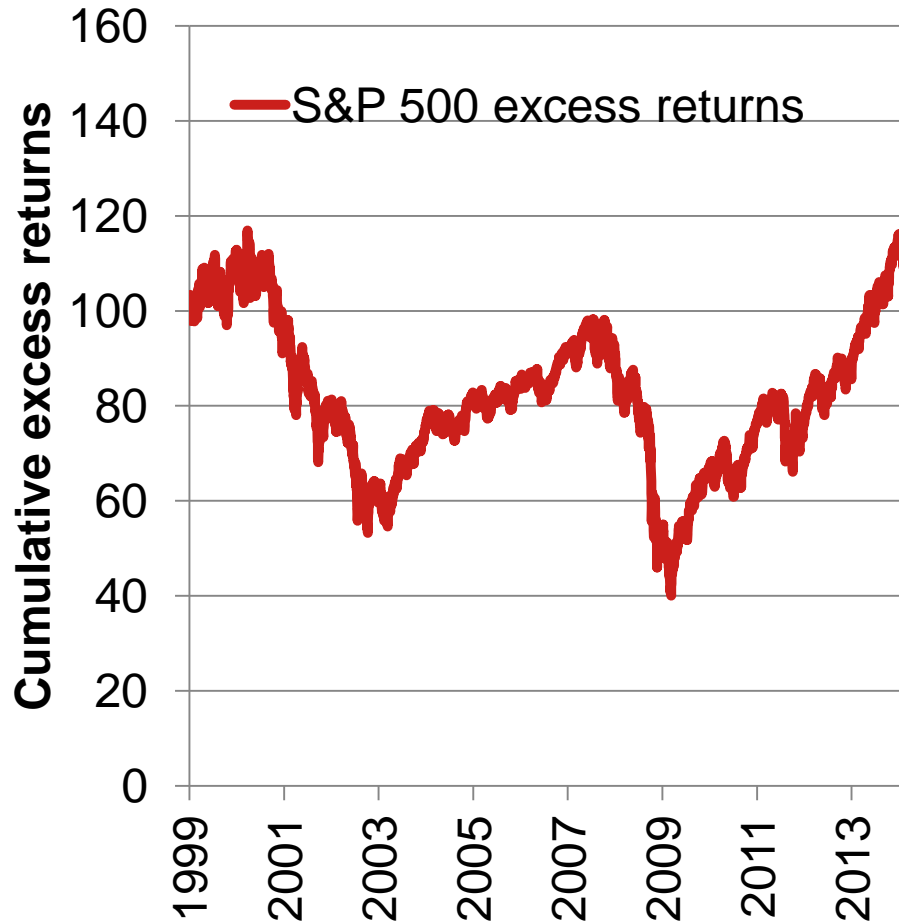
Long-term estimates of expected return on equities are typically derived from U.S. data only. There are reasons to suspect, however, that these estimates are subject to survivorship, as the United States is arguably the most successful capitalist system in the world. We collect a database of capital appreciation indexes for 39 markets going back into the 1920s. Over 1921 to 1996, U.S. equities had the highest real return of all countries, at 4.3 percent, versus a median of 0.8 percent for other countries. The high equity premium obtained for U.S. equities therefore appears to be the exception rather than the rule.

### The US experience appears to be an anomaly

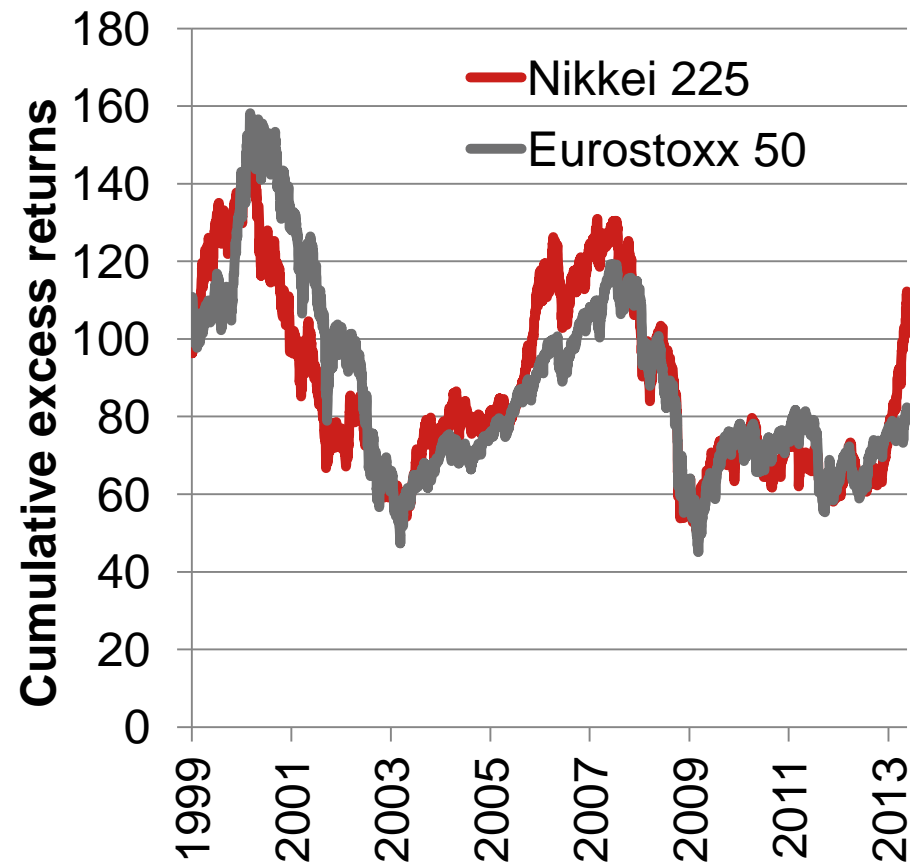


# The last 15 years looks like the theory in America...

Even recent US experience has not lived up to expectations

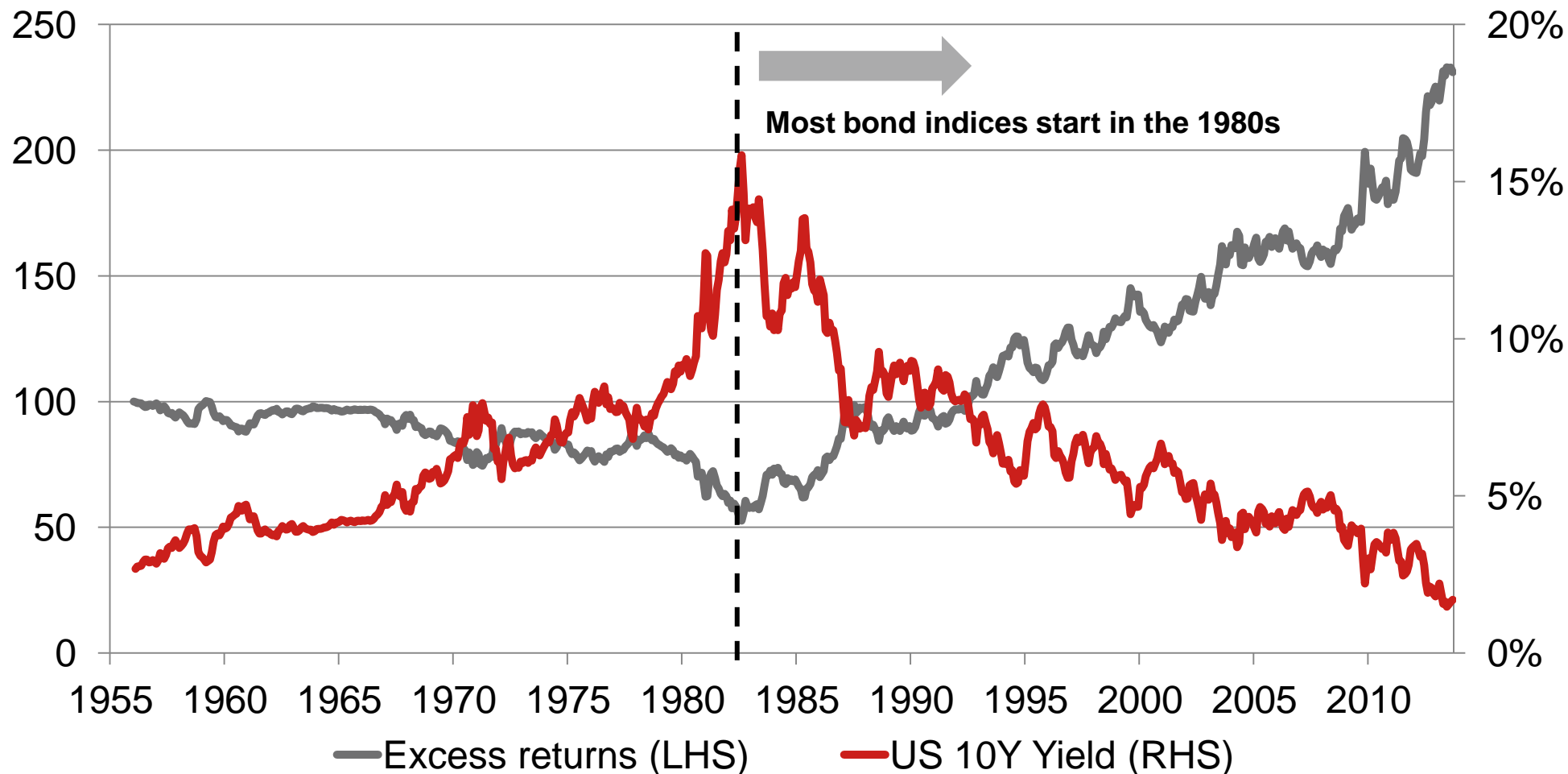


... and in Europe and Japan.



# Fixed Income risk premia look just as fragile

What are expected returns, conditional on low yields at the beginning?



**Are you doing “pseudo-analysis”? Should you care?**



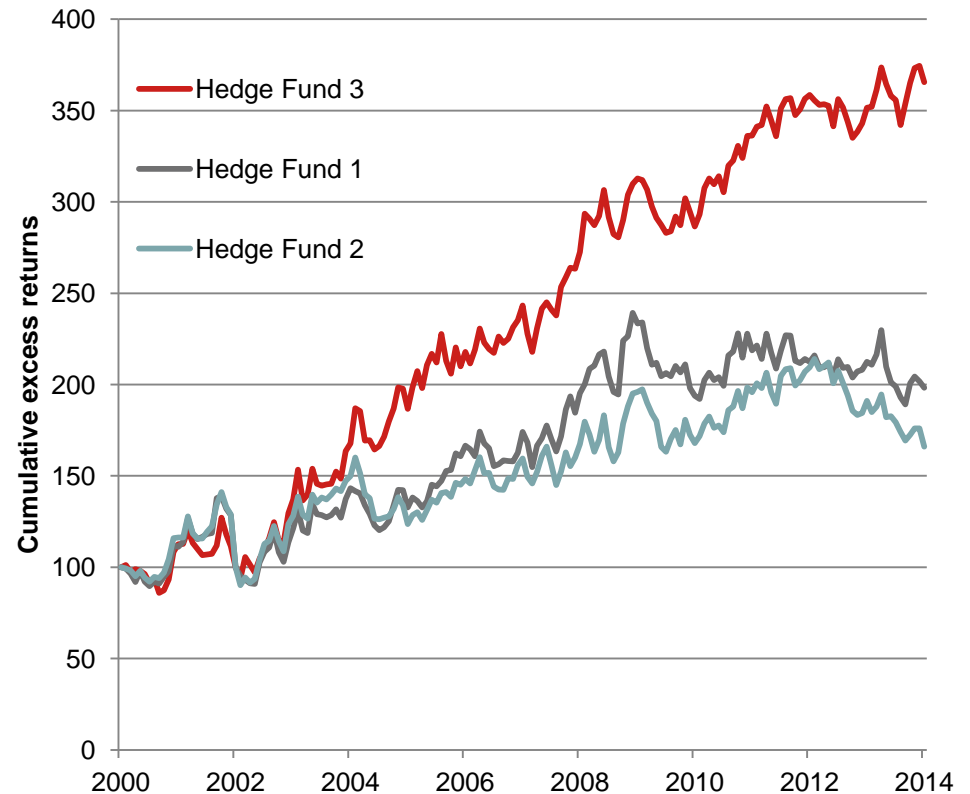
# How do you decide what you know?

Why does this problem exist? Why will it be difficult to solve?

## Reasons

- Structurers/promoters being devious
- Investors who only insist on track records
- Retail will only buy when expensive
- Distributors want simple stories
- Even managers who succeed in one climate may not in another
- The industry may be axed for a given type of strategy, e.g. operations can only handle long-only
- Boards have limited imaginations
- The belief that past is prologue.

## Funds which were the toast of the town can underperform



**What are we going to do about it?**

## Make it fit like a mitten, not like a glove

- Don't optimize for Sharpe, avoid monkey rules
- Use as much time-series and cross-sectional data as possible, but...



VS.



# The data will never be enough

## Theory *before* 1973

- CAPM derived in one-period context
- Static framework
- Volatility and risk premia taken as given, constant
- Even if risk premia change over time, such changes are not predictable
- Random walk assumed

## Theory *after* 1973

- Single period to multi-period
- Static to dynamic
- Endogenous risk premia and volatility
- **Risk premia are time-varying** and predictable
- **Random walk not necessary** for efficient markets, even in theory

INTERNATIONAL ECONOMIC REVIEW  
Vol. 14, No. 2, June, 1973

### RISK AVERSION AND THE MARTINGALE PROPERTY OF STOCK PRICES\*

BY STEPHEN F. LEROY

#### 1. INTRODUCTION AND SUMMARY OF CONCLUSIONS

RECENT EMPIRICAL STUDIES of the random properties of stock prices<sup>1</sup> have supported the conclusion that rates of return on stock follow a martingale—i.e., that the expected rate of return on stock conditional on past realized rates of return is always equal to its unconditional expectation. In addition, the martingale property has received theoretical support from recent work by Samuelson [10].<sup>2</sup> However, Samuelson's result depends on the assumption that investors require an exogenously given expected rate of return. It is natural to inquire whether the martingale property can be derived when the assumption of a given expected rate of return is relaxed. That question will be discussed in this paper.

If it is no longer assumed that the expected rate of return may be taken as given, then it becomes necessary to consider how the expected rate of return is determined, and this involves analyzing the relation between the riskiness of stock and the risk-aversion of investors. We are led to consider models of portfolio selection of the type developed by Tobin [13], [14] and Markowitz [6], and the associated models of capital market equilibrium of Sharpe [12] and Lintner [5], since these deal explicitly with this question. However, it is apparent that models of the Sharpe-Lintner type, though they do relate the expected rate of return to the optimizing behavior of risk-averse investors, can cast no light on the martingale question. This is so because these models assume a one-period

## What else?

- Overfitting is not solved by longer backtests alone, or less complexity alone...
  - What could be longer and simpler than 30 years of long-only bonds?
- Black: “A theory is accepted not because it is confirmed by conventional empirical tests, but because researchers persuade one another that the theory is correct and relevant”
  - Said equilibrium can be general and dynamic without being “rational”
  - Embraced Kahneman/Tversky, Bayesian analysis way before it was hip
  - Would rather be clearly wrong, than sort-off right.
- Quant is at its best playing defence, not offense
  - Avoid bad ideas
  - Assume “noise”
  - Look to avoid mistakes rather than seeking “truth”.

# Appendix A1

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