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DB Foundations

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Linear Signal Blending

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Beyond the Basics and the Benefits of Metric Diversification

The academic literature often describes fundamental factors as single metrics. However, practical experience has shown that these factors are better defined as multi-metric concepts and combined. Combining multiple metrics provides a balanced view of each asset where a single metric may be distorted by firm level accounting or financing policies. There are also benefits of diversification from combining uncorrelated signals which allow you to increase the Sharpe Ratio of a strategy.

Many equity portfolio managers still use simple weighting techniques (equal or fixed weights to various metrics). This approach is favoured due to its simplicity and transparency. However, it only takes into account the relative risk, rewards, and relationships of the signals based on naïve assumptions. This has prevailed despite significant advances in portfolio construction techniques that have applications to signal blending. Additionally, it is important to look beyond the Sharpe Ratio and consider the exposures and risk contributions embedded during the blending process. We find that thoughtful signal blending leads to both enhanced risk-adjusted performance and risk allocation.

- **The Egalitarian Manager**: equal weighting provides a strong benchmark when evaluating other techniques. However, it ultimately has fundamental shortcomings with regards to the behaviour of different signals which results in unintended signal positions.
- **The Just Manager**: Risk Parity weighting using the signal portfolio covariance matrix delivers equal risk contribution that appropriately reflects the point-in-time asset level signals. This allows us to account for risk coming from time varying exposures to additional factors and leads to improved risk-adjusted performance.
- **The Meritocratic Manager**: incorporating alpha into a signal blending framework enhances factor performance further if the alpha is good. We see significant improvement combining metrics to factors from simply using recent performance as alpha. However, it is more difficult to add value when combining disparate factors into a multi-factor model.

Deutsche Bank AG/London

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A letter to our readers

The influence of data and analytics has had far reaching effects into all of our personal and professional lives. While finance has been at the forefront in many ways, we are still seeing dramatic shifts in how investors interact with data on a daily basis. Not only are more data being generated than ever before, but perhaps more importantly the tools necessary to analyze and extract value from data have continued to advance as well. With open source programming languages providing the functionality and massive open online courses providing the training, the barriers to entry into the quantitative investment management space have been greatly reduced. Paired with a healthy appetite for analytics for traditional investors and non-traditional data sources for quants, the worlds of quantitative and fundamental investing have become increasingly intertwined. Indeed, our data science effort sits at the intersection of these worlds utilising quantitative techniques to extract fundamental insights (Moniz 2017).

However, for transparency reasons, many investors still prefer using relatively simplistic approaches for generating alpha despite these advances. With this in mind, we are launching a DB Foundations series to help bridge the gap between quantitative techniques and fundamental insights. The series will provide short and focused discussions around best practices related to model development using case studies.

We start by looking at various techniques to blend signals; metrics to factors and factors to alphas. Traditional single-metric definitions of equity factors common to the academic literature provide a relatively crude proxy for the underlying driver of returns. Factors that are more broadly defined provide significant improvements in terms of risk-adjusted performance. However, many practitioners still rely on narrowly defined factors with naïve weighting schemes that overweight more volatile components and ignore correlations. Additionally, it is important to consider the objective of the technique being used to properly evaluate the method rather than simply looking at risk-adjusted returns. We hope you enjoy the rest of this report.

Spyros, James, Paul, Andy, Jacopo, Aris, Caio, and Vivek

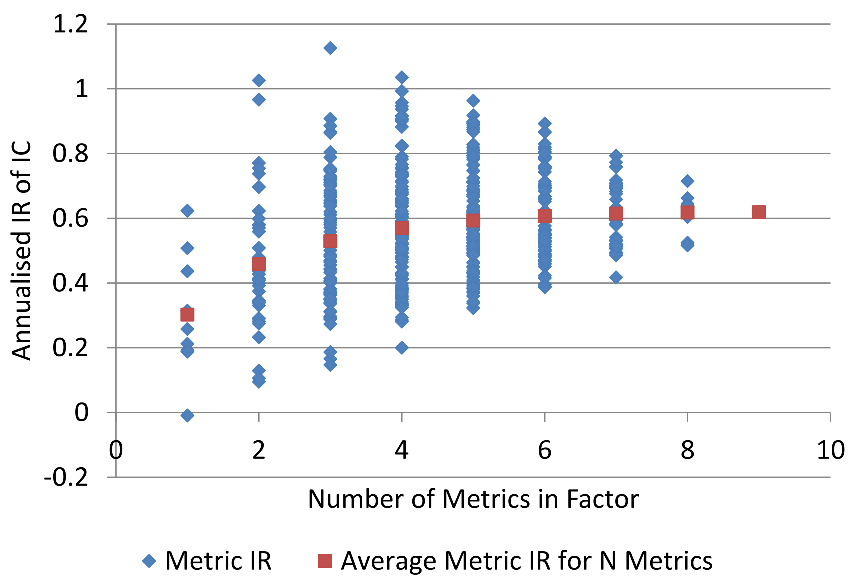
Deutsche Bank Quantitative Strategy Team

Design Choices: Blending

Factor models lay the foundation for many quantitative equity managers. These models are constructed to formalise a linear return generating process of various factors. These factors typically represent non-diversifiable risks relevant to the cross-section of asset returns. These can be viewed as explicit exposures to macro innovations (e.g. GDP Growth, Inflation) or as more abstract risks proxied by company level information (e.g. Value, Size).

While the academic literature often describes these as single metrics (e.g. Value = Book to Market), these fundamental factors are better captured holistically as multi-metric concepts, each metric contributing as a (noisy) proxy for the latent factor. This helps to provide a balanced view of each asset where a single metric may be distorted by firm level accounting or financing policies. Figure 1 shows the performance benefit of combining multiple metrics in a Quality factor in MSCI Europe 1995 to Present. Starting with a base of 9 Quality metrics, we backtest all possible equal weight factor definitions varying the number of metrics included. We find that as the number of metrics increases the average risk adjusted performance increases, while the dispersion decreases.

Figure 1: Metric Diversification for Quality Factor - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , MSCI

However, blindly creating multi-signal strategies can suffer from substantial biases despite generally producing good in-sample outperformance (Novy-Marx 2016). For now, we take a pragmatic approach based on economic intuition. Rather than exhaustively testing possible metrics and rank ordering each such that it produces a positive result, we rely on fundamental rationale to choose relevant metrics for each factor.

Moving to a multi-metric approach requires these metrics to be blended in some way. We will initially focus on factor construction. We then combine a number of core factors to build a multi-factor model. Our metrics and factors are constructed on a sector neutral basis (e.g. within group normalisation). We have seen that some factors benefit from the implicit industry group tilts of an unconstrained construction methodology (Osiol 2016). However, we are concerned with the stock-specific performance of the various factors in this publication rather than their sector timing ability.

Signal Blending Research Design

For our analysis, we first convert our factor scores into portfolio holdings. This allows us to use more advanced techniques that directly blend the signals reflecting the constituents at a specific point-in-time. This gives us a more timely and accurate representation of the signals at the time of rebalance when compared to using time series of factor returns or ICs. In addition, the performance of these portfolios should primarily reflect the blending techniques as opposed to other portfolio construction considerations. There are two intuitive ways of converting scores to portfolios; Alpha Aligned Portfolios (AAP) and Factor Mimicking Portfolios (FMP) (Alvarez 2012, Wang 2014).

Alpha Aligned Portfolios are portfolios that are directly aligned with your alpha scores. This is achieved by scaling the score such that the resulting portfolio has a targeted level of ex-ante volatility. By construction, these portfolios have reasonable volatility (user defined) with performance that is highly correlated with the time series of ICs. H_{AAP} represents the holdings to our alpha aligned portfolio with **a** as our factor score and **V** as an asset by asset covariance matrix (Equation 1).

(Equation 1) $$H_{AAP} = scalar \cdot \boldsymbol{a}$$

$$scalar = \frac{risk\ target}{(a'V\ a)^{1/2}}$$

Factor Mimicking Portfolios are portfolios that mimic the risk factor returns from a cross-sectional regression as used in risk model construction. The resulting portfolios will have unit exposure to a signal and zero exposure to all other signals included in the construction step. H_{FMP} represents the holdings for our factor mimicking portfolios with **X** as the matrix of asset level exposures and **V** as an asset by asset covariance matrix (Equation 2).

(Equation 2) $$H_{FMP} = (X'V^{-1}X)^{-1}X'V^{-1}$$

We prefer to use Alpha Aligned Portfolios for this analysis. First, these portfolios more closely replicate the univariate performance of the candidate signals. Second, they are independent of the other candidate signals which influences the FMP orthogonalisation. Third, it provides transparent portfolio weights without the information loss and elevated specific risk associated with long-short quantile portfolios. The remainder of the paper utilises Alpha Aligned Portfolios with a 10% ex-ante volatility for all backtested analysis.

It is important to evaluate the various techniques from both a risk and return perspective. While the backtested Sharpe Ratio is an important consideration, we believe that investors that stop there are missing an important part of the picture, namely risk. It is important to consider the objectives of blending signals when evaluating their efficacy. This is particularly important when blending metrics to factors where the objective is to find a combination that not only performs well but also accurately reflects the factor. In addition to typical performance statistics, we extend our analysis to include a custom holdings based attribution to better understand which signals are driving the risk and returns of our composite portfolios (Wang 2014).

Signal Exposure of a portfolio is the holdings weighted average of the asset level exposures to the underlying risk factor. The exposure gives an indication of the direction and magnitude of the return contribution from each of the underlying signals. This provides a simple measure of the importance of each underlying component. However, this ignores differences in return distributions for the underlying signals (i.e. a large exposure to a low volatility signal will have a relatively limited impact on returns).

Signal Exposure Volatility scales the portfolio exposure as described above by the volatility of the signal. Intuitively, factors with higher volatility are going to be larger drivers of return per unit exposure. This provides a more representative measure of the importance of the individual signals on portfolio returns. However, this does not account for correlation amongst the signals.

Signal Risk Contribution goes one step further and incorporates the signal correlation with the portfolio to decompose total portfolio risk. The signal risk contribution has the property that the portfolio risk is the sum of the signal risk contributions. This gives a more complete picture of the impact of the underlying signals.

We focus on the exposures and risk contributions coming from the underlying signals for our attribution analysis. The exposure shows us the relative weight we place on each signal when creating the composite. The risk contribution gives us a holistic view into the importance of each signal from a risk perspective.

Metric Blending: A Case Study in Value

In this section, we outline a number of potential techniques to blend signals, working from simple equal weighting to more sophisticated techniques. We focus on the construction of a Value factor as a case study to illustrate the various techniques. The Value premium is a prominent factor discovered and documented in the academic literature, most famously by Fama and French (1992). They show that long-short portfolios of High Minus Low Book-to-Market (Value) ratio companies generate statistically significant excess returns. The outperformance of these portfolios is often described in terms of rational asset-pricing; investors demand a higher risk premium as compensation for holding riskier assets (e.g. more exposure to distress risk).

Value provides an ideal case study to show the benefits of multiple metrics providing a more nuanced view of a company. These are historically defined as a fundamental metric deflated by price. Though, we have seen that cash flow based and enterprise value deflated metrics have exhibited strong performance, particularly in recent years. Additionally, some traditional value metrics have underperformed in recent periods. However, it is important to consider the fundamental characteristics of the metrics rather than simply the metrics that performed best in our backtest history. We choose a mixture of metrics that provide a holistic view of each company, defensive/cyclical and across the capital structure: Earnings Yield, EBIT to Enterprise Value, Free Cash Flow Yield, Cash Flow to Enterprise Value, Book to Market, and Dividend Yield.

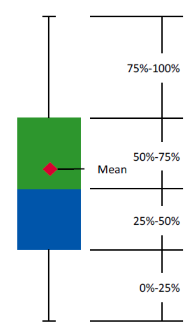
The Egalitarian Manager: Equal Weights

The most common approach to combining signals is equally weighting. It is favoured due to its simplicity. In many empirical fields, simpler models often outperform more complicated models out-of-sample by avoiding overfitting the noise in the training set. In practice, given a reasonable choice of metrics, this has also historically been a difficult benchmark to beat in terms of performance. Without a strong prior belief in the relative merit of the metrics, many feel that it is adequate to let all the metrics have an equal seat at the table. Unfortunately, this is not the reality as more volatile and correlated signals will dominate the final composite. The egalitarian manager has been left with oversized exposures to the riskiest signals in the room.

Metric Attribution

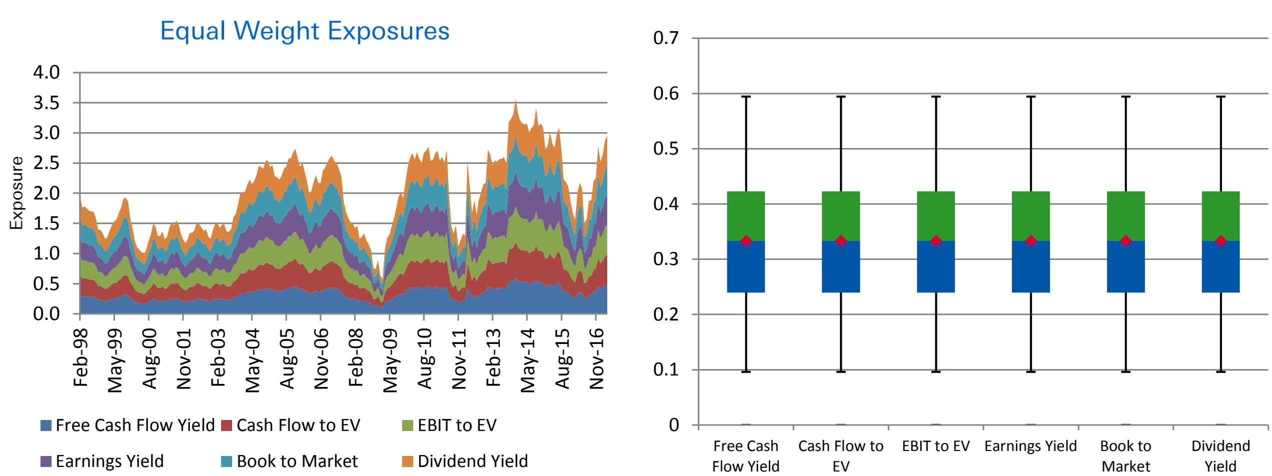
This result becomes abundantly clear when we carry out our custom risk attribution of the Alpha Aligned Portfolio for the equal weight Value factor. Figure 3 displays the notional exposures in terms of the individual metrics contained within the Value factor. By construction, each metric receives the same weight when building the Factor. However, the total notional exposure varies from period to period in order to meet the 10% ex-ante volatility target, but the relative exposure to each factor is the same within each period. For example, estimated volatility levels during the Global Financial Crisis were elevated which meant that the portfolio needed less notional exposure to reach its volatility target. This can be seen in the left chart of Figure 3 which shows the time series evolution of the notional exposures. The right chart in Figure 3 shows that each metric has the same the distribution of exposures over the period. The top/bottom points are the min/max exposure, the blue and green box represents the interquartile range, and the red dot represents the mean exposure as in Figure 2.

Figure 2: Explanation of Summary of Time Series Exposure or Risk Contribution Charts



Source: Deutsche Bank Quantitative Strategy

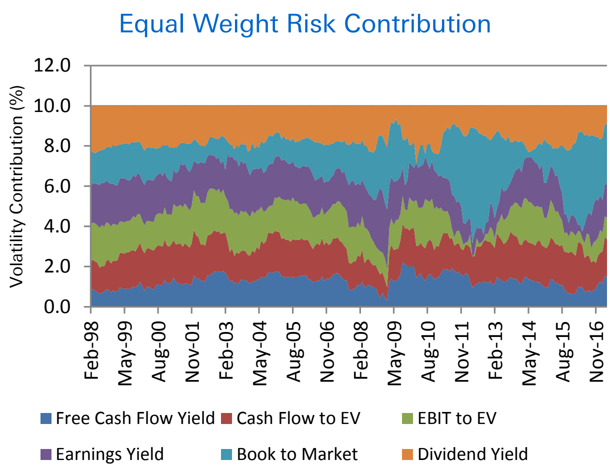
Figure 3: Value (Equal Weight) Metric Notional Exposures - MSCI Europe

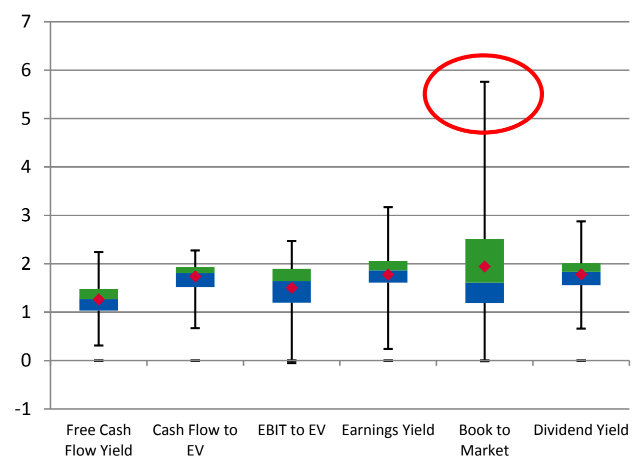


Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Similarly, Figure 4 displays the risk contributions of the individual metrics contained within the Value factor. As with the exposures, the left chart shows the time series evolution of risk contribution. We can see that at each period the sum of risk contributions equals 10% by construction given our volatility target. However, despite equal exposure each period, there is significant variation in terms of risk contribution. This has been particularly pronounced with regards to Book to Market which contributed nearly 60% to the portfolio ex-ante risk in 2012! This can be easily seen looking at the right chart in figure 4. We can see that maximum risk contribution for Book to Market sits just below 6% of our 10% target. This is in contrast to the other metrics which very rarely contribute more than 3% to ex-ante risk.

Figure 4: Value (Equal Weight) Metric Risk Contributions - MSCI Europe



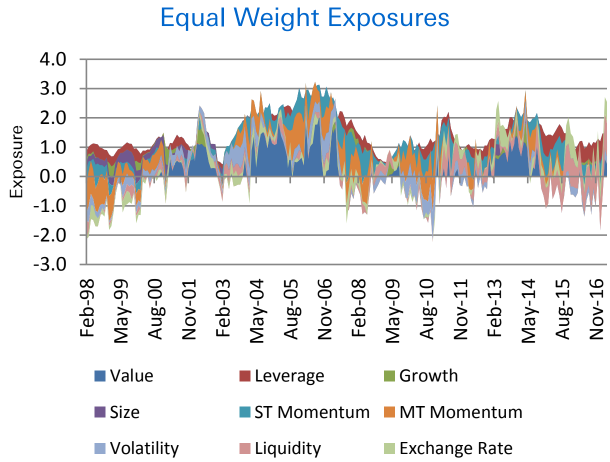


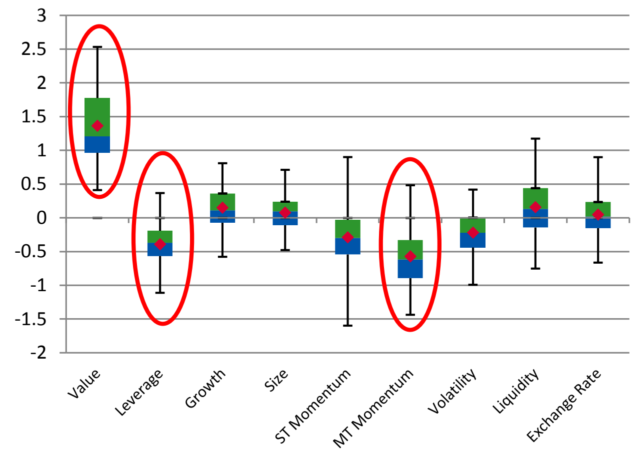
Source: Deutsche Bank, Factset, Thomson Reuters , Axioma, MSCI

Style Attribution

The factor construction process should also consider how the final factor interacts with other known risk factors. We carry out the same analysis as above by looking at the portfolio in terms of the Axioma style factors. We can see that the equal weight case does primarily provide exposure to Value with some negative exposures to leverage and momentum as seen in right hand chart of Figure 5. This is intuitive as negative momentum would indicate price deterioration which can make companies look cheap until either 1) new fundamental data is released in line with investor expectations or 2) the price recovers to realign with the fundamental data. The negative exposure to leverage is coming from our inclusion of Enterprise Value based metrics which penalise leverage. In fact, we find broadly similar exposures from the various style factors across methodologies. The choice of metrics is the primary determinant of exposure to other styles with a few exceptions which we will highlight along the way.

Figure 5: Value (Equal Weight) Axioma Style Notional Exposure - MSCI Europe

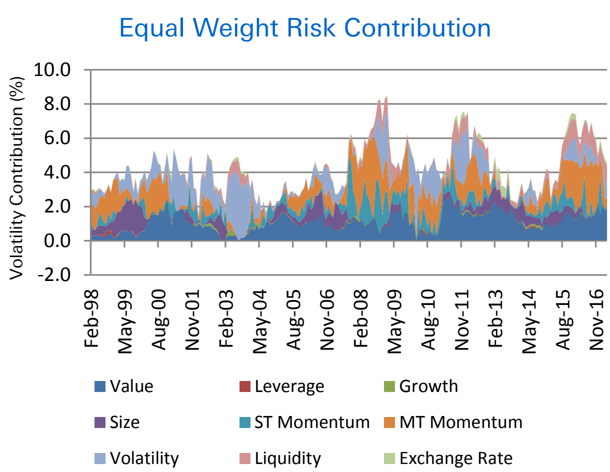


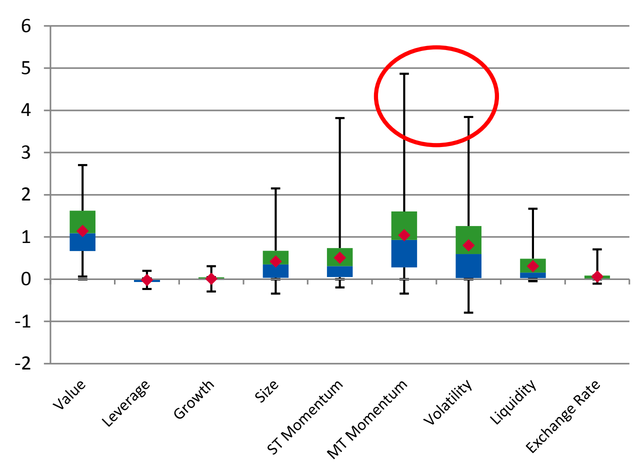


Source:Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

The exposures only tell part of the story as a small exposure can still have a large impact due to the relatively high volatility of certain style factors. For example, Medium Term Momentum and Volatility tend to have seemingly small exposures that lead to significant risk contributions at various points in the period. In fact, their risk contribution reaches nearly 50% and 40% of the risk budget respectively as seen in the right hand chart of Figure 6.

Figure 6: Value (Equal Weight) Axioma Style Risk Contribution - MSCI Europe



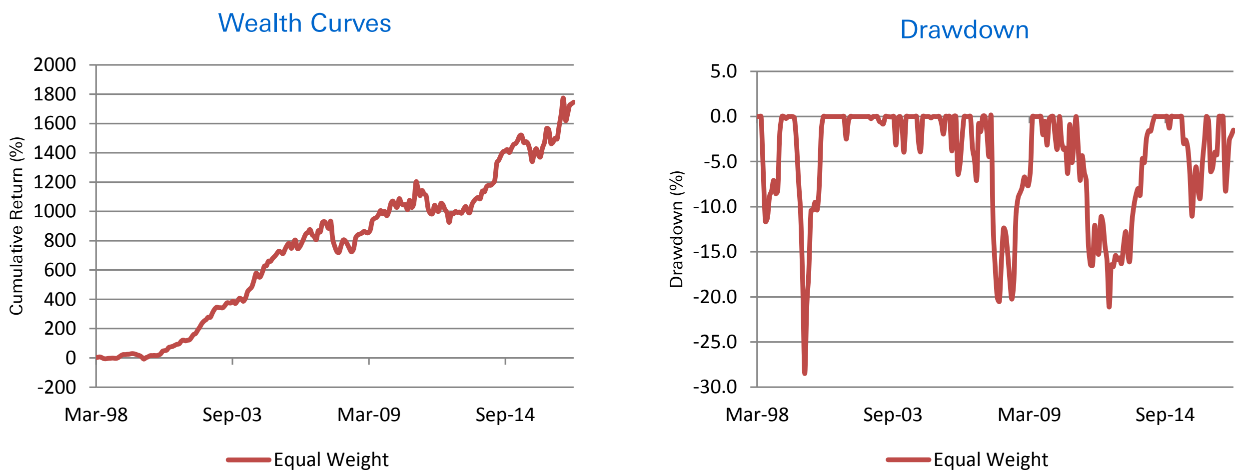


Source:Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Portfolio Performance

This portfolio performs reasonably well over the period. Though, we do see pronounced drawdowns around the Global Financial Crisis and European Sovereign Debt Crisis. However, this is to be expected given the interpretation of the Value premium as a reward for exposure to distress risk. It provides encouraging results for our Value factor as well as a good benchmark for the subsequent techniques.

Figure 7: Value (Equal Weight) Portfolio Performance - MSCI Europe



Factor Performance

	Return (%)	Volatility (%)	Sharpe Ratio	Max DD (%)
Equal Weight	16.35	13.74	1.19	-28.48

Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

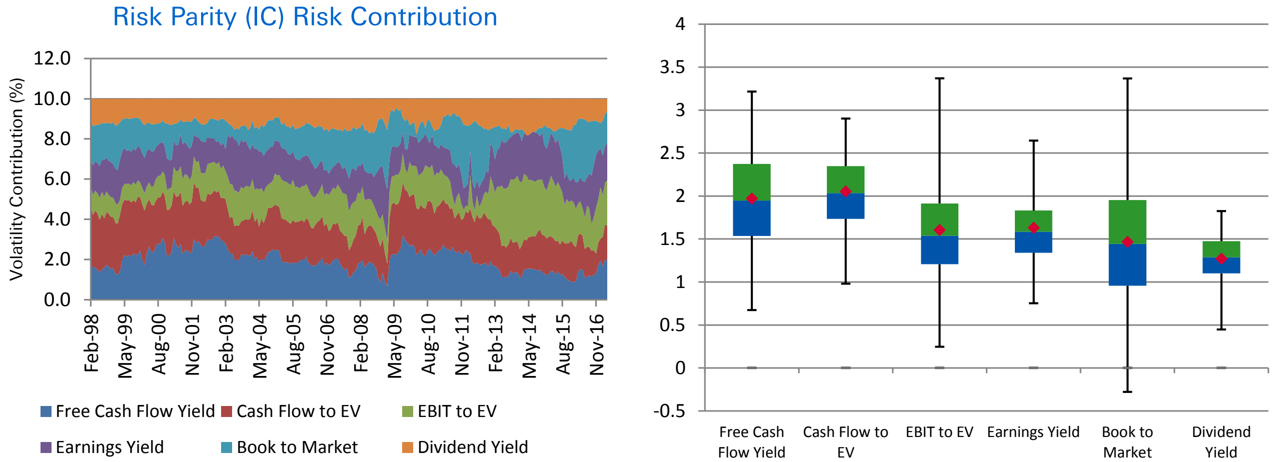
The Just Manager: Risk Parity

How can a portfolio manager allocate across their signals more equitably? A number of risk-based portfolio construction techniques such as inverse volatility weighting and risk parity have gained popularity in recent years for these types of problems. Due to the computational intensity, this technique has been largely restricted to cross-asset portfolios which have a limited number of assets. However, there is clear potential for these techniques in the realm of signal blending.

We focus on Risk Parity weighting as it more fully addresses the main issues with equally weighting, varied signal volatilities and correlations. This technique allocates each metric identical risk contribution on an ex-ante basis. Common implementations focus on blending asset or factor returns directly rather than accounting for the covariance of the current signal constituents. This subtle difference has a clear interpretation. The first approach treats the signals simply as investable assets, a portfolio construction problem. The second approach accurately treats the signals as stock level features, a signal blending problem.

The first approach ultimately fails to deliver a true Risk Parity solution when viewed through our custom metric attribution. Figure 8 shows the risk contribution of the various metrics when the Factor combination is based on the historical metric Information Coefficients. Instead of allocating to riskier factors, this technique consistently allocates more to the less risky metrics. In this case, we have increased contribution from Cash Flow and Enterprise Value based metrics which have provided more stable performance. However, it still provides unintended variation in the risk contribution from the underlying metrics.

Figure 8: Value (Risk Parity - ICs) Metric Risk Contributions - MSCI Europe

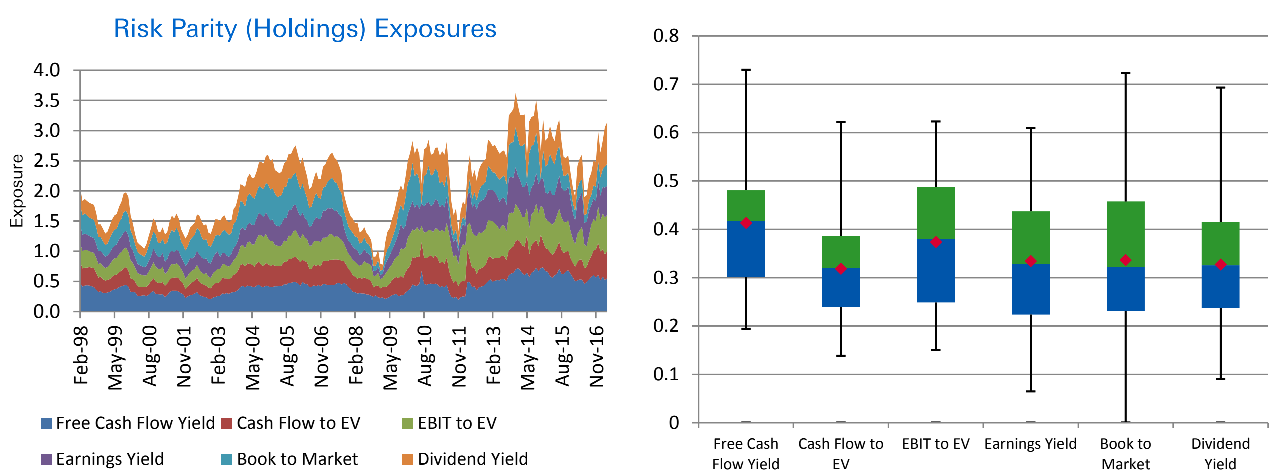


Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Metric Attribution

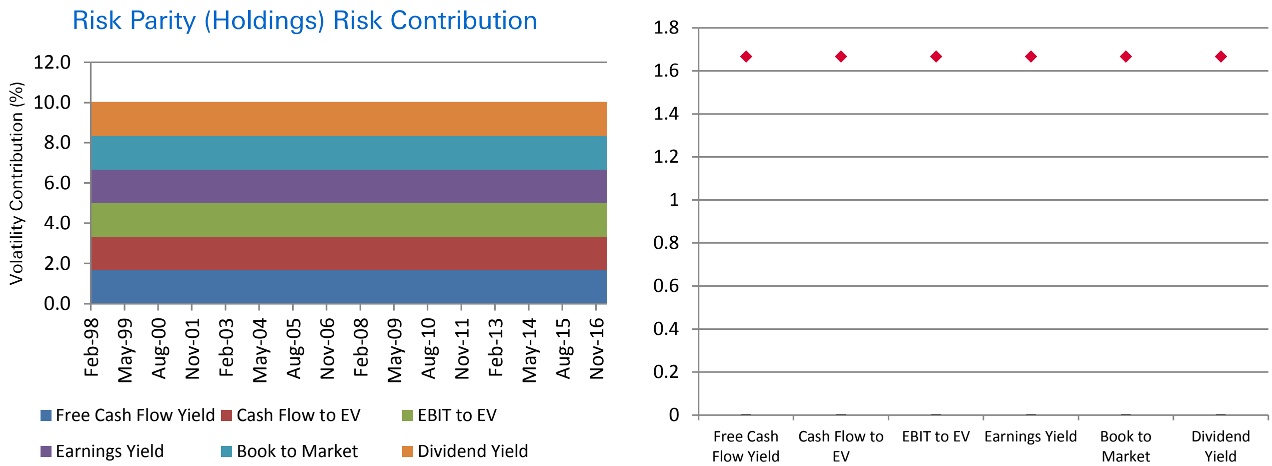
Instead, we apply the Risk Parity approach to a signal portfolio covariance matrix by using an asset level covariance matrix and our signal portfolio holdings. This new covariance matrix will reflect the relationship between the current signal constituents and any time varying exposures to additional risk factors. Figure 9 shows the exposures of our Risk Parity Value factor in terms of the underlying metrics. There is clearly more exposure variation than equal weighting. Though, the changes are subtle and do not result in extreme positions. Importantly, we can see that this approach does effectively balance the risk contribution across the underlying metrics as seen in figure 10.

Figure 9: Value (Risk Parity - Holdings) Metric Notional Exposures - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 10: Value (Risk Parity - Holdings) Metric Risk Contributions - MSCI Europe

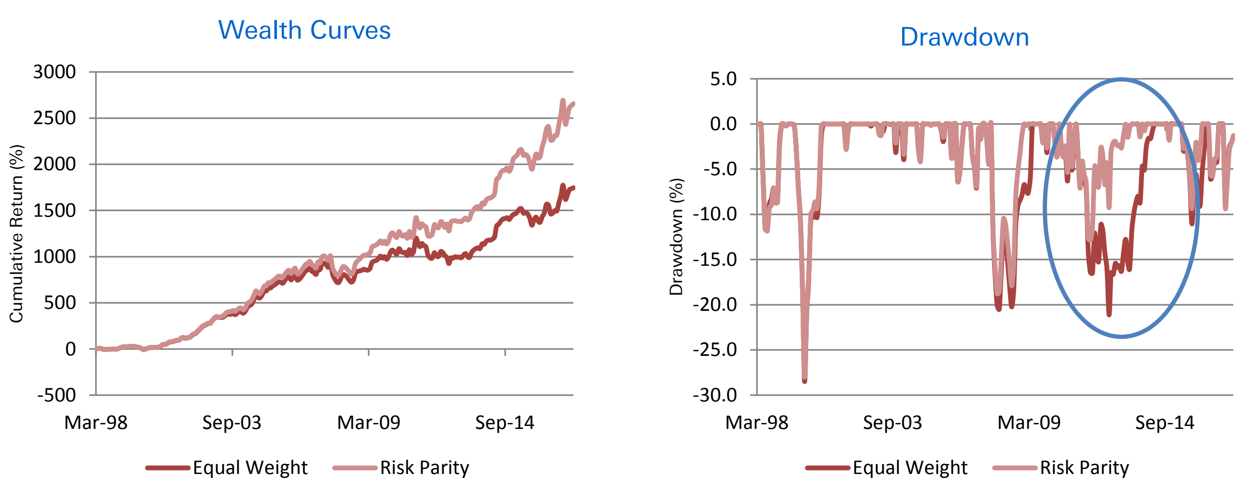


Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Portfolio Performance

The main objective of this technique is to correct the deficiencies in an equally weighted approach from a risk perspective. However, while secondary, it is useful to see the impact in terms of portfolio performance. We see an across the board improvement in comparison to the Equally Weighted factor. This Risk Parity blended factor delivered higher risk-adjusted returns and a shallower drawdown during the European Sovereign Debt Crisis compared to the Equal Weight Portfolio.

Figure 11: Value Portfolio Performance Comparison (Risk) - MSCI Europe



Factor Performance

	Return (%)	Volatility (%)	Sharpe Ratio	Max DD (%)
Equal Weight	16.35	13.74	1.19	-28.48
Risk Parity	18.80	13.54	1.39	-28.01

Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

The Meritocratic Managers: Alpha Risk Parity and Mean Variance Optimisation

Alpha Risk Parity *(ARP)*

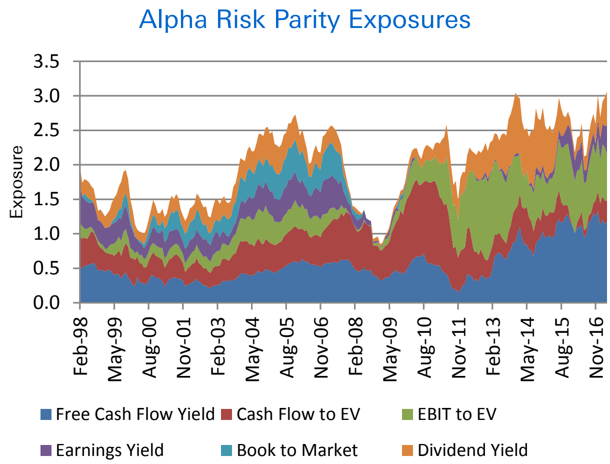
In the previous section, we showed that risk-based weighting methods are superior to naive methods when a manager does not have views on the relative performance of the signals. However, many managers will have prior beliefs on the relative merits of the various signals. These can be determined fully systematically using forecasting models, or more discretionarily based on the manager's view of the world. So, how can a portfolio manager with views on the relative merit of each metric allocate across their signals more effectively? Allocating signal exposure proportionate to the manager's expectations suffers from the same pitfalls as equally weighting. This will increase the exposure, but it will still overweight riskier metrics relative to the manager's intention by ignoring the signal covariance. However, you can extend the Risk Parity methodology to allocate risk proportionate to the expected performance rather than equally across signals. For example, a signal that is expected to perform twice as well relative to another signal receives twice the risk contribution.

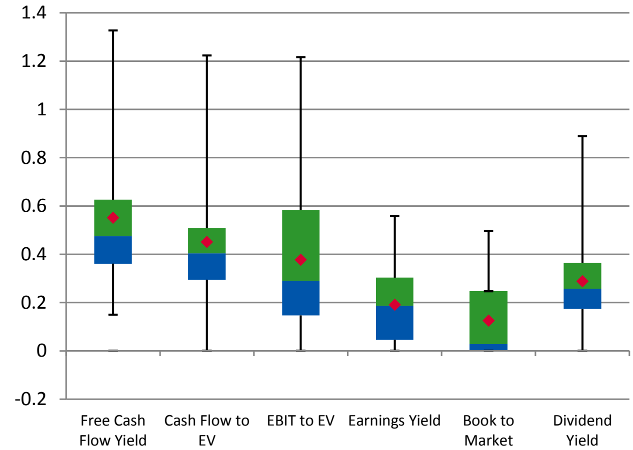
We implement this using the signal portfolio covariance matrix to estimate our risk contributions. This accurately reflects the current signal scores which provide a more accurate and timely perspective on risk. We let recent signal performance be our guide to expected performance, using the risk-adjusted IC (Mean IC/Std Dev IC) over the past 60 months. While rather simplistic, it helps us focus on the benefits of the blending methodology rather than confounding the results with a signal rotation model.

Metric Attribution

Figure 12 shows the time series evolution of the exposures of Alpha Risk Parity to the underlying metrics. Early in the period, we see relatively muted differentiation amongst the strategies as value metrics performed well generally. However, we have seen more differentiation in metric performance and subsequently risk budget towards the end of the test period. This is particularly true in the period following the Global Financial Crisis as the more defensive, cash flow based value metrics provided stronger performance. Subsequently, dividend yield and EBIT to EV play a stronger role as quantitative easing drove investors towards higher yielding names and hopes of an improving economy led investors to accept the risk associated with accruals, which differentiates Cash Flow and EBIT. These trends are highlighted in the left chart of figure 13 in terms of risk contribution.

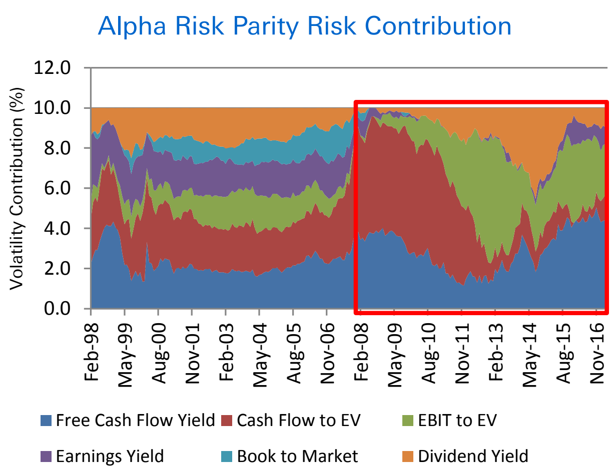
Figure 12: Value (Alpha Risk Parity) - Metric Notional Exposures - MSCI Europe

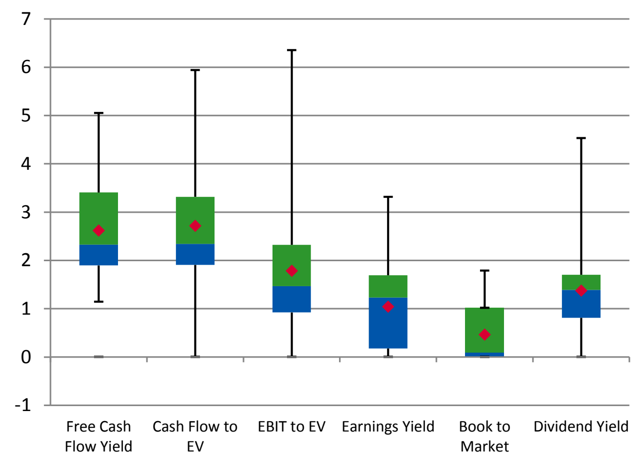




Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 13: Value (Alpha Risk Parity) Metric Risk Contribution - MSCI Europe





Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

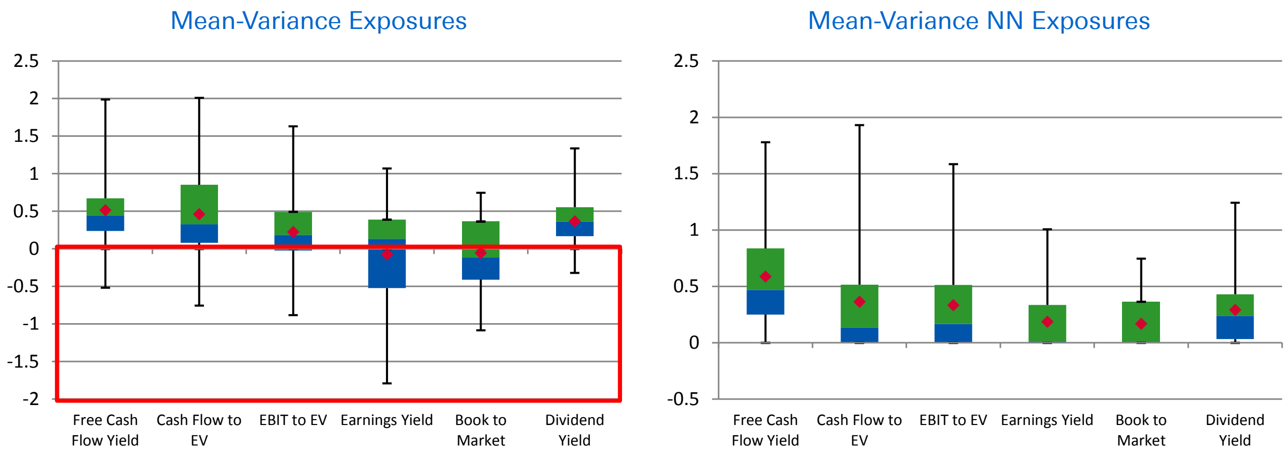
Mean-Variance Optimised (MVO)

Mean-Variance optimisation is perhaps one of the most ubiquitous techniques within portfolio construction and signal blending. It provides an optimal weighting in terms of Sharpe Ratio given the expected performance and covariance of the signal returns or ICs as in Grinold and Kahn (2000). Given high quality estimates, this should provide the best weighting as it explicitly maximises risk-adjusted performance rather than allocating heuristically as in ARP. While this is typically applied in factor return or IC space, we continue to work with the signal portfolio covariance matrix as it controls for secondary signal exposures.

However, there are number of concerns surrounding MVO based techniques. The results depend on the accuracy of the inputs which are assumed to be arbitrarily precise when they are in fact highly uncertain. In many instances, this can lead to concentrated solutions that underperform simpler methods. More fundamentally, it is often applied blindly within signal weighting without consideration of the objective. For example, the optimisation will highlight secondary exposures that have performed well (e.g. Quality like metrics in Value). This is compounded with an unconstrained optimisation as it also allows for negative exposures on the underlying components. This is not necessarily intuitive as a blending tool for metrics that are defined and oriented to capture the same latent factor.

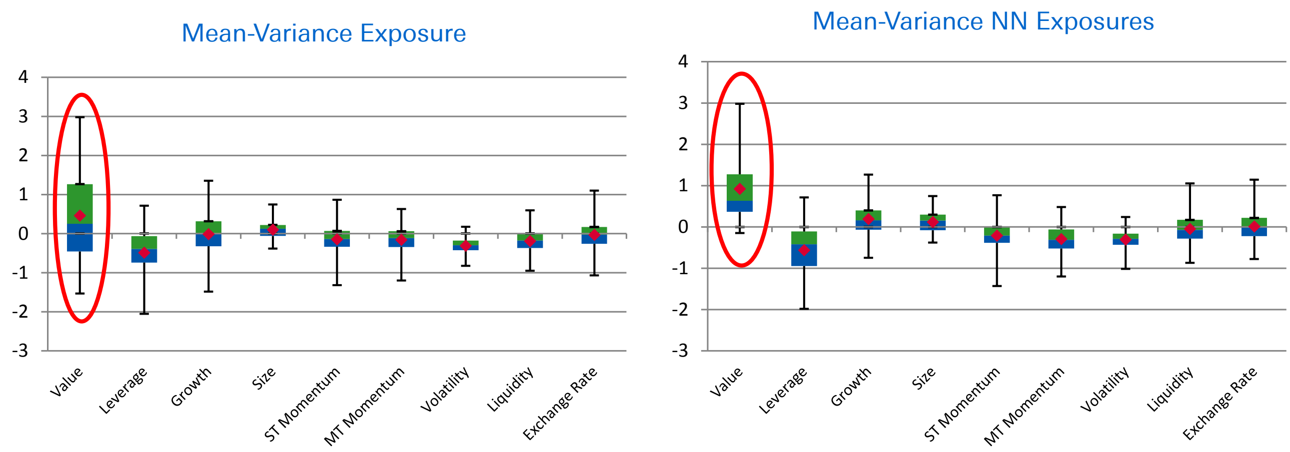
We can see this with Value in Figure 14 and Figure 15. The MVO solution tilts heavily towards the more quality like value metrics and negative exposures to more traditional value metrics. However, from a style exposure perspective, this has resulted in a strategy that tilts away from Value and towards low Leverage. This is not a great result when the objective is to build a Value factor! We also imposed a non-negativity constraint to mitigate the most extreme case of negatives position on metrics we believe to be rewarded in the long run. This leads to a more consistently positive exposure to Value which can be seen comparing the left and right charts in figure 15.

Figure 14: Metric Notional Exposure Analysis Unconstrained MVO vs Constrained MVO - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 15: Axioma Notional Exposure Analysis Unconstrained MVO vs Constrained MVO - MSCI Europe

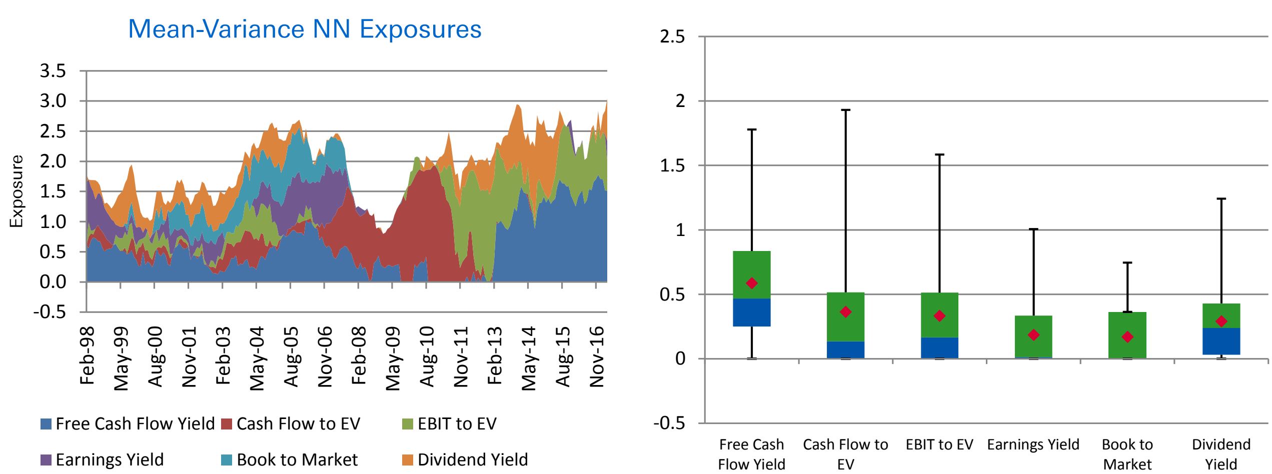


Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Metric Attribution

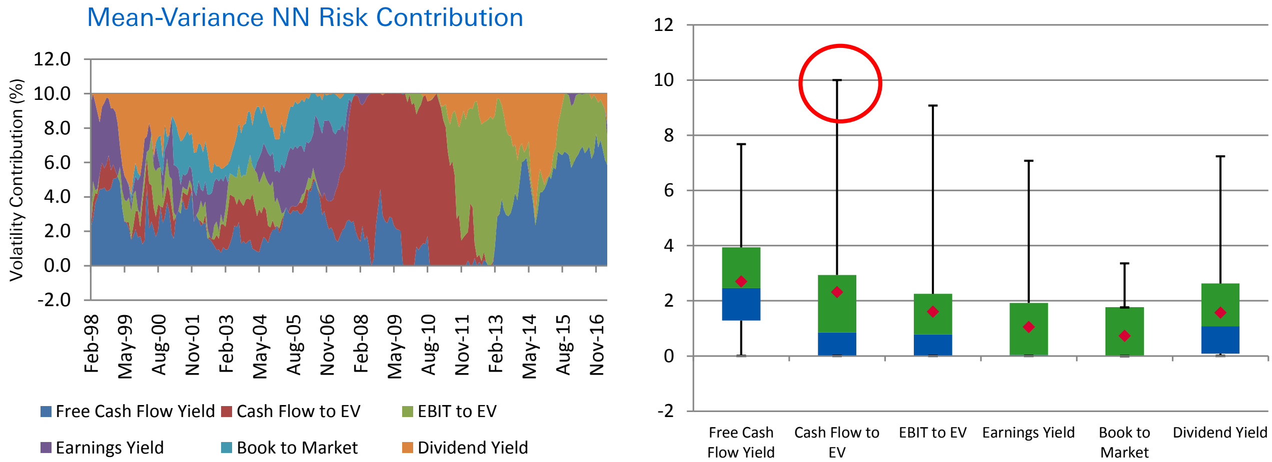
The left chart of Figure 16 shows the time series evolution of the notional exposures of non-negative MVO to the underlying metrics. We see more variation in exposures across metrics throughout the period which tend to be more concentrated compared to the other methods. In fact, following the Global Financial Crisis, we see that Cash Flow to EV is the only factor selected in a handful of periods. This can be seen most easily in terms of risk contribution in Figure 17 with Cash Flow to EV maximum contribution taking the entire 10% risk budget. In general, the indicator is heavily weighted towards Free Cash Flow Yield and Dividend Yield. As with ARP, the period coming out of the Global Financial Crisis has been dominated by defensive Value.

Figure 16: Value (Mean Variance Non-Negative) Metric Notional Exposures - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 17: Value (Mean Variance Non-Negative) Metric Risk Contributions - MSCI Europe

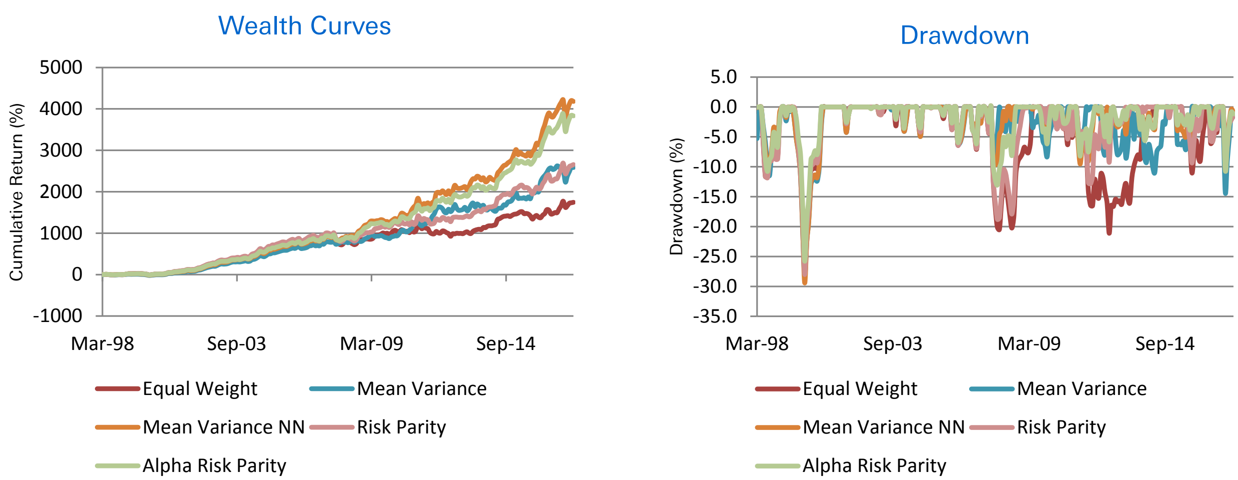


Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Portfolio Performance

We find that incorporating alpha in addition to risk has considerable benefits even when relying exclusively on historical performance. However, it seems beneficial to exercise some judgement with regards to extreme exposures. There is a substantial benefit for the MVO weighting to constrain to positive exposures to the underlying metrics (~20% increase in risk adjusted returns). Comparing ARP to and MVO, we see little difference in terms of risk-adjusted performance. However, we prefer ARP as it provides less concentrated signal weights and had less severe drawdowns.

Figure 18: Value Portfolio Performance Comparison (Risk and Alpha) - MSCI Europe



Factor Performance

	Return (%)	Volatility (%)	Sharpe Ratio	Max DD (%)
Equal Weight	16.35	13.74	1.19	-28.48
Risk Parity	18.80	13.54	1.39	-28.01
Alpha Risk Parity	21.02	12.61	1.67	-25.78
Mean Variance	18.64	13.37	1.39	-28.28
Mean Variance NN	21.55	12.79	1.69	-29.42

Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Metric Blending - Summary

Equally weighting metrics remains the most common technique in factor construction and provides a good benchmark for other techniques. However, it is an overly simplistic framework that takes implicit positions on riskier metrics. Alternative factor construction methodologies do a better job allocating risk across metrics to reflect the portfolio manager's intentions. We find these alternative portfolios improve both in terms of risk budgeting and risk adjusted performance. For the interested reader, we have also included an appendix discussing potential statistical blending methodologies.

Factor Blending: A Multi-Factor Comparison

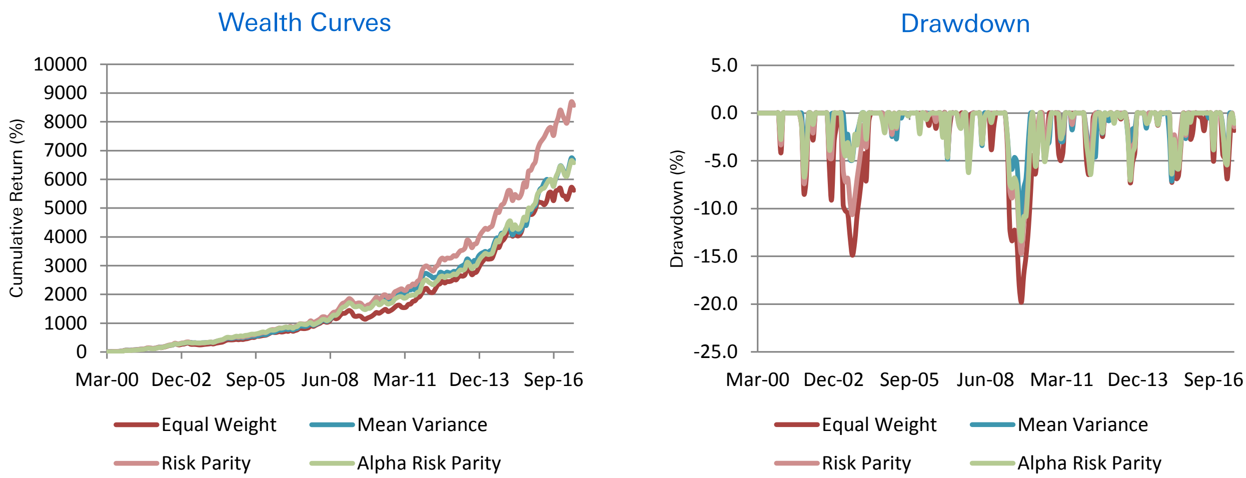
In our prior section, we found that alternative allocation strategies can be used for signal blending that improves risk-adjusted performance and are more robust to signal concentration. We extend the analysis to blending factors into a multi-factor model. In this exercise, we blend three common quantitative equity factors constructed using the Risk Parity methodology as described above. The backtested portfolios are constructed in the same manner as the previous section, Alpha Aligned dPortfolios scaled to 10% ex-ante volatility.

- **Value**: Earnings Yield, EBIT to Enterprise Value, Free Cash Flow Yield, Cash Flow to Enterprise Value, Book to Market, Dividend Yield
- **Quality**: Return on Invested Capital, Gross Profit to Total Assets, Accruals, Percent Accruals, Change in Asset Turnover, Asset Turnover, Net Margin, EBIT Margin, Net Debt Equity
- **Momentum**: First 11 Month, First 5 Month, EPS Revisions Breadth, CFPS Revisions Breadth

Portfolio Performance and Factor Attribution

We find the difference between techniques is less striking when combining our factors into a model. While Equally Weighting still lags the other methods, the gap is less extreme compared to the factor construction method. It did experience a deeper drawdown due to an oversized exposure to the Momentum crash in 2009. In fact the Equal Weight model lead to the most concentrated positions in terms of risk due to the large Momentum exposure which contributed so significantly that Value had a negative contribution to risk in a handful of periods which can be seen in Figure 20. We can see in Figures 22 and 23 that the alpha driven techniques provide similar exposures to the three factors. Though, ARP weights tend to evolve more smoothly while MVO weights tend to be quite noisy. Both methodologies downweight momentum due to its volatility. Interestingly, it is Risk Parity that leads performance in terms of risk-adjusted returns. This is in line with conventional wisdom that simply using recent performance is insufficient for a factor rotation strategy. The quality of the performance is essential for alpha driven blending strategies and needs to be considered when choosing a factor blending technique.

Figure 19: Multi-Factor Portfolio Performance Comparison (Risk and Alpha) - MSCI Europe

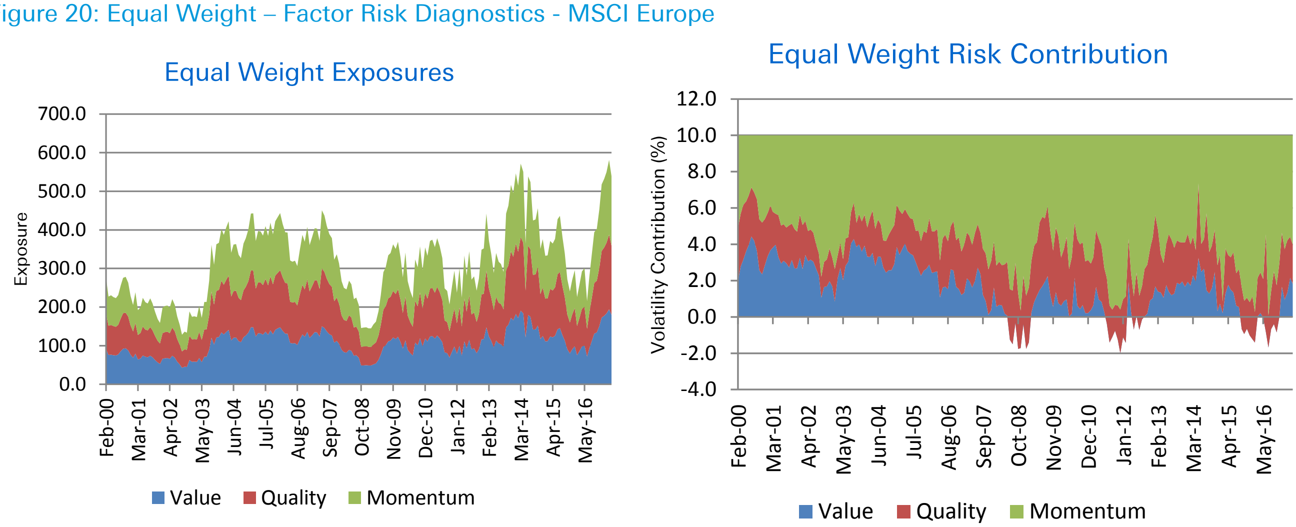


Model Performance

	Return (%)	Volatility (%)	Sharpe Ratio	Max DD (%)
Equal Weight	26.44	13.09	2.02	-19.80
Mean Variance	27.68	11.66	2.37	-11.13
Risk Parity	29.52	12.29	2.40	-14.70
Alpha Risk Parity	27.58	12.35	2.23	-13.40

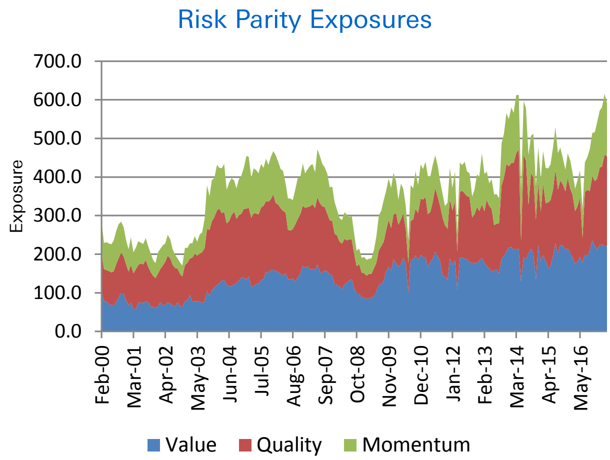
Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

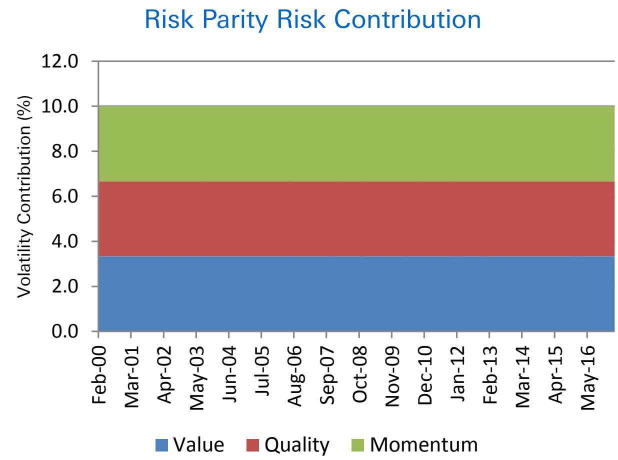
Figure 20: Equal Weight – Factor Risk Diagnostics - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

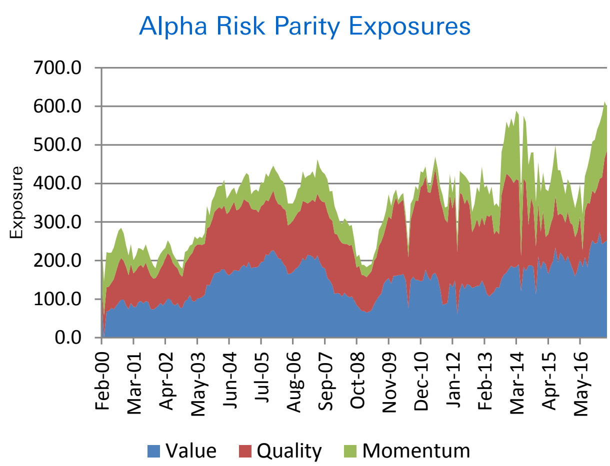
Figure 21: Risk Parity - Factor Risk Diagnostics - MSCI Europe

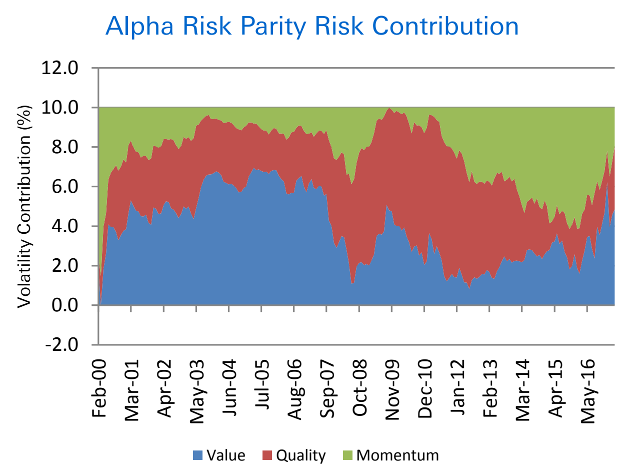




Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

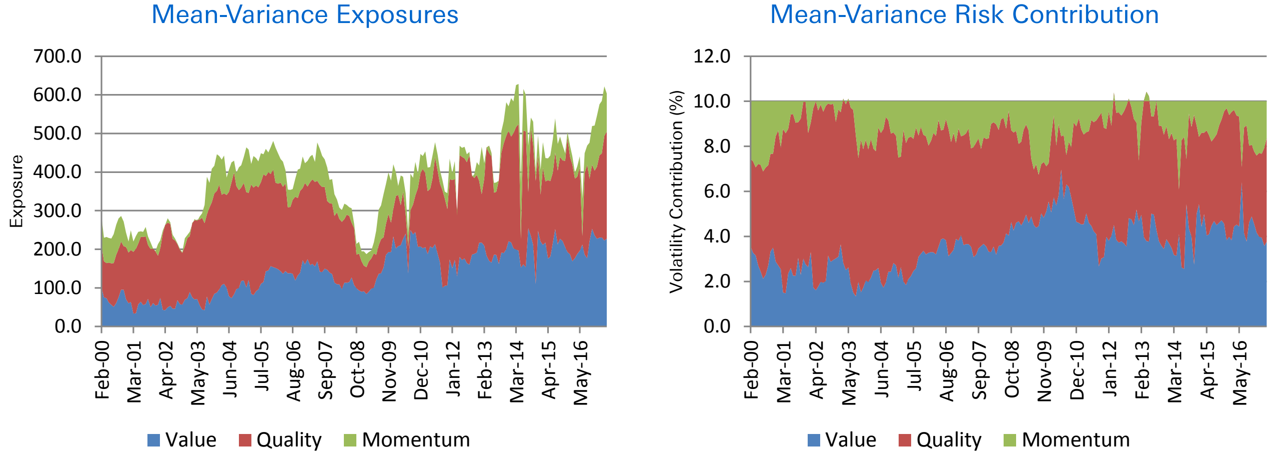
Figure 22: Alpha Risk Parity - Factor Risk Diagnostics - MSCI Europe





Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 23: Mean-Variance Factor Risk Diagnostics - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

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Appendix A: Discussion of Statistical Methods

Regression Methods: Ordinary Least Squares and Regularized Regression

Regression methods are some of the most widely used and valuable tools in econometrics. The most common technique is Ordinary Least Squares (OLS) regression. The Beta ols estimates are given by Equation 3.

$$\text{(Equation 3) } \hat{B} = \min_{\beta} ||y - XB||^2$$

OLS is a particularly tool when trying to both make predictions and draw inference about the underlying relationships. However, it is possible to improve prediction through the use of shrinkage techniques at the expense of biased coefficients. We implement an elastic net regression which shrinks the coefficients based on the sum of the absolute coefficients (L1 norm) and sum of squared coefficients (L2 norm) as shown in Equation 4.

$$\text{(Equation 4) } \hat{B} = \min_{\beta} ||y - XB||^2 + \lambda[\propto ||B||^2 + (1-\propto)||B||_1]$$

It can be shown that OLS, Ridge, and LASSO regressions are special cases of the elastic net (OLS: lambda=0,Ridge: alpha=1, LASSO: alpha=0). The choice of the shrinkage penalty can yield significantly different results. For example, the Ridge penalty will shrink the coefficients of correlated variables towards each other. LASSO on the other hand will tend towards sparse solutions, picking one of the correlated variables and discarding the rest. In the context of metric blending, this means that the factors will tend towards more balanced or concentrated metric exposures as α moves from 1 to 0.

We use a pooled regression of forward returns on metric scores with a 5 year rolling window to forecast forward beta adjusted returns, dropping the time dimension from the data. The coefficients are akin to estimates of expected factor returns that are time invariant. We select the lambda such that it minimizes the mean 10 fold cross-validated error. As with the main results, we impose a non-negativity constraint on the weights.

Latent Factor Analysis

Latent Factor Analysis is a statistical dimensionality reduction technique used to combine different measures. This approach looks to analyse the variations in a number of observed variables that are primarily driven by unobservable, common factors. This type of unsupervised learning has many applications across a variety of disciplines. If we think of the individual metrics as proxies for a non-diversifiable risk factor, we can use these techniques to extract the metric exposures to the underlying factor.

Again, we do not want to position against specific metrics within factor families. This makes popular techniques such as principal component analysis (PCA) unsuitable for our purpose. Fortunately, this type of problem extends to other domains (e.g. facial recognition, gene expression, speech enhancement) and recent research in machine learning has focused on providing tractable solutions

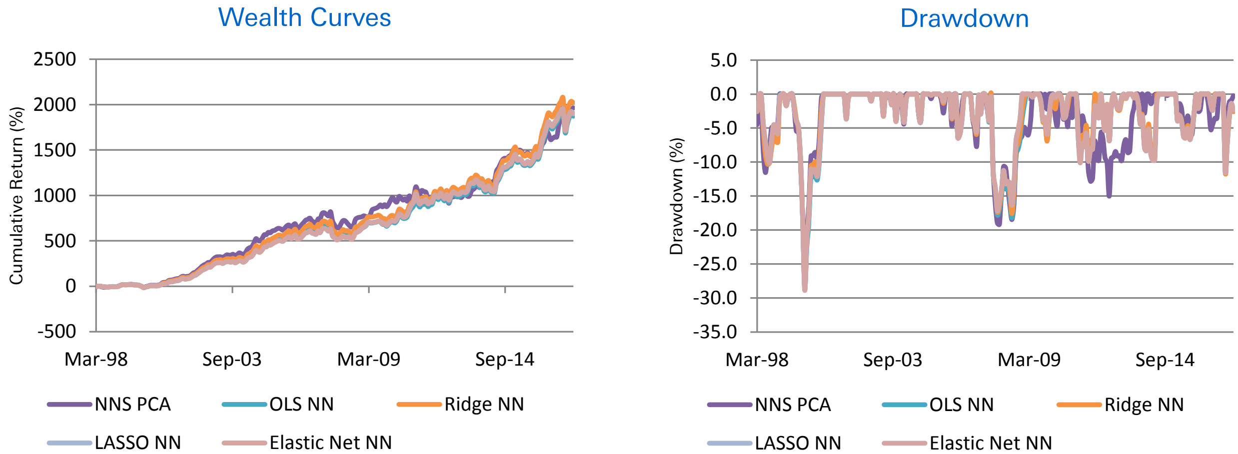
(Zass and Shashua 2006, Sigg and Buhmann 2008). We utilise the algorithm of Sigg and Buhmann to extract the first constrained principal component of the time series of ICs. We use the exposures from this analysis to weight our metrics to arrive at a final Value factor. This technique is most appropriate when the factor of interest is relatively homogenous as we are extracting the first non-negative principal component. For example, Value is a more focused concept (i.e. divergences in relative value). Though, it may be less appropriate for a Quality factor as it is a multidimensional concept (e.g. profitability, capital efficiency, low default risk).

Metric Attribution and Portfolio Performance

We highlight the results from the Elastic Net Regression. However, we note that all four methods produced very similar results in terms of both metric attribution and performance. This isn't particularly surprising given that, at their core, they have very similar objectives. However, this result highlights the benefits of shrinkage techniques are more pronounced with a greater number of predictors. For example, the feature selection element of LASSO and Elastic Net is critical when dealing with wide data (more factors than observations) as is often the case in areas like genome-wide association studies (GWAS). We note that the regression approach may be more beneficial when incorporating sparse signals, such as events, which can suffer from low breadth in specific periods. For example, a manager could run a pooled regression of forward returns on a multi-factor score and event driven signals to refine the signal.

Overall, we see marginal gains in terms of risk-adjusted performance when compared to the Equally Weighted benchmark. Though, the statistical methods underperformed the other methods above. The non-negative PCA typically allocated quite evenly across metrics with the exception of Book to Market leading to a slight outperformance towards the end of the period relative to Equal Weight. The regression methods on the other hand take more active positions across the metrics as it is effectively trying to maximize IC. However, it underperforms relative to the Mean-Variance which better accounts for the risks across signals.

Figure 24: Value Portfolio Performance Comparison (Statistical) - MSCI Europe

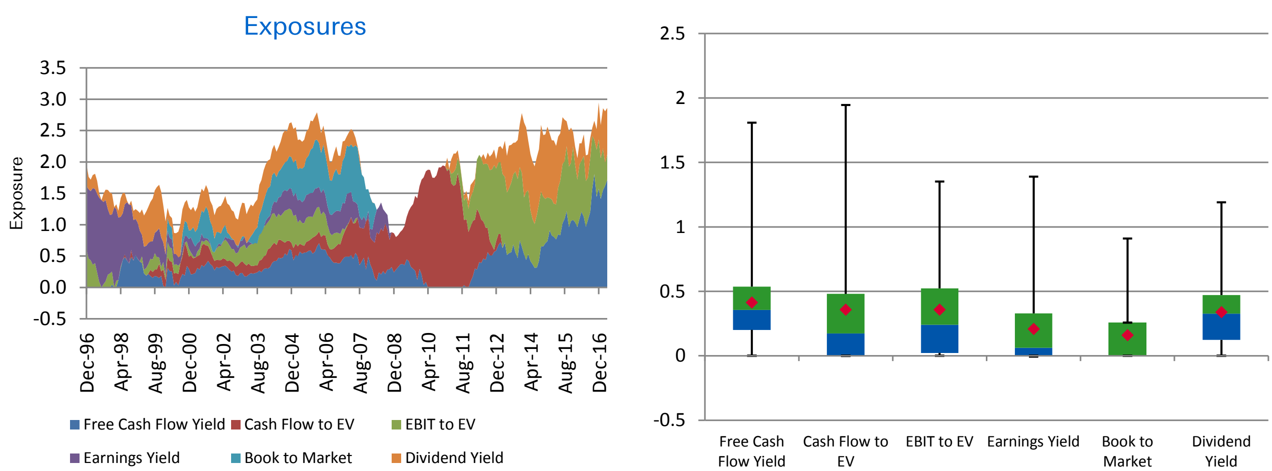


Factor Performance

	Return (%)	Volatility (%)	Sharpe Ratio	Max DD (%)
NNS PCA	17.03	13.56	1.26	-28.33
OLS NN	16.75	13.04	1.28	-28.58
Ridge NN	17.19	13.18	1.30	-28.39
LASSO NN	16.85	13.02	1.29	-28.85
Elastic Net NN	16.84	13.03	1.29	-28.86

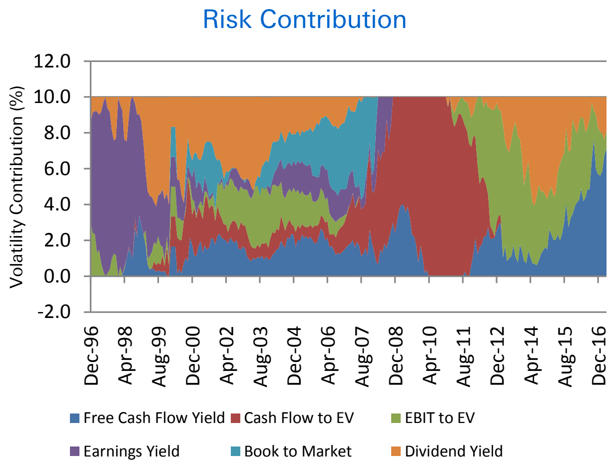
Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

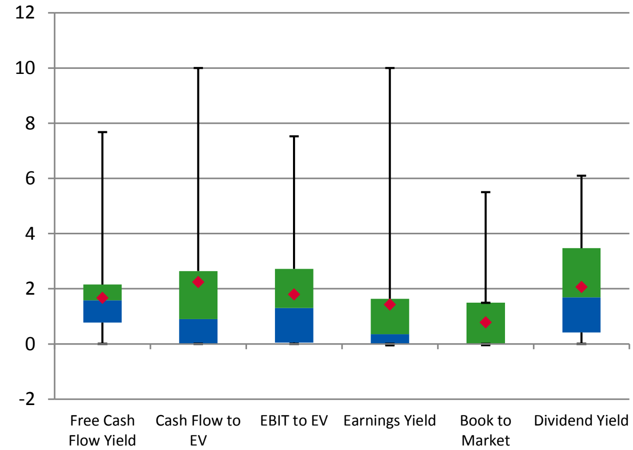
Figure 25: Value (Elastic Net) Metric Exposures - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

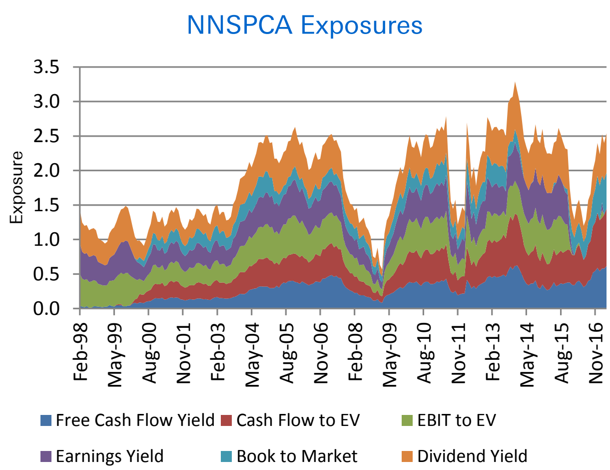
Figure 26: Value (Elastic Net) Metric Risk Contributions - MSCI Europe

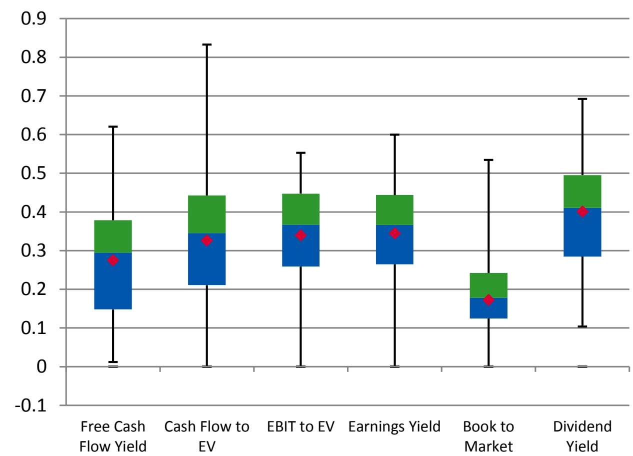




Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

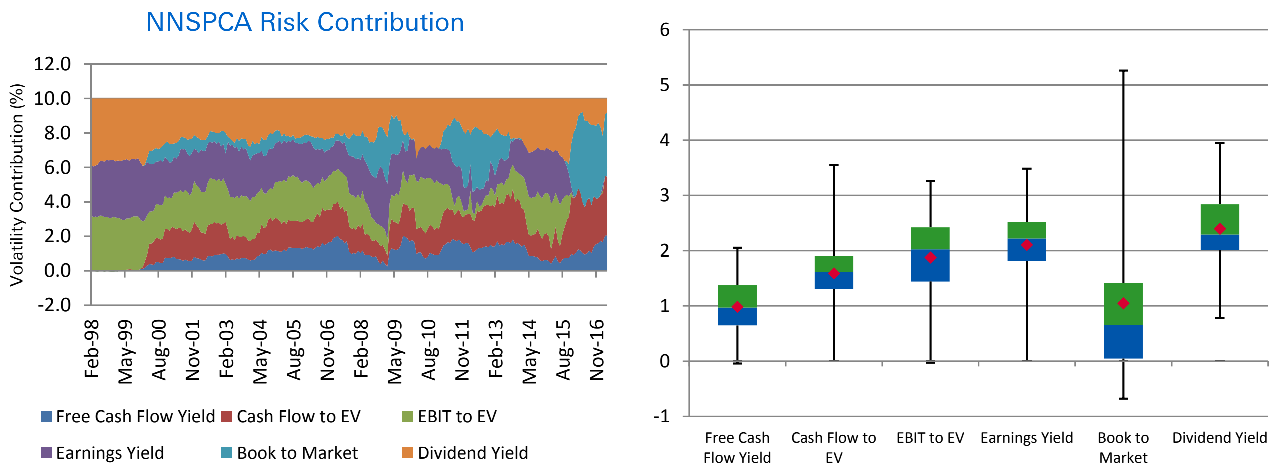
Figure 27: Value (NNSPCA) Metric Exposures - MSCI Europe





Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Figure 28: Value (NNSPCA) - Metric Risk Contributions - MSCI Europe



Source: Deutsche Bank, Factset, Thomson Reuters , Axioma , MSCI

Appendix 1

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