Betting on back-tests?

Analysing the performance of alternative risk premia from investment banks

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Our thought leadership papers deliver thought-provoking analysis of key investment themes. Through focused and unique insights into topical issues, we aim to provide investors with a deeper understanding of the challenges and opportunities within global investment markets.

Introduction

Academic studies over many decades have helped investors better understand the fundamental drivers of returns. Some of these sources of return can be isolated into alternative risk premia. A number of investment banks now offer products that replicate these alternative risk premia strategies. This gives investors access to low-cost, liquid alternatives to traditional asset classes. They offer diversification potential to investors. These products typically come with compelling back-tested track records to illustrate these features.

In practice, these products have not delivered returns consistent with their respective back-tested track records. Why not? And have the diversification benefits persisted in the live environment? This paper analyses a comprehensive set of alternative risk premia products from eleven investment banks to answer these questions. Our analysis leads us to question the performance of alternative risk premia in different economic regimes.

Executive summary

What is the investment issue?

Our understanding of the fundamental drivers of investment returns has improved thanks to decades of academic studies. For example, we understand that equity investors can expect long-term returns above the market through exposure to different factors such as value, quality, momentum, small size and low volatility.

Systematic investment strategies are able to isolate many of these sources of return. This allows investors to construct portfolios that diversify across a number of alternative risk premia. Similar systematic strategies can be applied to other asset classes and in multi-asset strategies. Many strategies are implementable using liquid, traded instruments.

In order to access a full suite of alternative risk premia, the investor must have:

- a reasonable level of market knowledge
- appropriate trading systems
- the appropriate infrastructure for trade settlement
- collateral management systems
- access to borrowing and
- risk management tools.

Investment banks are well placed to meet these needs. A large number of investment bank-sponsored products have been launched over recent years.

The investment selection and portfolio construction for these products are determined by formulaic, non-discretionary sets of rules. This allows the investment banks to present back-tested performance statistics to potential clients. Most products have short live track records, but impressive back-tested returns.

However, investors have discovered that the performance in the live environment rarely lives up to the back-test. The author's analysis aimed to understand why. He also analysed whether the diversification benefits persisted in the live environment.

Which existing studies have addressed this issue?

Several research papers have conveyed scepticism over results publicised on the simulated performance of investment strategies. Three studies capture the key issues.

McLean and Pontiff [2016] reviewed the performance of 97 strategies identified in academic research as offering alternative returns to the stock market. They found that 26% produced lower returns out-of-sample and 58% produced lower returns post-publication. They suggested that the excess return is lower once investors have learned about a mispricing from academic publications.

Harvey et al. [2016] argues that extensive data mining means it does not make sense to use the usual criteria to establish the statistical significance of factors that claim to explain expected returns. They argued that a much higher hurdle is required. They argued that most claimed research findings in financial economics are likely false.

Suhonen et al. [2016] carried out a similar analysis to our own. They analysed 215 alternative risk premia products offered by investment banks. They found that the Sharpe ratio fell from 1.2 during their respective back-test periods to 0.31 during live performance. It was this study that led us to ask: is this result fully explained by the problems of data mining? Or could there be a more fundamental explanation? And what happened to diversification in the live environment compared to the back-test?

How does the author tackle the issue?

The author created a database of 747 alternative risk premia strategies, offered by 11 global investment banks.

The author screened the database to remove duplicate indices; those driven by the same underlying factor and only different in the nuances of portfolio construction. Where duplicates existed, the author selected the most liquid market, the most liquid security and/or the oldest strategy. Any strategy that was a combination of other strategies was removed. The sample was reduced from 747 strategies to 218 independent strategies.

The author carried out four analyses; two to examine performance and two to examine diversification.

First, he calculated the Sharpe ratio for each strategy, separating each between the back-test period and the live environment.

Second, he examined the average Sharpe ratio of the overall sample over time, from 1995 to 2018.

Third, he used statistical factor analysis – principle component analysis – to decompose the statistical drivers for the basket of risk premia strategies offered by each of the banks. This allows him to compare these drivers in the back-test environment to the live environment.

Different investment banks offer different numbers of strategies. In order to compare the results for their basket of strategies, he calculated a concentration ratio that was adjusted for the number of strategies. This analysis produces a measure of diversification for the basket of strategies offered by the banks in back-test and live environments.

Fourth, he compared concentration measures of the overall universe over time. He calculated the Meucci Diversification Ratio between 1991 and 2018 (the weighted sum of each strategy's volatility divided by the total basket volatility) to analyse the change in diversification.

What were the findings?

The average Sharpe Ratio declined from 0.81 during the back-test to 0.20 in the live environment. This Sharpe ratio is below the 0.31 result found by Suhonen et al. in their 2016 study. While the data sets are somewhat different, this is in line with our expectations given the poor performance of most alternative risk premia in 2018.

20% of strategies saw their Sharpe ratio increase in the live environment.

The average Sharpe ratio of the overall sample trended lower over the last decade. Therefore this deterioration began before the majority of the alternative risk premia were available as live indices.

The principle component analysis produced very similar results in the back-test and live periods. Similarly, when the results are combined into a concentration ratio and compared across the eleven banks, there is no material difference between results in the back-test and live environments.

The Meucci Diversification ratio rose from a level close to the long-term average in 2009 to a record high in June 2015, declining steadily thereafter. At the end of the study, in July 2018, this measure was close to its long-term average.

What are the investment implications?

The deterioration in Sharpe ratio between the back-test environment and the live environment is consistent with previous studies. This is, therefore, consistent with the theory that the deterioration can be explained – in part – by the influence of data mining.

The author's own due diligence of investment bank risk premia strategies finds that the majority use simple, logical rules with few parameters. This reduces the potential influence of overfitting.

The fact that the deterioration in Sharpe ratios began before many of the strategies went live suggest that data mining is not the only explanation for the decline. This leads us to question the cause of the deterioration. Other factors, such as different economic regimes, may influence the performance of risk premia.

A central premise of factor investing is that the factors must be robust, intuitive, persistent and supported by empirical evidence. Amenc et al. [2015] provide two definitions of robustness: relative robustness, the ability to produce similar performance in similar market conditions; and absolute robustness, the capacity to outperform regardless of market conditions.

We note that the value factor within equities has performed poorly over the last decade. This is a common factor within investment bank risk premia products. This suggests that some of the deterioration in Sharpe ratios may be due to cyclical factors rather than structural. In other words, the value factor may have delivered relative robustness in an adverse environment for the strategy. The cyclical influences on the performance of alternative risk premia is a worthy topic for further research.

The author found that the diversification benefits of investing in a diversified basket of alternative risk premia are robust, being largely unchanged between back-test and live results. The study found that the average Sharpe ratio remained positive in the live environment, albeit significantly lower than suggested by the results in back-tests. This leads the author to conclude that a portfolio of alternative risk premia, diversified across asset classes and strategies, can be expected to produce attractive risk adjusted returns.

"The experience of many investors has been that risk-adjusted returns failed to match those achieved in back-tests."

Part I

Accessing alternative risk premia

Investment bank offerings

Alternative risk premia have attracted a great deal of attention from academics and investors. 'Alternative risk premia', 'Alternative beta', 'smart beta', 'style premia' and 'risk premia' are all different labels for methods of investing in the underlying fundamental factors that drive market returns.

This approach to investing is founded on the belief that a portion of returns historically generated by active investment managers can be replicated through simple algorithms. These algorithms have been packaged into products that offer transparency, liquidity and lower costs than the actively managed products they aim to replace.

Investment banks have sought to meet this demand with a seemingly endless list of strategies. These cover a broad range of asset classes and geographies. The pitch-packs to potential buyers inevitably include impressive simulated returns calculated by quantitative analysts within the investment bank – or back-tests.

Unfortunately, the experience of many investors has been that risk-adjusted returns failed to match those achieved in the back-tests. They deteriorated once the strategies began trading 'live'. Banks have been accused of using 'over-fitted' models to produce appealing back-tests in order to generate flows. However, many champions of these claims have performed limited due diligence on the matter. Little attempt has been made to research and understand the underlying drivers of the deterioration in returns.

This paper offers a more nuanced investigation of these alternative risk premia strategies. It provides results that allow for a more comprehensive debate on the use of overfitting. In addition to analysing performance before and after the 'live' date, we consider the performance of alternative risk premia over time, from 1995 to 2018. And we analyse the diversification benefits of the basket of strategies offered by investment banks before and after the 'live' date.

Academic literature review

Given the growth of the risk premia universe, some strategies have inevitably come under scrutiny of overfitting. Several research papers have conveyed scepticism around publicised simulated performance; including Bailey et al. [2014], Harvey and Liu [2015], Novy-Marx [2015], Harvey et al. [2016], McLean and Pontiff [2016] and Wiecki et al. [2016].

A common argument is that the quantitative exercises involved in identifying, developing and implementing risk premia strategies rely on the analysis of historical data. As a result, they are susceptible to biases arising from data mining, multiple testing, and selective reporting.

In particular, Suhonen et al. [2017] focused on the performance of strategies sponsored by investment banks (referred interchangeably as strategies or indices), the subject of this study. These strategies come with a published investment algorithm. They examined the persistence of risk-adjusted returns after the 'live' date – that is, when the strategies were launched in the market.

The key finding was a deterioration of the median Sharpe ratio across 215 risk premia strategies; from 1.20 during their respective back-test periods, to 0.31 during live performance. Our work corroborates the results of Suhonen et al. [2017].

"The results of this paper allow for a more comprehensive debate on the use of overfitting."

Part II

Performance of alternative risk premia

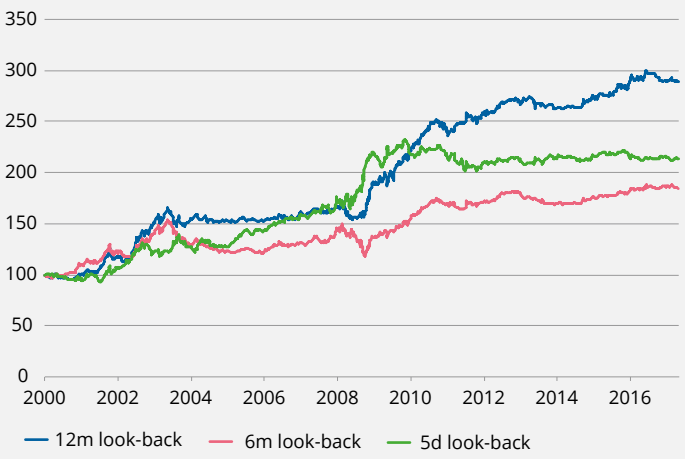
Deterioration of Sharpe ratio

We analysed 747 alternative risk premia strategies offered by eleven global investment banks, using daily data. These invested across five different asset classes: commodities; credit; equities; FX; and interest rates. The average back-test length was 11.6 years and average live performance period was 3.9 years. We found a median Sharpe ratio deterioration of 83% (mean deterioration 75%). This is consistent with the results of Suhonen et al. [2017] (median deterioration of 73%), albeit the deterioration in our study was greater.

Within this universe, there existed a large number of indices within the same asset class based on the same strategy. These indices only differed in terms of specific instruments, countries or maturities. A central premise of alternative risk premia is that it should be robust across quadrants; that is, we should therefore be agnostic to nuances of portfolio construction.

We use the example of interest rate momentum to illustrate the challenge for investors looking to select strategies. This strategy looks to capture returns from momentum in interest rates. Momentum can be defined and measured over different periods of time. Figure 1 illustrates the performance of these strategies using look-back periods of 12 months, six months and five days. The strategy was successful in each case, but the end results were markedly different. However, there is no investment theory – or intuition – that would have helped steer investors towards what turned out to be the best-performing strategy. In our analysis, we consider strategies that differ only by look-back period to be duplicates of one another.

Figure 1: Performance of an interest rate momentum strategy using different look-back periods



Source: 11 investment banks, Aberdeen Standard Investments, July 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

To remove duplicate indices, we applied four rules:

1. if the same strategy is applied to different countries in the same asset class, the most liquid market is selected (typically the US)
2. if the same strategy is applied to different instruments in the same asset class, the most liquid instrument is selected (e.g. 10 year maturity for fixed income products and crude oil for commodities)
3. if a strategy is replicated by modifying the parameters, the oldest strategy is used
4. any strategy which is a combination of other strategies is removed. (For example, some providers offer multi-factor indices such as 'equity quality & value'. We only include the individual factor indices: 'equity quality' and 'equity value'.)

After applying these rules to our universe of 747 risk premia, the number of strategies in our sample was reduced to 218. For this sample, the median deterioration in Sharpe ratio was 81% (compared to 83% for the full universe), with mean deterioration 75% (see figure 2).

Figure 2: Sharpe ratios (SR) during back-test and live performance periods over 218 strategies

	Back-test SR	Live SR	SR Diff	SR % Change
Average	0.81	0.20	-0.61	-81%
Median	0.74	0.17	-0.60	-75%
Min	-0.58	-1.59	-2.63	-3643%
Max	3.01	1.95	1.21	3465%

Source: 11 investment banks, Aberdeen Standard Investments, July 2018

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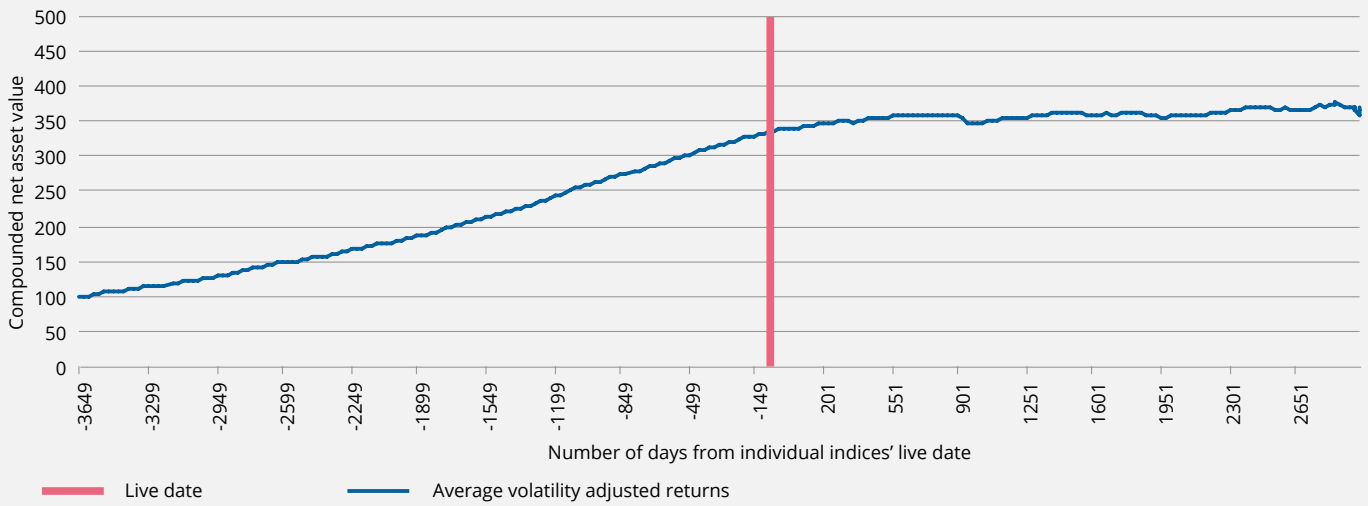
The greater deterioration in the 'live' Sharpe ratio compared to Suhonen et al. is as expected. It is consistent with the continued deterioration in the performance of most alternative risk premia. Suhonen et al. carried out their calculations in March 2015, while we carried out our study in July 2018.

Figure 3 presents the average volatility-adjusted returns over 218 risk premia strategies. These are centred on each individual strategy's live start date. This illustrates the 'flattening' of performance in the 'live' environment compared to the back-test period. This result also suggests that the compulsion for investment banks to publish new and 'different' alternative risk premia indices contributed to the deterioration in live performance. On the whole, they happened to have produced more of the strategies which have had the greatest deterioration. In particular, a number of new equity value indices have been launched at a time of poor performance for this strategy.

We calculated the Sharpe ratio changes across different asset classes represented in our sample (see figure 4). We found notable declines across most asset class and strategy groupings. However, 20% of strategies produced Sharpe ratios in the 'live' environment that were higher than their back-tested results.

Figure 3: Average volatility-adjusted returns, centred on each individual strategy's live date.



Source: 218 risk premia strategies from 11 investment banks, Aberdeen Standard Investments, July 2018

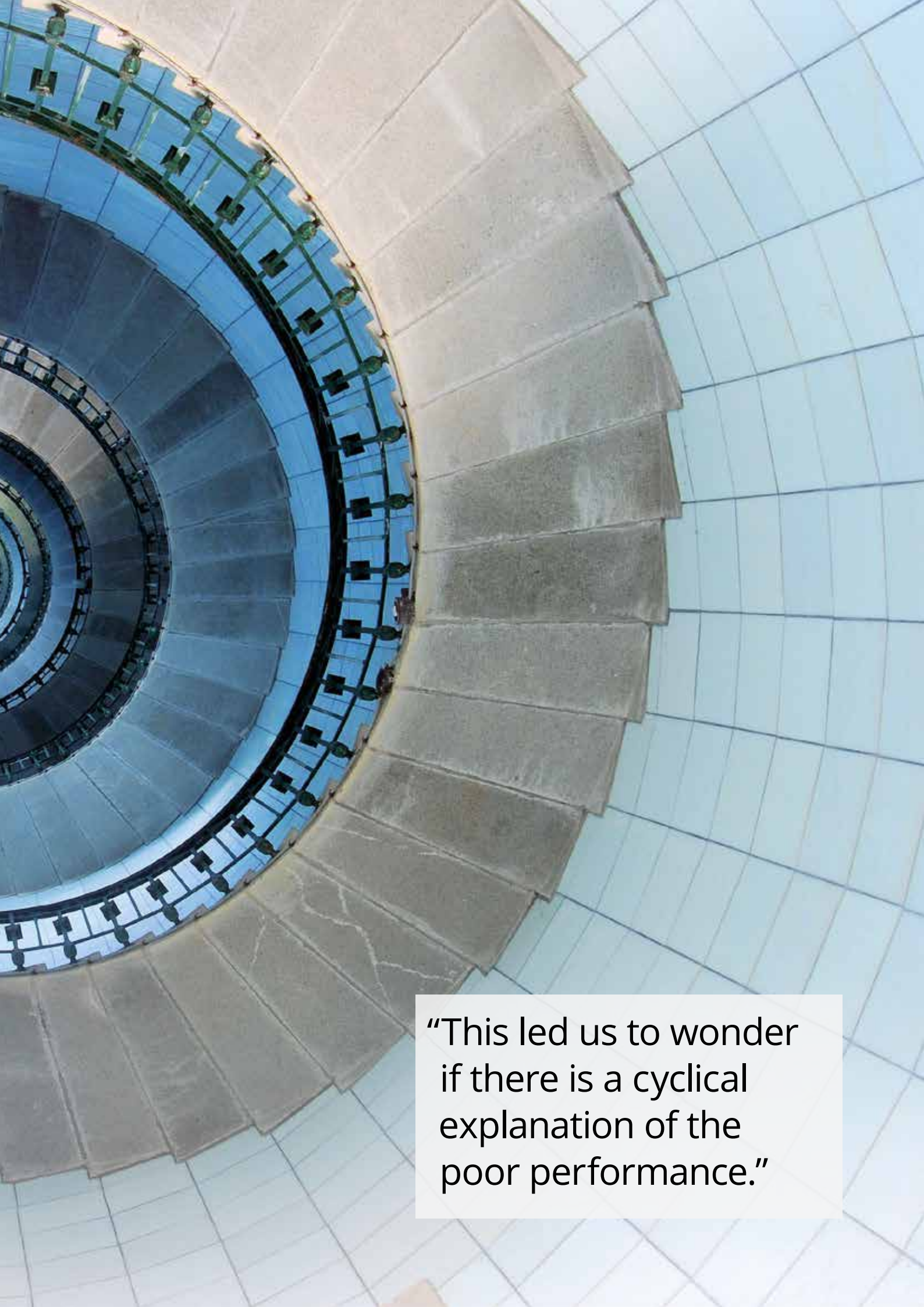
These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

Figure 4. Sharpe ratio differences: live performance minus back-tested results

	Commodities	Credit	Equities	FX	Rates
Carry	-1.11	1.21	-0.79	-0.85	-0.58
Curve	-0.29	0.21			-1.15
Event Driven			-0.61		0.48
Liquidity	-0.27	-1.66	0.28	-0.31	-0.96
Low Beta		-0.01	-0.17		
Mean Reversion	-1.17		-0.74	-0.29	
Momentum	-0.02	-0.96	1.01	-0.71	-0.93
Quality			0.31		
Size			0.09		
Value	-0.82	-0.89	-0.47	-0.93	-1.05
Volatility	-1.12	-0.84	0.15	-0.72	0.95

Source: 218 risk premia strategies from 11 investment banks, Aberdeen Standard Investments, July 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.



"This led us to wonder if there is a cyclical explanation of the poor performance."

Cyclical behaviour of Sharpe ratio

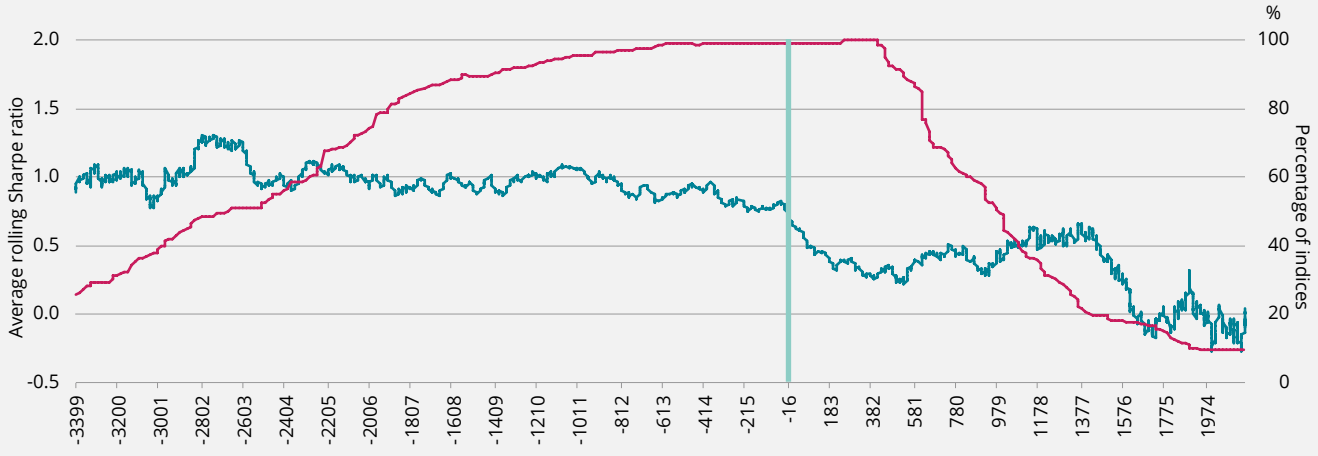
The deterioration in Sharpe ratios raises questions about the quality of the alternative risk premia indices on offer. Yet many of these indices are designed to deliver widely accepted forms of persistent returns – such as value, momentum and size. This led us to wonder if there is a cyclical explanation of the poor performance. To gain an understanding of the cyclical behaviour, we studied performance over time.

In figure 5, we plot the rolling one-year Sharpe ratio averaged across 218 strategies. These were centred on each individual strategy's live date to see the effect of 'going live'. It also shows the percentage of indices included in the data at each point. The back-test period averaged 12.0 years, while the average live period is just 4.4 years.

We found a noticeable deterioration in the risk-adjusted return, or Sharpe ratio. This was consistent with the results on returns alone presented in figure 3. However, by contrast to the previous analysis, we found that the Sharpe ratio had already declined for several years before the live date.

Figure 6 shows the rolling one-year Sharpe ratio from January 1990 to July 2018, aggregated according to the time periods when the data for the underlying strategies are available. In this analysis, the deterioration in the Sharpe ratio begins long before we have a majority of 'live' indices. The deterioration in risk-adjusted returns had already begun in the back-test data. This result suggests that the deterioration cannot be fully explained by over-fitting of backtests.

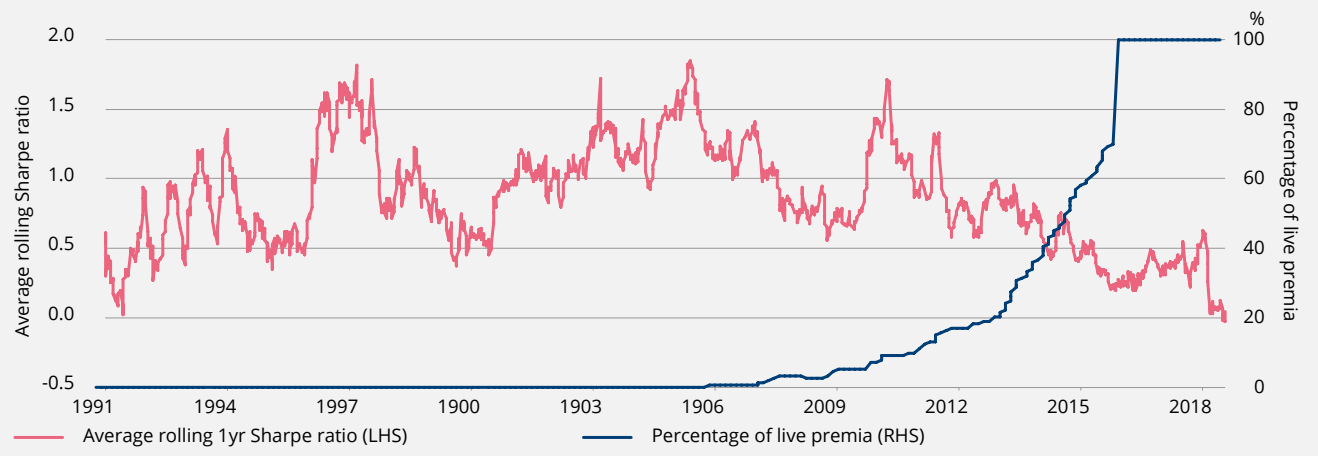
Figure 5: Average Sharpe ratio, one-year rolling window, centred on the live date for each individual strategy



Source: 218 strategies from 11 investment banks, Aberdeen Standard Investments, September 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

Figure 6: Sharpe ratio: one-year rolling window, 1990 - 2018



Source: 218 strategies from 11 investment banks, Aberdeen Standard Investments, September 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

"The deterioration in the Sharpe ratio begins long before we have a majority of 'live' indices. This suggests that the deterioration cannot be fully explained by over-fitting of backtests."

Part III

Robustness of diversification

Alternative risk premia are systematic strategies designed to deliver returns from alternative beta. Few providers of risk premia would be brave enough to claim they offer alpha.

Investors should expect modest risk-adjusted returns from individual strategies. However, combining orthogonal – or independent – sources of returns together creates the potential for attractive risk-adjusted returns. Investment banks typically present the diverse indices they offer alongside a correlation matrix showing low correlations between the indices.

We investigated whether there was a change in the correlations between the back-tested results and the live environment. After all, it is just as easy to data-mine for correlations as for performance. (That is, it is just as easy to use historic data to generate a basket of strategies offering attractive diversification as it is to over-fit the data to generate attractive returns).

We use two methods of assessing the independence of risk premia strategies offered by investment banks: statistical factor analysis, using principle component analysis; and concentration analysis, using the Meucci Diversification Ratio. We compare results before and after 'live' date.

Statistical factor analysis

We analysed the returns of the basket of strategies offered by each of the eleven banks as a whole. The number of indices offered by these banks ranged from 10 to 33. We used principle component analysis to decompose these returns into their statistical drivers. It is important to note that these statistical factors are different from the fundamental factors, such as value or size, that we have discussed previously.

As an example, figure 7 presents the results for a single investment bank, offering 17 alternative risk premia indices. Each principle component represents a statistical factor that explains the returns of the combined basket of strategies. These are ranked by the percentage explained, shown in the vertical axis.

We found little difference in the statistical drivers of returns between the back-test and live periods. This suggests that the components of the basket have maintained their relative independence.

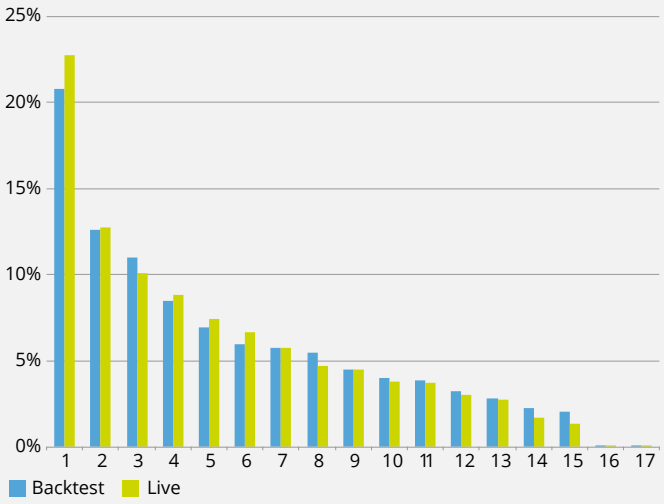
Concentration analysis

To quantify the change in concentration, we aggregated the principle component eigenvalues using the Herfindahl-Hirschmann Index. (This is more commonly used for judging market competition or index concentration.) We summed the square of each eigenvalue to arrive at a concentration ratio. The larger the number, the more concentrated the basket.

Because some banks offer more strategies than others, these results alone do not allow for a fair comparison across providers. Therefore these numbers were multiplied by the number of strategies in each bank dataset. This created a measure that could be compared across banks. The results are presented below (see figure 8).

Principle component analysis of select bank indices using back-test and live data to July 2018.

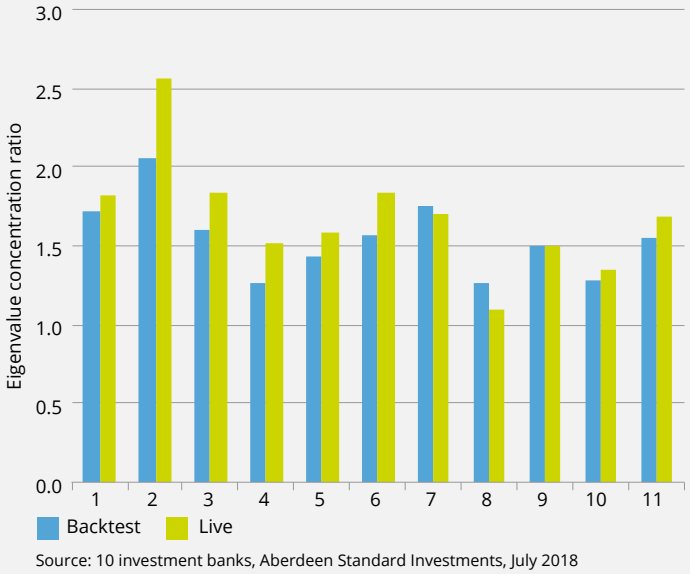
Figure 7: Proportion of premia index variance explained through eigenvalue decomposition, example bank indices in back-test and live periods



Source: 11 investment banks, Aberdeen Standard Investments, September 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

Figure 8: Concentration analysis: comparison of back-test versus live period using eigenvalue decomposition



Source: 10 investment banks, Aberdeen Standard Investments, July 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

The results show there was no material change in concentration between the back-tested period and the live results.

Diversification analysis

The Meucci Diversification ratio provides a measure of the diversification of a basket of strategies. It allows us to compare the change in diversification over time. We performed the analysis on the baskets from each bank, excluding one that had too few strategies for a meaningful analysis. To allow comparison across the ten banks, the results were adjusted for the number of strategies included.

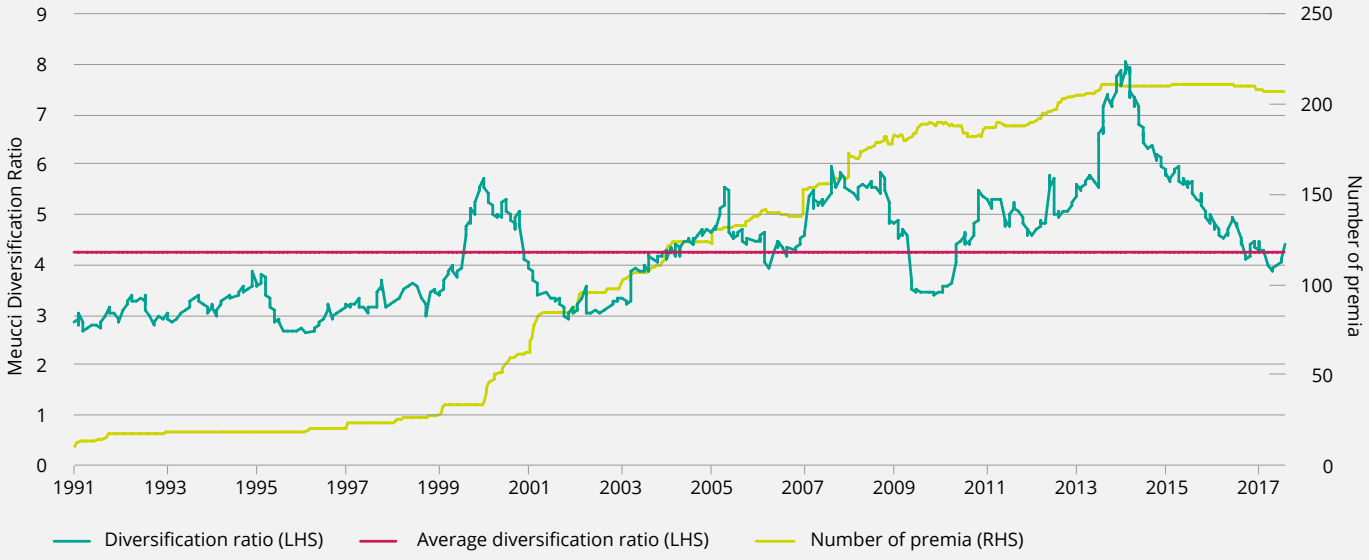
Meucci Diversification

The Meucci Diversification ratio provides an intuitive understanding of diversification, while also being easy to compute. It is the weighted sum of the volatility of each strategy divided by the volatility of the total basket. A ratio of two implies that combining strategies led to a halving of volatility, compared to the weighted average of the individual strategies. A ratio of one implies that there is no reduction in volatility when the strategies are combined.

For the universe as a whole, we calculated the Meucci Diversification Ratio (the weighted sum of each strategy's volatility divided by the total basket volatility). We found that diversification in July 2018 was close to its long-term average. It had risen to a high in June 2015), subsequently declining despite a more challenging period for alternative risk premia strategy.

Figure 9. Measuring diversification across the risk premia universe

Meucci Diversification Ratio, rolling 52 weeks, using equal weight across 218 strategies, volatility adjusted.



Source: 11 investment banks, Aberdeen Standard Investments, July 2018

These figures relate to simulated past performance. When interpreting the results, the investor should always take into consideration the limitation of the model applied. The simulated past performance of the model is not a guide to future results.

"There was no material change in diversification between the back-tested period and the live results"

Conclusion

We compiled a comprehensive universe of 747 alternative risk premia strategies, from 11 global investment banks. This universe was filtered to remove overlapping strategies. This left a sample of 218 strategies, representing the 'flagship' indices from each bank. We analysed both the full universe and the filtered sample. We examined performance and diversification. Our analysis compared results in the back-test period to results after the strategies went live. This involved centring the analysis of each strategy on their respective live date. We also analysed the results over time, from 1995 to 2018.

Our analysis corroborated the deteriorating Sharpe ratio reported in existing literature. The average Sharpe Ratio declined from 0.81 during the back-test to 0.20 in the live environment. We found notable declines across most asset class and strategy groupings. However, 20% of strategies saw their Sharpe ratio increase in the live environment.

We observed that deterioration in the Sharpe ratio begins before a majority of indices went 'live'. The deterioration had already begun in the back-test period. The Sharpe ratio is not constant through time and displays a cyclical behaviour. This suggests that the deterioration cannot be fully explained by over-fitting of back-tests.

In particular, we note that this is consistent with the poor performance of value strategies over the last decade. We suggest that this could be due to cyclical rather than structural factors.

The average live period of just four years is insufficient to determine the true drivers of recent poor returns. We suggest that the impact of different economic and market regimes is worth exploring further in future studies.

Our analysis of diversification finds no material change between the back-test period and the live period. This suggests that the correlation matrices presented by investment banks are not the result of data-mining.

Our own due diligence of these strategies suggests the vast majority use simple, logical rules with few parameters. This reduces the potential influence of over-fitting.

What is a good Sharpe ratio? A recent paper that analysed the performance of Warren Buffett's portfolio provides some perspective. Buffett's Alpha [Frazzini et al. 2018] calculated the Sharpe ratio of Berkshire Hathaway to be 0.79 between 1976 and 2017. This was nearly double that of the overall market. It was higher than all US mutual funds that have been around for more than 40 years. In this context, a Sharpe ratio of 0.81 – as found in the average backtest – from a simple, algorithmic approach might seem unrealistically high. (To be clear, we appreciate that this is an apples versus oranges comparison: Buffett's portfolio is long-only while alternative risk premia are long-short strategies. But Warren Buffett is regarded as one of the world's finest investors, and his returns provide some context.)

A further finding of this paper was that Buffett's performance was "a reward for a successful implementation of value and quality exposures" – or alternative risk premia – "that have historically produced high returns".

In conclusion, risk-adjusted returns in the live environment were well below those in the back-test period. But they were still positive. And there is reason to believe that the deterioration in returns in recent years was, in part, due to other factors, such as cyclicality. However, further works is required to understand the cyclical drivers of alternative risk premia. We make no predictions about the outlook for this cycle.

We find the diversification benefits of a diversified portfolio of alternative risk premia to be robust in the live environment.

This suggests that a basket of indices can be combined into a diversified portfolio with the potential to deliver attractive risk-adjusted returns.

Alternative risk premia strategies are increasing popular. Investors are benefitting from increased choice and greater transparency. We hope this paper has brought new insights into the problems faced by investors in understanding these strategies. However, due diligence and a thorough understanding of the strategies remain essential.

references

Amenc, N., Goltz F., Lodh A. and Sivasubramanian S. An ERI Scientific Beta Publication, 2015a. *"Robustness of Smart Beta Strategies".*

Bailey, D.H., J.M. Borwein, M.L. Prado and Q.J. Zhu. *"Pseudo-Mathematics and Financial Charlatanism: The Effects of Back-test Fitting on Out-of-Sample Performance."* Notices of the AMS, Vol. 61 (2014), pp. 458-471.

Frazzini, A., Kabiller, D. and Pedersen, L.H. *"Buffett's Alpha."* Financial Analysts Journal, Vol, 74, No. 4, (Winter 2018).

Harvey, C.R. and Y. Liu. *"Back-testing."* The Journal of Portfolio Management, Vol. 42 (2015), pp. 13-28.

Harvey, C.R., Y. Liu and H. Zhu. *"...and the Cross-Section of Expected Returns."* The Review of Financial Studies, Vol. 29, No. 1 (January 2016), pp. 5-68.

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

Novy-Marx, R. *"Back-testing Strategies Based on Multiple Signals."* NBER Working Paper No. 21329, (July 2015).

Suhonen, A., M. Lennkh and F. Perez. *"Quantifying Back-test Overfitting in Alternative Beta Strategies."* The Journal of Portfolio Management, Vol. 43, No. 2 (Winter 2017), pp. 90-104.

Wiecki, T., A. Campbell, J. Lent and J. Stauth. *"All that Glitters Is Not Gold: Comparing Back-test and Out-of-Sample Performance on a Large Cohort of Trading Algorithms."* The Journal of Investing, Vol. 25, No. 3 (Fall 2016), pp. 69-80.

Important information

Investment involves risk. The value of investments, and the income from them, can go down as well as up and an investor may get back less than the amount invested. Past performance is not a guide to future results.

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*as at 30 Jun 2018

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