Overfitting and pseudo-analysis

Quantitative Strategies
Global Markets Research
EMEA

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When use of pseudo-maths adds up to fraud
By Stephen Foley

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

A recent paper argues that many quant strategies are false and a result of data-snooping. Bailey et al. accuse finance quants of charlatanism:

"Another thing I must point out is that you cannot prove a vague theory wrong. [...] Also, if the process of computing the consequences is inadequate, 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 the 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...
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

Mean reversion delivers negative returns

MA has a larger area of “heat” compared to cross-sectional

Source: Nomura Research
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

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Problems?

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

Source: Bloomberg, Nomura Research
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).

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**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 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.

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Who else has looked at overfitting?
• 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

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

* Inflation assumed to be 225bp

** Cash assumed to be 25bp
Mehra – Prescott showed standard models could justify only 40bpspa

Theory suggests a lower return for equities

Historical US equity returns exceed the theoretical value

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.

Source: The Equity Premium (A Puzzle) Mehra-Prescott (1985)
An empirical problem—survivorship bias

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

Global market excess returns are much closer to the theory. The US experience appears to be an anomaly.

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 bias, 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 last 15 years looks like the theory in America...

Even recent US experience has not lived up to expectations

... and in Europe and Japan.

Source: Bloomberg, Nomura Research
What are expected returns, conditional on low yields at the beginning?

Excess returns (LHS) | US 10Y Yield (RHS)

Most bond indices start in the 1980s

Source: Nomura Research, Bloomberg
Are you doing “pseudo-analysis”? Should you care?
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

Source: Bloomberg, Nomura Research
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…
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

Notes: In 1973 Stephen LeRoy published "Risk aversion and the martingale property of stock prices" in International Economic Review.
• 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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Appendix A1

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