Academic Research Monitor
Portfolio Construction and Overfitting

Equities

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Quantitative

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New ideas on risk-based allocations and on the issues of back-test overfitting
Is there any benefit in allocating risk across different clusters of assets? How can we limit the effect of frequent rebalancing and associated costs in a volatility-targeted investment? How dangerous is the effect of overfitting and how can we avoid it? We provide an overview of recent academic papers that offer insights on these questions.

Incorporating clustering in a risk-based portfolio optimisation
Asset returns cluster together when they share similar characteristics; think of assets in the same asset class or stocks in the same sector. The first paper that we review introduces a new idea in the family of risk-based portfolios and suggests a weighting scheme that allocates risk across different clusters of assets. We provide an illustrative example of allocating across 16 assets that belong in three different asset classes (commodities, equity indices and government bonds).

Incorporating the effect of transaction costs in a volatility-targeted investment
Volatility-targeted products have become very popular. However, dynamically adjusting the exposure to a risky investment typically requires frequent rebalancing, increasing the transaction costs. The second paper that we review suggests a way to incorporate trading costs into a volatility-targeting framework.

A literature review on the latest advances of overfitting issues in back-tests
There is a growing awareness of the problems of overfitting. Figure 1 illustrates how we can beat the market (S&P500 in this example) by 1 basis per day on an in-sample basis but fail significantly during the out-of-sample period. The academic literature has substantially expanded on the topic of back-test overfitting. We therefore decided to provide a broad overview of the recent literature, focusing in particular on the problems of overfitting, as well as on some suggestions on how to address them.

Figure 1: Can we beat the market? (market relative returns)

Source: UBS Quantitative Research. Constructing a static portfolio of S&P500 constituents in order to outperform S&P500 by 1 basis point per day. In-sample period: 1993 – 2007; out-of-sample period: 2008 – May 2016.

Introduction

Two aspects of portfolio construction

In this issue of our Academic Research Monitor we consider two recent papers that touch on the topic of portfolio construction but in very different ways (Figure 2). In the first paper the author introduces a new approach to building portfolios, which doesn't involve inverting the covariance matrix of returns – the source of much of the instability of optimised portfolios. The second paper considers the question of building a volatility weighting strategy in the presence of transaction costs.

Figure 2: Papers on portfolio construction

"Building Diversified Portfolios that Outperform Out-of-Sample" *Marcos López de Prado*	SSRN working paper, January 2016 Forthcoming at the *Journal of Portfolio Management*
"Volatility Weighting Over Time in the Presence of Transaction Costs" *Valeriy Zakamulin*	SSRN working paper, January 2016

Source: UBS

Overfitting

In the second section we return to the topic of overfitting which we discussed in an earlier edition of the ARM (October 2013, available here). There are a number of new papers on this topic (see Figure 3), which fall into two main categories: finding spurious factors and over-optimising the parameters in a trading strategy. Given the relative similarity of this group of papers, we decide to provide a broader literature review of all of them.

Figure 3: Papers on the problems of overfitting in backtests

"Backtest Overfitting in Financial Markets" *David H. Bailey, Jonathan Borwein, Marcoz López de Prado, Amir Salehipour and Qiji Jim Zhu*	SSRN working paper, February 2016
"Stock Portfolio Design and Backtest Overfitting" *David H. Bailey, Jonathan Borwein and Marcoz López de Prado*	SSRN working paper, July 2016
"Backtesting" *Campbell R. Harvey and Yan Lui*	SSRN working paper, July 2015
"Lucky Factors" *Campbell R. Harvey and Yan Lui*	SSRN working paper, July 2016
"The Future of Empirical Finance" *Marcoz López de Prado*	*Journal of Portfolio Management, Volume 41(4), 2015*
"All that Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms" *Thomas Wiecki, Andrew Campbell, Justin Lent and Jessica Stauth*	SSRN working paper, March 2016

Source: UBS

Portfolio construction

"Building Diversified Portfolios that Outperform Out-of-sample"

by Marcos López de Prado

Addressing "Markowitz's curse"

Portfolio optimisation methodologies, which require inverting the covariance matrix, are prone to estimation errors; instability, concentrated portfolios and underperformance out-of-sample are notorious issues associated with Markowitz's mean variance optimisation – sometimes referred to as the "Markowitz's curse". López de Prado (2016) proposes a method for constructing diversified portfolios, which circumvents the need to invert the covariance matrix and results in a strategy which is claimed to outperform out-of-sample. Bonus!

To add to the issues already mentioned, standard correlation matrices lack the concept of hierarchy, which is an important factor in the context of asset allocation or building a stock level portfolio. The ideal model should incorporate how stocks are related to each other and whether certain stocks are substitutes or complements of others. By introducing hierarchical relationships, the author offers an approach, named Hierarchical Risk Parity (HRP), to building diversified portfolios with stable and intuitive results.

Introducing the three-step "Hierarchical Risk Parity"

Essentially, the procedure carried out in this paper involves transforming a correlation matrix by means of a clustering algorithm which involves three stages:

- **Tree clustering** – the first stage entails using a distance metric to produce a tree structure which clusters stocks into related investments;
- **Quasi-diagonalization** – the covariance matrix is then rearranged so that the largest off-diagonal values lie around the diagonal;
- **Recursive bisection** – the final stage is when optimal weights are calculated. This is achieved by splitting allocations through adjacent subsets and weighting inversely according to the cluster's variance.

The objective of this approach is to create a tree structure which allows allocations to flow "top-down" through the tree rather than flow freely in non-intuitive ways.

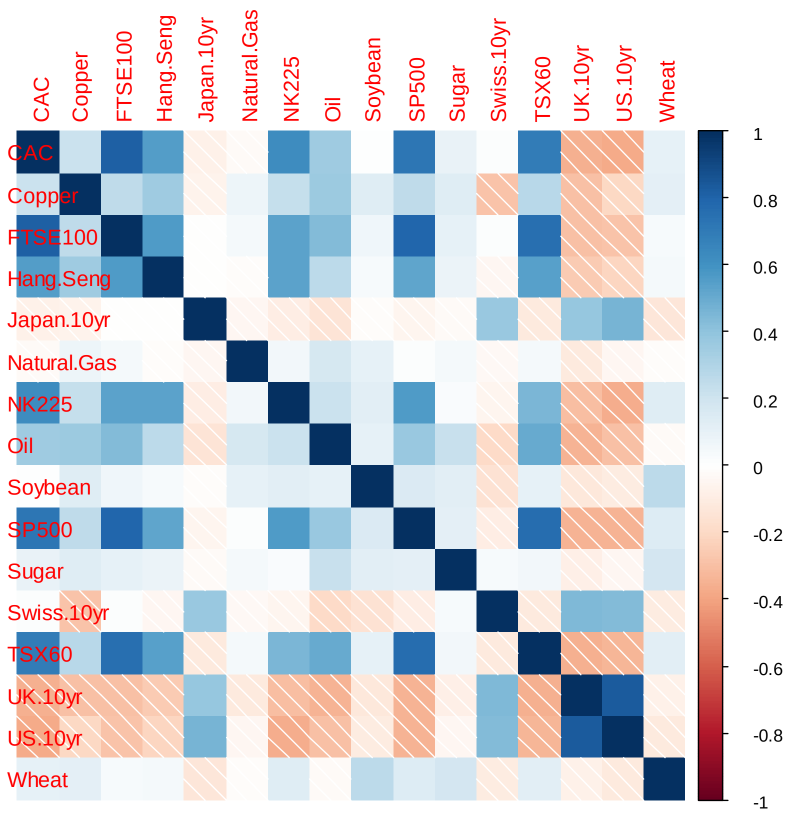
In order to illustrate the effectiveness of this approach, the author constructs three (in-sample) optimal portfolios based on a 10-asset universe, using HRP, minimum-variance and risk-parity[1] and compares their performance in and out-of-sample. The simulated results confirm that HRP portfolios exhibit better diversification compared to minimum-variance with a very similar level of standard deviation, hence offering better protection against idiosyncratic shocks. This results in out-of-sample outperformance thanks to the lower out-of-sample variance

[1] Whilst the author calls it risk-parity, it is in fact inverse-variance weighting.

Our reproduction

The paper's description of the algorithm is perhaps not the clearest, so we give an example here[2]. The universe that we use consists of 16 futures contracts (6 equity indices, 4 government bonds and 6 commodities) and is a subset of the universe we have used in all our cross-asset work. We use weekly return data for a three-year period between July 5, 2013 and June 24, 2016. The raw correlation matrix is shown in Figure 4 below; the assets are ordered alphabetically.

Figure 4: Correlation matrix of returns



Source: UBS

Step 1: Tree clustering

The first step is to convert the correlation to a distance using:

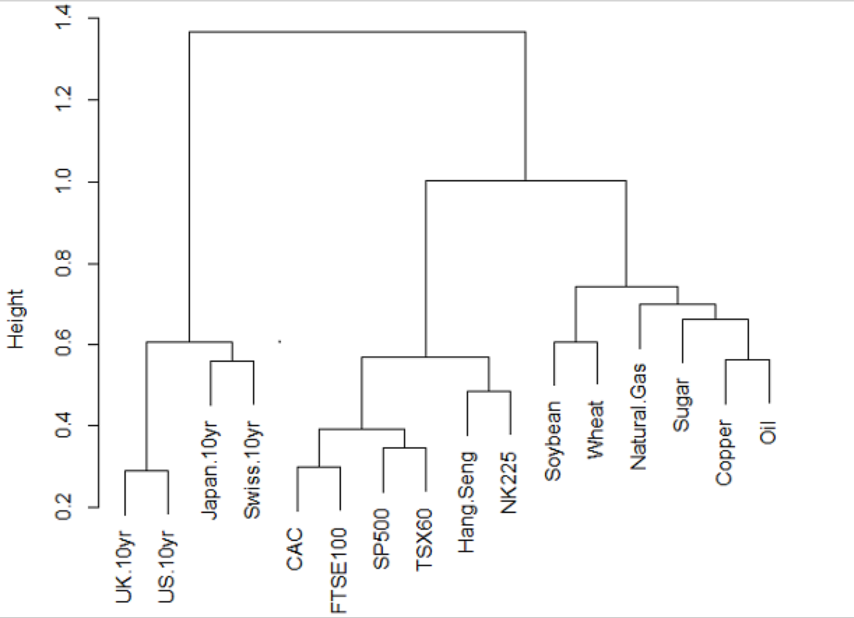
$$d_{i,j} = \sqrt{\frac{1}{2}(1 - \rho_{i,j})}$$

Then one has to run a clustering algorithm on the distance matrix. The author uses a Nearest Point Algorithm[3], but he says that any clustering technique can be used.

Figure 5 below shows one result of clustering these assets[4]. Unsurprisingly the government bonds form one cluster, the equity indices a second and the commodities a third.

[2] The working version of the paper that we reviewed contains code written in Python 2.x. Please note that if you use Python 3, you will seemingly fall foul of the fact that `random.seed` has changed and so you cannot directly reproduce the example of the paper.
[3] The Python implementation that is given in the paper uses the `scipy` clustering routines. If you use R, then `hclust` does the same job.
[4] We chose to use Ward's (1963) algorithm.

Figure 5: Cluster analysis of the 16 assets

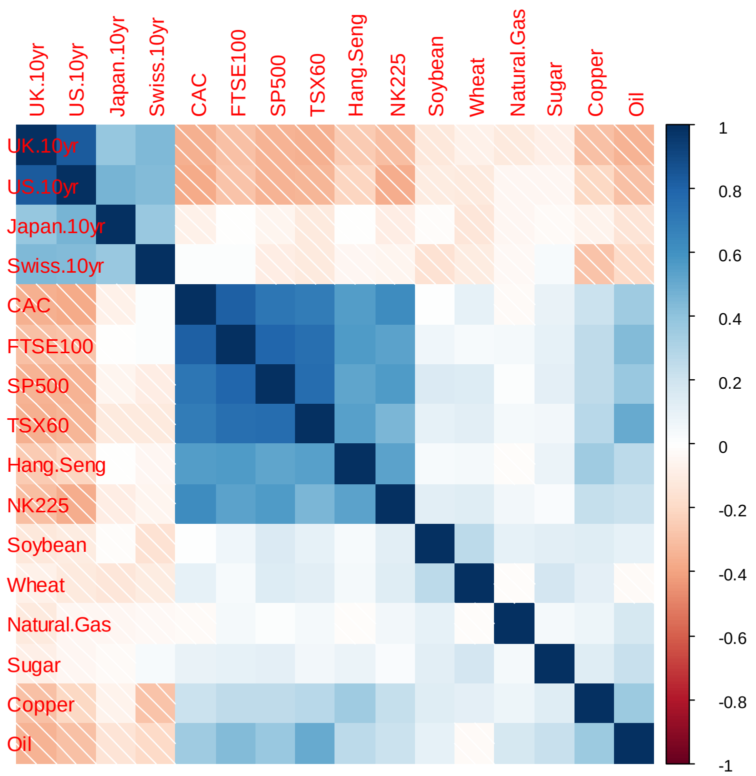


Source: UBS

Step 2: Quasi-diagonalization

The second step in the process is to use this clustering to reorder the correlation and covariance matrix to move the assets in each cluster together; see Figure 6.

Figure 6: Reordered correlation matrix



Source: UBS

Here we can see the two very strong clusters in the top half of the matrix (government bonds and the North American and European equity indices) together with the slightly "looser" cluster of commodities at the bottom. The idea of this step is to create a "somewhat diagonal" correlation and covariance matrix.

Step 3: Recursive bisection

The final step is slightly involved and is perhaps best illustrated by working the first step as an example. Start by splitting the universe in half (so into two eight-asset portfolios) using the re-ordered covariance matrix above. For each half create a portfolio weighted by the inverse of the asset variances[5] and calculate the variances of these two sub-portfolios, V_1 and V_2. Then put a fraction

$$\alpha = 1 - \frac{V_1}{V_1 + V_2}$$

of the weight in the first portfolio and $1 - \alpha$ in the second portfolio[6]. Then divide each eight-asset portfolio into two four-asset portfolio and repeat. This stops after the next step when we allocate the weight between four two-asset portfolios. The results are shown in the table below.

Figure 7: Comparing the three allocations

	Min Variance	Inverse Volatility	HRP
UK 10yr	1.16%	8.78%	3.51%
US 10yr	-4.52%	11.02%	5.53%
Japan 10yr	95.24%	33.77%	74.76%
Swiss 10yr	4.93%	13.47%	11.89%
CAC	0.22%	3.00%	0.32%
FTSE100	-2.33%	3.81%	0.52%
SP500	0.46%	4.24%	0.66%
TSX60	2.42%	4.00%	0.59%
Hang Seng	-0.48%	3.04%	0.43%
NK225	0.51%	2.40%	0.27%
Soybean	0.08%	2.63%	0.39%
Wheat	0.80%	1.99%	0.22%
Natural Gas	0.18%	1.20%	0.09%
Sugar	0.09%	1.98%	0.24%
Copper	0.71%	2.92%	0.41%
Oil	0.54%	1.75%	0.15%

Source: UBS

Our view

Although we like the approach and the idea behind this – effectively allocate within clusters and then between them, we do have a few concerns. If we change the clustering approach or the correlation-to-distance formula then one obtains a (slightly) different weighting scheme. Also we wonder about the use of the approximate minimum variance optimisation within the sub-portfolios; why do this rather than an approximate risk parity (i.e., volatility parity) approach? Overall, it is an interesting addition to the portfolio construction literature.

[5] This is a slightly odd step given the "risk parity" name. Weighting by the inverse of the variance is the solution to the minimum variance portfolio if one assumes the covariance matrix is diagonal. Risk parity would involve weighting by the inverse of the volatility, while also controlling for pairwise correlations.
[6] Again this is the two asset minimum variance solution.

"Volatility weighting over time in the presence of transaction costs"

by Valeriy Zakamulin

How to incorporate the effect of transaction costs in a volatility-targeted strategy?

Volatility-targeted products are currently very popular. The idea is simple: one varies the weight between a risky asset and a non-risky asset in order to maintain a constant forecast volatility for the overall portfolio. This is effectively weighting the risky asset in a portfolio by a factor which is inversely proportional to its volatility.[7]

For example, if we wish to have a portfolio with a target volatility of 10% and our current forecast of the risk asset's volatility is 16% then we would put 62.5% of our money into the risky asset and the remaining 37.5% into a risk free asset. We would then rebalance this in the next period in order to maintain this target volatility of 10%. Ideally one rebalances daily, but this has the potential issue of having high turnover and hence high transaction costs.

This paper by Zakamulin (2016) considers the issue of running a more general volatility-based weighting scheme and explores how to incorporate transaction costs.

Maximising the Sharpe ratio

The paper starts by asking the question of what proportion y_t of our investment should be put into the risky asset in each period where the objective is to maximise the Sharpe ratio over time. The answer, if one assumes that the mean return is constant in each period, is to set

$$y_t = \frac{A}{\sigma_t^2}$$

for any arbitrary positive constant A, which is set to $\sigma_{benchmark}^2$. We note that in our publication *Beyond Volatility Targeting* we show that if we assume the volatility can be modelled by a stochastic volatility model then the volatility in the above expression should be raised to something close to, but less than, 2.

This expression is fine but ignores transaction costs. Ideally, one would change the weights continually, but this is obviously both impractical and expensive. The obvious choice is to only rebalance at finite intervals (every day, week, month), but extending the period reduces the accuracy of the volatility forecast and hence makes the returns to the above strategy less than optimal. There is probably a choice of the rebalancing frequency which is "the best", but there is no way to determine this.

Adding in transaction costs by assuming the solution

The author suggests that the "*best method to find the optimal strategy with transaction costs is to account for the presence of transaction costs in the formulation of the problem*". But solving this problem can be extremely hard if it is even possible. However, leaning on a large literature[8] on solving this type of problem, the author takes a short cut and assumes the form of the solution. From the literature we know the optimal strategy is "*rather simple and has two essential features: (1) the existence of a no-transaction zone and (2) a smooth response to changes in variables*".

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[7] This is a topic on which we have written in the past in *Understanding volatility targeting strategies* (October 2011), *Beyond volatility targeting* (June 2012) and *Extending volatility targeting* (September 2013).

[8] For example: Davis and Norman (1990) for portfolios; Hodges and Neuberger (1989), for option pricing and hedging.

In order to "mimic" these features the author considers solutions where there is a "no-transaction" region of the form:

$$y_t = \left(\frac{\sigma^2_{benchmark}}{\sigma^2_t}\right)^{\eta} \pm B$$

The parameter η determines how aggressively risk exposure is adjusted in response to volatility changes. The parameter B is the bandwidth that defines the half-size of the no-transaction region for non-negative parameters η and B.

The trading rule instructs no trading when y_t lies within the above region; if it is outside the region one trades back to the nearest edge. In the absence of transaction costs (and with predictable volatility) the optimal strategy has $\eta = 1$ and $B = 0$. As transaction costs increase η falls and B increases.

Fitting the parameters

The question then comes on how to find these two parameters. The author suggests a grid search strategy. This requires calculating the returns to the strategy for various values of (η, B) together with varying trading frequencies and transaction costs (levels used in the analysis: 0.1%, 0.25% or 0.50%).

Measuring performance

In order to compare the performance of the different trading strategies with the original the author use the M^2 measure suggested by Modigliani and Modigliani (1997). This is defined as follows:

$$M^2 = (SR_a - SR_b) \times \sigma(R_{b,t})$$

where SR stands for Sharpe Ratio, the subscript α refers to the trading strategy and b to the benchmark. This can be thought of as the return difference between the strategy and the benchmark if the volatility of the strategy is adjusted to match that of the benchmark.

Main findings of the empirical analysis

After running a Monte Carlo simulation the author states a number of conclusions:

- If transaction costs are zero then if one is using daily rebalancing then as suggested above the best values are $\eta = 1$ and $B = 0$.
- If the rebalancing frequency falls to either weekly or monthly then the best solution is at $\eta = 0.75$ which lessens the dependency on a less-accurate volatility forecast.
- Increasing transaction costs increases B and decreases η.
- No matter what the level of transaction costs is, the best performance always comes with daily rebalancing. However the difference between the performance of the optimal strategy with costs and the theoretical strategy can be huge.

Finally, the author conducts a historical simulation using the returns of six Fama and French (1993) 2x3 size and book-to-price portfolios for the period between 1989 and 2014 with rather similar results to the Monte Carlo study.

A Literature Review on Overfitting

There is a growing awareness of the problems of overfitting. Papers such as "*… and the Cross-Section of Expected Returns*" by Harvey, Liu and Zhu (2016) and "*Does Academic Research Destroy Stock Return Predictability?*" by McLean and Pontiff (2016), which we have reviewed in detail in past ARM issues (see the August 2013 and December 2014 issues, respectively), have highlighted the problems of overfitting (or data mining), reproducibility and multiple testing in finance. In this section of the ARM, we give a brief summary of some of the newer papers in this area. Given the subjects of the papers significantly overlap we decided to present a general discussion.

"The future of empirical finance" by López de Prado (2015)

"The Future of Empirical Finance" by López de Prado (2015) provides an overview of three problems faced by financial academics and practitioners: (a) multiple-testing, (b) the fact that finance practice is adaptive (i.e., finding an effect probably leads to it disappearing due to arbitrage) and (c) the fact that it is impossible to rerun history in a laboratory. In the following paragraphs we review all three of them.

(a) Multiple testing

Multiple testing is not a new statistical area – Bonferroni noted it in 1936 (and the problem is pictorially summarised rather well at https://xkcd.com/882/). However, the author observes that most econometrics textbooks do not address the problem. Also, the author observes that out-of-sample testing doesn't really help – one just runs a number of in-sample specifications until the out-of-sample test works (a simple example, if non-financial example, of this "p-hacking" is available at http://fivethirtyeight.com/features/science-isnt-broken/#part1)

The author suggests a number of remedies – firstly papers could be required to include a section describing how authors have adjusted for multiple testing. Also referees could ask the authors of a paper to reproduce the results on a different data set; and there could be a public forum where authors would post their data and readers could provide evidence for (and against) a discovery.

"Backtesting" by Harvey and Liu (2015)

This problem is discussed at length in ***"Backtesting"*** by Harvey and Liu (2015), where the authors develop an analytical approach to calculate by how much an in-sample Sharpe Ratio should be reduced to account for data mining (what should the "haircut" be).

Suppose we have a strategy which has a mean return of $\hat{\mu}$ and a standard deviation of $\hat{\sigma}$. There is a simple relationship between the Sharpe Ratio ($\widehat{SR}$) and the t-statistic which tests whether the average return is zero:

$$t - ratio = \frac{\hat{\mu}}{\hat{\sigma}/\sqrt{T}}$$

and

$$\widehat{SR} = \frac{\hat{\mu}}{\hat{\sigma}}$$

where T is the number of periods.[9]

[9] As an aside, the authors note that "*This equivalence between the Sharpe ratio and the t-statistic […] justifies the use of the Sharpe ratio as an appropriate measure of the attractiveness of an investment strategy under our assumptions.*"

Their approach involves transforming the Sharpe ratio to a t-statistic, calculating the p-value for this t-stat, adjusting the p-value for multiple-testing and then transforming this back to the so-called "haircut Sharpe ratio". Expectedly, they find that strategies with higher Sharpe ratios tend to have a lower haircut.

"Lucky Factors"

by Harvey and Liu (2015)

In *"Lucky Factors"* the same authors (Harvey and Liu, 2015) address a related question – in their words "how do we assess whether a variable such as a dividend yield predicts stocks returns given that so many other variables have been tried?" They use a bootstrap method in order to make inferences about both predictive regressions and cross-sectional regressions. Applying their approach they find a surprising result: for value weighted individual stocks there is one dominant factor – the market; with an economically small contribution from the profitability factor. Equal weighting provides some evidence of value and size factors.

(b) Adaptability

For the second problem of adaptability, López de Prado (2015) suggests that research "*could be mainly concerned with quantifying the parameters of well-thought prior theories*" and cites market microstructure research as being a good case study for this.

(c) There is only one history

For the third problem the only real solution is better and closer interaction between academia (where "*the retraction rate of […] papers […] is extremely low compared to other empirical fields*") and financial firms (witness the high attrition rate in hedge funds) — with this product's intention to help drive increased awareness and understanding of academic studies.

"Stock Portfolio Design and Backtest Overfitting"

by Bailey, Borwein and López de Prado (2016)

In **"*Stock Portfolio Design and Backtest Overfitting*"**, Bailey, Borwein and López de Prado (2016) describe a program they have developed which "*given any desired performance profile, [it] designs a portfolio […] that achieves the desired profile based on in-sample backtest data*". They show that although the portfolios match the in-sample data they "*perform erratically*" out-of-sample.

Where could this be a problem? The authors highlight a study in 2012 by Vanguard Group that "*the median time between the definition of a new index and the inception of a new exchange traded fund based on the index dropped from almost three years in 2000 to only 77 days in 2011*". As part of the same study, Vanguard found that "*out of 370 indexes for which they were able to obtain reliable information, 87% of the indexes outperformed the broad U.S. stock market over the time period used for the backtest, but only 51% outperformed the broad market after inception of the index*".

Our illustrative example

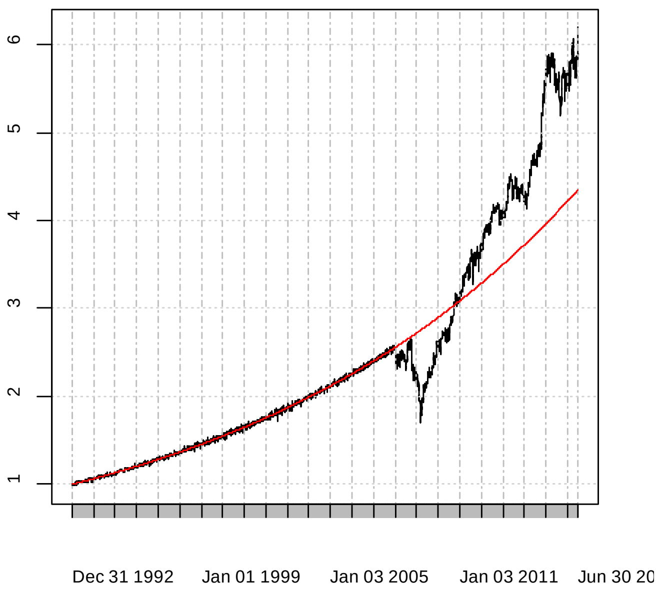
In order to illustrate the above point, we took the universe of the S&P 500 as of the end May 2016 and selected those companies which have returns back to 1993 (which gave us a universe of 303 names).[10] We use the first 15 years as our in-sample period and the subsequent 8 years as the out-of-sample period. We then assume two target return profiles; the first is a steady 6% per annum growth. The second is a return which equals the S&P 500 return plus 1 basis point per day (so, effectively beating the market by roughly 2.5% a year). Using the in-sample period, we solve for a static allocation for the available universe, given the above target return profiles.

Figures 8 & 9 below show that we can in fact match the target return perfectly in-sample; however, out-of-sample the returns from the portfolio look nothing like those desired. Commenting on the S&P 500+ example in Figure 9, where we show

[10] There is an obvious survivorship bias here, but this is not the focus of the analysis.

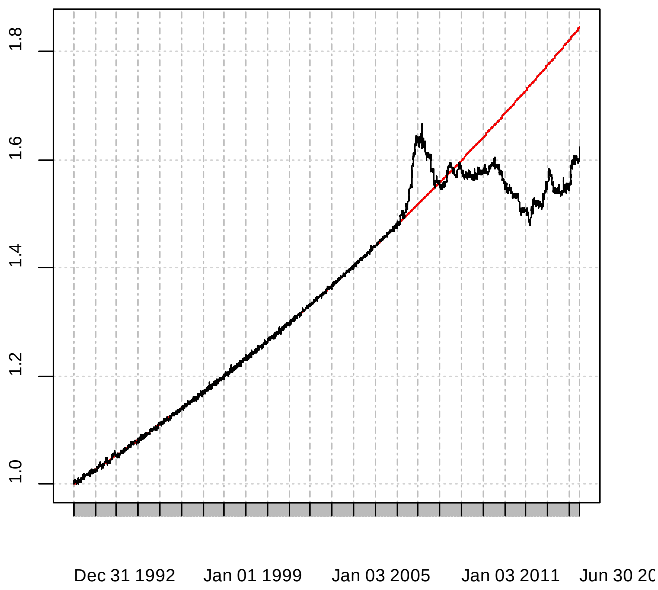
the relative performance, we clearly outperform in-sample as planned. However, out-of-sample the relative performance goes sideways – that is, on average we perform in line with the index.

Figure 8: Steady Growth example: In- and out-of-sample performance



Source: UBS Quantitative Research

Figure 9: "S&P 500+" example: In- and out-of-sample relative performance



Source: UBS Quantitative Research

Why is it that we can fit almost any target profile and yet the performance out-of-sample completely fails to match the target? The authors point out that one is simply carrying out a massive search over all possible weighting factors where one is looking to minimise the squared difference in returns between the desired return pattern and the weighted sum of stock returns. If we have 100 assets and we only allow weights from 0 to 100% in steps of 0.1% then the number of sets of weighting factors is roughly 100^{1000} or 10^{2000} (which the authors point out is vastly greater than the number (10^{86}) of elementary particles in the visible universe). Given we have chosen our weights from this massive set then overfitting is unavoidable.

Along a similar vein, in "*Backtest Overfitting in Financial Markets*", the authors describe two on-line tools, which optimise trading strategies based on either seasonality or a forecasting equation. Both tools highlight how running only a small number of variations of the parameters of a strategy and then selecting the largest in-sample Sharpe Ratio will significantly overstate the out-of-sample Sharpe Ratio.

"Backtest overfitting in financial markets"

by Bailey, Borwein, Salehipour, López de Prado and Zhu (2016)

The authors of "*All that Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms*" show that these problems exist for real trading strategies. The authors have access to all the results of strategies developed on the Quantopian web-based platform which allows people to research, develop and backtest trading algorithms (see https://www.quantopian.com for details). Although the actual algorithms are confidential, the authors have access to all the returns, positions and transactions generated by an algorithm, and given the algorithms are time-stamped in the system's database they can identify the true in-sample and out-of-sample periods.

"All that Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms"

by Wiecki, Campbell, Lent and Stauth (2016)

Out of their initial sample of 7,152 algorithms, various filters reduced this to a set of 888 algorithms. Their initial test is to compare the Sharpe ratio from the last year of each algorithm's in-sample (IS) period to that of the preceding IS period. They find a strong and significant relationship (R^2 of 0.21, $p < 0.0001$). The authors argue that this is a baseline against which to compare the out-of-sample (OOS) results.

Comparing the IS and OOS periods gives a weakly negative, but highly significant correlation between annual returns (R^2 of 0.015, $p < 0.001$) but a positive correlation between the IS and OOS Sharpe ratio (R^2 of 0.02, $p < 0.0001$). The authors focus on this discrepancy and argue that the IS Sharpe ratio can be increased by either increasing mean returns or decreasing volatility. It appears that the former is, probably unsurprisingly, more prone to overfitting. They also find significant evidence that the more backtests a user ran, the bigger the different between IS and OOS performance.

The authors point out that the adaptability problem mentioned above (i.e., publishing reduces the effectiveness of a strategy) cannot explain the reduction in Sharpe ratios as the algorithms on the platform are probably not publicly known. So overfitting becomes the more likely hypothesis for this reduction.

The final question the authors attempt to answer is whether the OOS Sharpe Ratio can be predicted. They use a random forest and they find that although the previous year's Sharpe ratio is an important feature, so are the skewness, the kurtosis and the tail ratio (the ratio between the 95^{th} and the (absolute) 5^{th} percentile of the daily return distribution) are also important: strategies that focus on reducing tail events seem to have better OOS Sharpe Ratios.[11]

[11] They do make the comment that the machine learning analysis is in-sample and really needs to be reproduced out-of-sample!

References

Bailey, D.H., J.M. Borwein, and M. Lopez de Prado (2016). Stock Portfolio Design and Backtest Overfitting. *Available at SSRN: http://ssrn.com/abstract=2739335*

Bailey, D.H., J.M. Borwein, M. Lopez de Prado, A. Salehipour, and Q.J. Zhu (2016). Backtest Overfitting in Financial Markets. *Automated Trader, 2016, Forthcoming. Available at SSRN: http://ssrn.com/abstract=2731886*

Bonferroni, C. E. (1936). Teoria Statistica delle Classi e Calcolo delle Probabilita.

Davis, M.H.A. and Norman, A. R. (1990). Portfolio Selection with Transaction Costs, *Mathematics of Operations Research, 15* (4), 676–713.

Fama, Eugene F., and K. French (1993). Common risk factors in the returns on stocks and bonds*. Journal of Financial Economics 33*(1) (1993), 3-56.

Harvey, C.R. and Y. Liu, (2015). Backtesting *Available at SSRN: http://ssrn.com/abstract=2345489*

Harvey, C.R. and Y. Liu, (2015). Lucky Factors. *Available at SSRN: http://ssrn.com/abstract=2528780*

Harvey, C.R., Y. Liu and H. Zhu (2016). … and the Cross-Section of Expected Returns. *Review of Financial Studies, 29*(1), 5-68.

Hodges, S.D. and A. Neuberger. (1989). "Optimal Replication of Contingent Claims under Transaction Costs", *Review of Futures Markets*, 8, 222–239.

López de Prado, M. (2015). The Future of Empirical Finance, *Journal of Portfolio Management, 41*(4) 140-144. Draft available at: http://ssrn.com/abstract=2609734

Lopez de Prado, M. (2016). Building Diversified Portfolios that Outperform Out-of-Sample. *Journal of Portfolio Management, forthcoming*. *Available at SSRN: http://ssrn.com/abstract=2708678*

McLean, R.D. and J. Pontiff (2016). Does Academic Research Destroy Stock Return Predictability? *Journal of Finance, 71*(1), 5-32.

Modigliani, F. and L. Modigliani (1997). Risk-Adjusted Performance. *Journal of Portfolio Management, 23(2), 45-54.*

Vanguard Group (2012), "Joined at the hip: ETF and index development" *Available at https://pressroom.vanguard.com/nonindexed/7.23.2012_Joined_at_the_hip.pdf*

Ward Jr, J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association, 58*(301), 236-244.

Wiecki, T., A. Campbell, J. Lent, and J. Stauth (2016). All that Glitters Is Not Gold: Comparing Backtest and Out-of-Sample Performance on a Large Cohort of Trading Algorithms. *Available at SSRN: http://ssrn.com/abstract=2745220*

Zakamulin, V. (2016). Volatility Weighting Over Time in the Presence of Transaction Costs. *Available at SSRN: http://ssrn.com/abstract=2615260*

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