Quantitative Investment Strategies Panorama

Risk ‘n mix – The what, why & how of cross asset Risk factor investing

Primer

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Quantitative Cross Asset
Global

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Risk factor investing gains traction among asset owners

While the concept of Risk factors isn’t new, Risk factor investing across asset classes has gained traction only relatively recently. In our view, this has been driven by the rapid emergence of ‘Smart’ beta and alternative factors, combined with a growing frustration with the risk-reward of traditional asset allocation approaches, which typically involve capitalisation-weighted, geographical exposure across asset classes. Risk factor investing as a concept aims to identify a parsimonious set of *tradable* factors that have economically sound reasons to be associated with a consistently positive risk premium.

Generalising Carry, Momentum & Value across assets

Carry (expected returns if prices/rates/curves are unchanged), Momentum (preference for up-trending versus down-trending assets) and Value (preference for ‘cheap’ versus ‘expensive’ assets) are well documented Risk factors that lend themselves to generalisation across asset classes. Our hypothetical back-tested analysis since 2004 suggests that even simple expressions of Carry, Momentum and Value would have exhibited stable and very low levels of correlation (0% on average) with each other, ideal for factor-based portfolio creation.

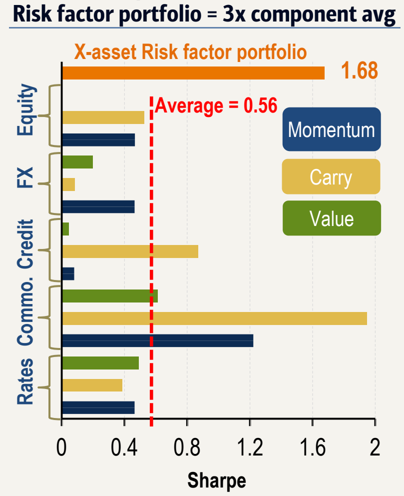
Favour Equal Risk Contribution-based portfolio allocations

When assessing allocation or optimisation techniques applied to Risk factors, we favour simplicity, parsimony and real-world suitability over complexity that is engineered for the sake of *historical* performance. We also prefer using methods that rely on historical risk (and correlation) over return metrics, as returns are harder to forecast based on past trends. We rank 6 different allocation methods applied to Carry, Momentum & Value factors based on (high) risk-adjusted returns, (low) risk, (low) asset turnover, (low) concentration risk & (high) diversifying power. Our hypothetical back-tested analysis suggests that the Equal Risk Contribution (ERC) allocation method would not only have achieved consistently high scores across these criteria but would also be likely to yield stable results for a wide range of factor strategies in different market environments.

Creating a cross asset portfolio of Risk factors

Investors may choose between (i) creating multi-asset Risk factor clusters (e.g., Value, Carry and Momentum) and combining these clusters into a Risk factor portfolio, (ii) creating asset class clusters (e.g., Carry, Value and Momentum in rates), and then combining those, or (iii) allocating to all the strategies in one go. Our back-tested analysis shows that a 2-step allocation process which combines Risk factors into groups and then combines them (using ERC at both stages) would have offered a solid balance between the stability of weights, concentration risk, diversification and historical risk-adjusted performance. Indeed, our hypothetical back-testing suggests this approach would have delivered an increase in portfolio Sharpe of 3x vs the average Sharpe of the simple constituent strategies from 2006 to 2016 (Chart 1).

Chart 1: Sharpe of ERC-based x-asset Risk factor portfolio = 3x component avg



Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance

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Making the case for Risk factor investing

In this piece, we review popular Risk factors and consider how they can be generalised across equities, credit, rates, currencies and commodities. We motivate why Risk factor investing in our view is more than just a re-classification exercise and adds to the toolkits of both portfolio and risk managers. Finally we outline multiple ways to combine Risk factor exposure across asset classes.

Risk factors are not new, but Risk factor investing is

In the last several years, Risk factor investing has captured the imagination of asset owners worldwide, with systematic means of harvesting potential returns from distinct, rewarded risks across asset classes becoming increasingly popular. While Risk factors themselves are not new and trace their history way back to the formulation of the Capital Asset Pricing Model (CAPM) in the 1960s, their use in investable, systematic strategies for constructing multi-asset portfolios is relatively recent. In our view, this is being driven by two secular trends:

1. **A growing frustration with the risk-reward of traditional building blocks** of portfolios (e.g. capitalisation weighted exposure to regions and asset classes), coupled with a desire to identify and better manage *common* risks across asset classes. Exhibit 1 depicts the typically high correlation between geographical regions of the same asset class and between asset classes, e.g., equities vs HY credit, govt. bonds vs IG credit and EM equities vs diversified commodities. Worryingly, these high correlations have tended to increase further in crises such as the 2008 GFC, where diversification benefits may be expected (see Chart 7). In part due to this, investors are increasingly adopting 'risk'-based allocation processes as opposed to capital allocations.

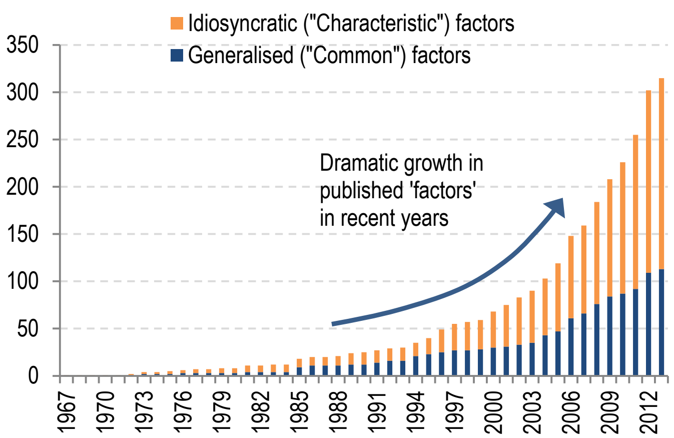
Exhibit 1: In the long run, regional exposure has offered limited diversification benefits as have some asset class combinations (encircled areas)

		Equity				10y Govt. Bonds				Credit						Commodity	
		US	EU	Japan	EM	US	Germany	Japan	UK	US IG	EU IG	Asia IG	US HY	EU HY	Asia HY	BCOM	Gold
Equity	US		82%	55%	73%	-33%	-35%	-21%	-33%	-8%	-4%	-12%	54%	46%	31%	37%	8%
	EU	82%		62%	76%	-36%	-38%	-26%	-37%	-7%	-2%	-13%	54%	51%	33%	33%	3%
	Japan	55%	62%		65%	-28%	-30%	-43%	-32%	0%	1%	-6%	45%	46%	36%	28%	2%
	EM	73%	76%	65%		-25%	-31%	-27%	-27%	6%	3%	2%	57%	54%	48%	51%	27%
10y Govt. Bonds	US	-33%	-36%	-28%	-25%		73%	43%	72%	77%	50%	71%	-9%	-13%	2%	-15%	12%
	Germany	-35%	-38%	-30%	-31%	73%		45%	83%	58%	70%	52%	-13%	-15%	-5%	-20%	6%
	Japan	-21%	-26%	-43%	-27%	43%	45%		40%	28%	30%	30%	-12%	-15%	-8%	-11%	6%
	UK	-33%	-37%	-32%	-27%	72%	83%	40%		55%	51%	50%	-13%	-18%	-6%	-18%	9%
Credit	US IG	-8%	-7%	0%	6%	77%	58%	28%	55%		72%	81%	39%	36%	38%	2%	10%
	EU IG	-4%	-2%	1%	3%	50%	70%	30%	51%	72%		63%	33%	40%	34%	0%	2%
	Asia IG	-12%	-13%	-6%	2%	71%	52%	30%	50%	81%	63%		29%	29%	54%	2%	17%
	US HY	54%	54%	45%	57%	-9%	-13%	-12%	-13%	39%	33%	29%		87%	63%	35%	6%
	EU HY	46%	51%	46%	54%	-13%	-15%	-15%	-18%	36%	40%	29%	87%		67%	29%	2%
	Asia HY	31%	33%	36%	48%	2%	-5%	-8%	-6%	38%	34%	54%	63%	67%		27%	12%
Commodity	BCOM	37%	33%	28%	51%	-15%	-20%	-11%	-18%	2%	0%	2%	35%	29%	27%		48%
	Gold	8%	3%	2%	27%	12%	6%	6%	9%	10%	2%	17%	6%	2%	12%	48%	

Source: BofA Merrill Lynch Global Research. Data is from Jan-2003 to Jan-2016. US equity (MXUS), EU equity (MXEU), Japan equity (MXJP), EM equity (MXEF), US 10y treasury (MLT1ER10), Germany 10y Bund (MLEIRXER Index), Japan 10y JGB (MLEIJBER), UK 10y Gilt (MLEIGER), US IG (C0A0), EU IG (ER00), Asia IG (ACIG), US HY (H0A0), EU HY (HE00), Asia HY (ACHY), Bloomberg Commodity Index (BCOM), Gold (MLCXGCER)

2. **The recent rapid growth of *Smart beta*** (i.e., enhanced, optimised or adaptive, investable Risk factor exposure, see Chart 2) as well as alternative tradable Risk factors linked to implicit assets like volatility, correlation and dividends. This has, in turn, led to development of several systematic rules-based strategies/indices that are designed to isolate the return of factors which have typically earned a risk premium over long periods of time.

Chart 2: A 'zoo' of 300+ Risk factors has emerged in published form in recent years, a direct contributor to the 'Smart' beta phenomenon



Source: Harvey, Liu & Zhu, "...And the cross-section of expected returns", Apr 2013. Factors are from papers in finance, economics & accounting journals & SSRN working papers, collated by the authors. http://ssrn.com/abstract=2249314

Exhibit 2: Value, Size, Trend/Momentum, Quality, Low Vol and Carry are some of the best known Risk factors within equities

Source: BofA Merrill Lynch Global Research

Clearing the air on definitions: Risk factors versus Risk premia

The terms Risk factor and Risk premium are sometimes used interchangeably. In our view, it is important to outline the (subtle) differences between the terms at the outset. A Risk factor is simply any variable that may contribute to some proportion of an asset's return (and risk), e.g. inflation (a macro-economic factor), duration (an asset class-specific factor) or Carry (a broad technical factor). Risk premium on the other hand is the expected compensation in excess of some lower risk benchmark for owning the asset.

Now, a positive Risk premium may be associated with a number of Risk factors, e.g. Equity Risk premium associated with well documented[1] factors like Value, Size, Momentum, Quality, Low Vol, Carry, and so on (Exhibit 2), rather than just CAPM market beta. We therefore prefer associating the term Risk premium with broad compensation for exposure to a wide range of risks while Risk factors themselves are (ideally) indivisible.

> In our view, the ultimate goal of factor investing is to identify a parsimonious set of *tradable* Risk factors that have economically sound reasons to be associated with a consistently positive Risk premium

Towards a universe of cross-asset Risk factors

In recent years, academic research and market practitioners have attempted to generalise a number of popular Risk factors across asset classes. Using publicly available data from MSCI, BofA Merrill Lynch Global Research and Bloomberg as described in Table 1, we show how the factors **Carry**, **Momentum** and **Value** may be expressed very simply across multiple asset classes[2]. While it is technically possible albeit more operationally challenging to generalise more factors like Size, Quality, etc, we limit our focus to these three given their relative prominence in practice and academic literature. Finally, it is important to acknowledge the rapid growth of **Volatility** as an alternative Risk factor, which not only lends itself naturally to generalisation across asset classes but has also become increasingly tradable in recent years. For the purpose of this piece, we focus on linear Risk factors.

[1] Fama & French (1992); Jegadeesh & Titman (1993), Baker & Haugen (2012)
[2] All 15 time series used here *attempt* to isolate the factors they represent (i.e. they are constructed as long-short strategies. Not all are investable & are only indicative.

Table 1: Generalising Carry, Momentum and Value across asset classes

	Risk factors		
	Carry	**Momentum**	**Value**
Asset classes	*(Positive) expected returns if status quo prevails*	*Behavioural preference for winners over losers*	*Compensation for risk of buying cheap assets*
Equities[1]	Long high div yield stocks / short market	Long high price performance stocks / short market	Long cheap stocks / short market
Credit[2]	Long 3-5yr / short 10yr+ duration neutral	Long +ve momentum / short -ve momentum corp bonds	Long cheapening / short richening corp bonds
Rates[3]	Long 4th Eurodollar future / short 1st Eurodollar future	Long +ve momentum / short -ve momentum govt bonds	Long cheapening / short richening govt. bonds
FX[4]	Long high-yielding / short low-yielding currencies	Long +ve momentum / short -ve momentum currencies	Long undervalued / short overvalued currencies
Commodities[5]	Long far-dated / short near-dated commodity futures	Long +ve momentum / short -ve momentum commodity futures	Long cheapening / short richening commodity futures

Source: BofA Merrill Lynch Global Research, MSCI indices, BofA Merrill Lynch bond & bond futures indices, Bloomberg.
[1]Equity: Carry-> M2USAHDV & M5EUHDVD, Momentum-> MXUSMMT & MOEUMMT, Value-> MVUDUS & MXEU000V. Short: MSCI US & EU
[2]Credit: Carry-> C2A0 & C9A0 (US), ER02 & ER09 (Europe), AC02 & AC09 (Asia), UN02 & UN09 (UK). Momentum & Value-> C0A0 (US), ER00 (EU), ACIG (Asia) & UN00 (UK). All strategies use excess returns of BofA Merrill Lynch bond indices
[3]Rates: Carry-> Eurodollar futures (EDA Comdty CT), Momentum & Value use 10y Govt bond indices for the US (MLT1ER10), Germany (MLEIRXER), Japan (MLEILBER) and UK (MLEIGER)
[4]FX: G10 currency data. Carry-> highest yielding currencies vs lowest yielding, Momentum-> rank 1m spot returns, Value-> CPI-based purchasing power parity
[5]Commodities: Curve Carry (MLCXA6LS), Momentum (MLCXMSER), Value (MLCIMRLS)

Carry: 'If all else is equal'

Classical carry trades where an investor borrows in a low rate currency to lend in a higher rate currency have been much discussed in academic literature[3]. While there is little consensus when explaining the cross section of returns of such strategies, most commentators acknowledge that they are profitable in the long run, apparently flouting the concept of uncovered interest parity (i.e. the difference in interest rates should be the same as the expected change in exchange rates). Put another way, if exchange rates do not change (i.e. if all else is equal), the returns of such strategies are proportional to interest rate differentials. More broadly, we may define carry as the expected P&L of a strategy when prices are unchanged or status quo prevails – see for example our note Carry me higher, Jan-13.

In rates, we estimate returns of a Carry strategy that exploits the forward rate bias phenomenon in rates markets (forward rates tend to overestimate the future realisation of rates in an upward sloping yield curve) via going long the 4th Eurodollar future (3mth USD Libor rate up to 1yr forward) and short the 1st Eurodollar future (3mth USD Libor rate up to 3m forward), rolled every quarter.

In equities, we consider the beta-neutral returns of high div yield stocks in the US and Europe using MSCI indices (caveat: this is not as clean an exposure to equity Carry as going long high div yield stocks vs shorting low yield stocks, but it is operationally easier to synthesize and potentially less costly/prone to short crowding risk)

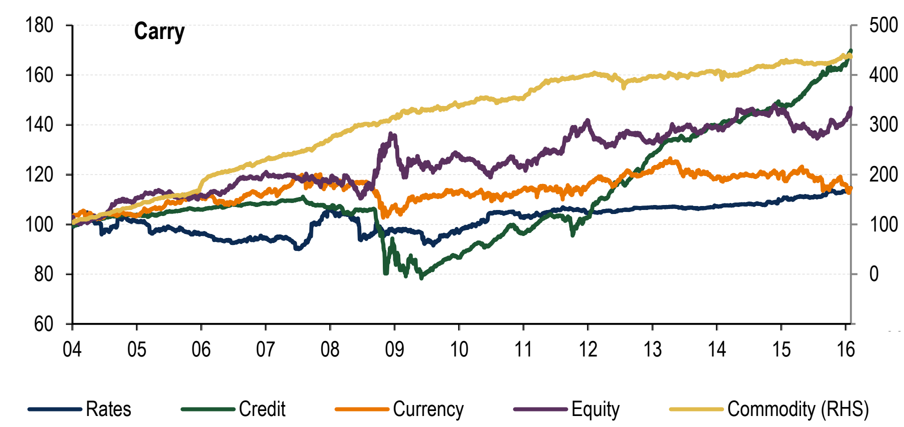
In credit, we estimate Carry returns by going long excess returns of IG corporate bonds in the US & Europe at the 3-5yr part of the curve, and short the 10yr part of the curve in duration-neutral fashion.

In commodities, we extract curve Carry across multiple commodities by going long far-dated futures contracts and short near-dated futures contracts.

Chart 3 shows the historical hypothetical back-tested results of Carry strategies across the asset classes, as defined above.

[3] See Lustig & Verdelhan (2007), Burnside et al (2011)

Chart 3: Carry strategies across asset classes



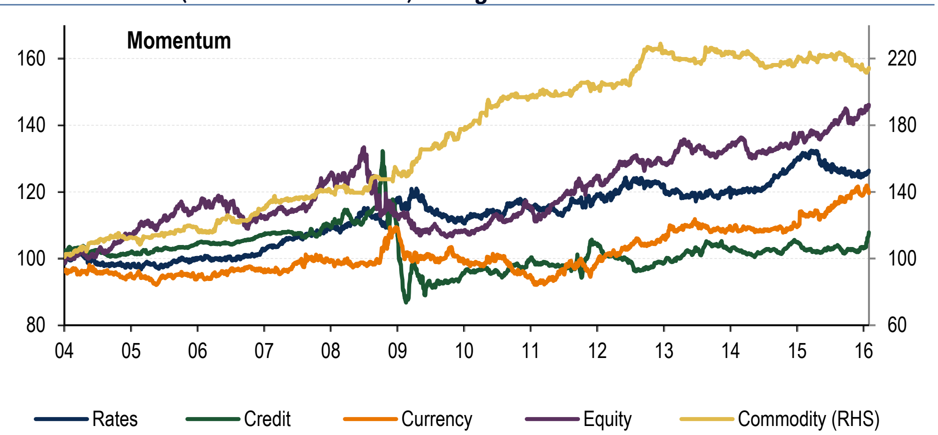
Source: BofA Merrill Lynch Global Research. Data: Jan-04 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Momentum: The trend is your friend

The momentum effect relies on a continuation of past patterns of asset returns. The capture of any momentum effect requires the selection of assets based on past return or return-related metrics in the expectation that such performance patterns are repeated in the future. Empirical academic literature examining the evidence for a momentum effect in asset prices is vast. Levy (1967) suggests stocks with higher than average past returns exhibit significant abnormal future returns. Grinblatt and Titman (1989), Jegadeesh and Titman (1993), Chan, Jegadeesh and Lakonishok (1996) and Carhart (1997) find that momentum is a useful indicator of future performance, which is not subsumed by market risk, size or value. Moreover, a rationale based on behavioural finance has been developed for the existence of momentum effects, based on investor under and over-reaction to news[4].

In **equities**, **credit**, **rates**, **currencies** and **commodities**, we characterise the Momentum factor by going long positive trend assets and short negative trend assets, where price trend is established by the crossing of short and longer dated moving averages or by ranking short term strategy returns in descending order. Chart 4 shows the historical hypothetical back-tested evolution of Momentum strategies across asset classes.

Chart 4: Momentum (or cross sectional trend) strategies across asset classes



Source: BofA Merrill Lynch Global Research. Data: Jan-04 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

[4] Daniel, Hirschleifer, and Subrahmanyam (1998) and Barberis, Shleifer and Vishny (1998)

Value: Cheaply does it

Numerous studies have shown a 'value' effect in equity asset pricing, whereby stocks that have low prices relative to their fundamentals (i.e. they are 'cheap') have empirically exhibited relatively superior risk-adjusted returns versus the broader market. For instance, Basu (1983) and Keim (1983) demonstrated that stocks selling at low prices relative to their earnings and book values or at low multiples to their sales have generated higher than average returns for investors. Also notably, Fama and French (1998) documented a strong value effect in both U.S. & international stock markets.

While value investing has been highly documented within equities since Benjamin Graham and David Dodd's work in the 1930s, there are many different measures of value that compete for investor acceptance. For equities, we assess Value using three fundamental metrics (book value to price, 12m forward earnings to price and dividend yield as determined by MSCI) and short the broader market in beta-neutral fashion.

Like in equities, there is little consensus on how to define fundamental value across different asset classes. We discuss one potential approach that relies on price technicals and compares prevailing asset prices to long run averages to quantify Value.

In credit, we calculate Value returns by going long corporate bonds which cheapened the most (i.e. the highest ratio of recent credit spread/ median 5y credit spread) and short ones which richened the most.

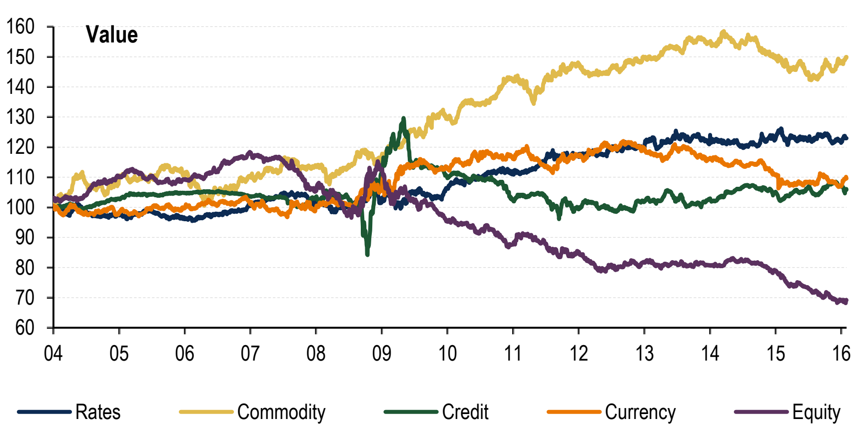
In currencies, we extract Value across G10 currencies by going long the most undervalued currencies (according to purchasing power parity) and short the most overvalued currencies.

In rates, we estimate Value returns by going long the government bonds that cheapened the most (i.e. the highest ratio of recent yield/ median 5y yield) and short the ones that richened the most.

In commodities, we consider a strategy that goes long the futures contracts that have cheapened the most (i.e. the lowest ratio of recent prices to average 5y prices) and short the futures contracts that have richened the most.

Chart 5 shows the historical hypothetical back-tested evolution of returns attributable to the Value factor, as per our definitions.

Chart 5: Value across asset classes (equity Value strategies have struggled the most in the last 10yrs)



Source: BofA Merrill Lynch Global Research. Data: Jan-04 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance

Important note: Most of our expressions of Carry, Momentum and Value across assets are simple, no-frills strategies. In reality, practical considerations like liquidity, market depth and crowding risk will help build market structure intelligence that, in conjunction with product innovation, should help create more robust factor building blocks.

Isolating factor exposure is rewarded with diversification

Exhibit 3 shows the pair-wise correlations of the strategies described above from Jan-04 to Jan-16. Apart from a distinct difference at the outset versus Exhibit 1 which had generally higher pair-wise asset correlations and hence bolder colours (we acknowledge that long-short portfolios may be market neutral and therefore have lower correlations), we note that:

- **Value & Momentum diversify each other**: Value & Momentum strategies exhibited the most negative correlation among factor pairs in our matrix. This is true not just in Rates & Credit where we may expect to see negative correlations given the way we express Value returns (by favouring mean reversion of long term price trends), but also in Equities, where we define Value using fundamental ratios & not price technicals. This suggests that Value & Momentum can be good diversifying factors, and is consistent with the intuition that when markets are momentum-driven, Value strategies may struggle as cheap assets may get cheaper still (and expensive assets more expensive). Indeed, Chart 6 supports this intuition as it shows that Value and Momentum strategies would have diversified each other (mostly negatively correlated), particularly in crises like the 2008 GFC.

- **Equity Value & Carry exhibited the highest correlation**: Market-neutral returns of cheap stocks and those of high div yield stocks (subject to div sustainability and persistence screens as determined by MSCI) exhibited the highest pair-wise correlation historically (~70%). Given dividend yield is often an input in value estimation, this is perhaps not so surprising and is consistent with the intuition that cheap stocks (which may have distressed prices) also happen to be those with relatively high dividend yields on average, i.e. offering carry opportunities if prices are stable.

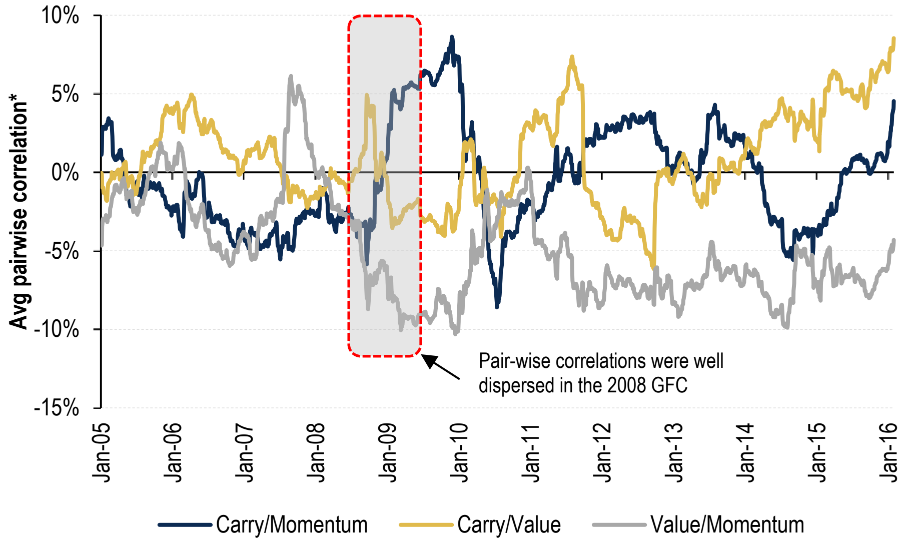
- **Average historical pairwise correlation of the strategies is ~0%**. Overall, the strategies would have had almost 0 correlation with each other from Jan-04 to Jan-16, a favourable result from the perspective of factor portfolio construction.

Exhibit 3: The pair-wise correlations* of long/short Risk factor strategies were historically low

		Rates			Commodity			Credit			FX			Equity		
		Carry	Trend	Value	Carry	Trend	Value	Carry	Trend	Value	Carry	Trend	Value	Carry	Trend	Value
Rates	Carry		7%	-9%	-4%	3%	-1%	4%	8%	-9%	-15%	2%	5%	4%	2%	-3%
	Trend	7%		-31%	1%	3%	0%	8%	7%	3%	2%	3%	5%	-1%	8%	-3%
	Value	-9%	-31%		-3%	3%	4%	-18%	-12%	-1%	-7%	1%	-2%	-4%	-1%	-5%
Commo.	Carry	-4%	1%	-3%		-10%	2%	6%	0%	-1%	3%	-1%	-6%	1%	-2%	3%
	Trend	3%	3%	3%	-10%		2%	4%	0%	-2%	13%	2%	-3%	1%	-8%	2%
	Value	-1%	0%	4%	2%	2%		-5%	-2%	-7%	-2%	-8%	4%	4%	-14%	0%
Credit	Carry	4%	8%	-18%	6%	4%	-5%		41%	-5%	2%	0%	-15%	1%	3%	-1%
	Trend	8%	7%	-12%	0%	0%	-2%	41%		-49%	-4%	7%	-6%	14%	-8%	8%
	Value	-9%	3%	-1%	-1%	-2%	-7%	-5%	-49%		7%	-6%	4%	-5%	0%	2%
FX	Carry	-15%	2%	-7%	3%	13%	-2%	2%	-4%	7%		-15%	-17%	-14%	-3%	-8%
	Trend	2%	3%	1%	-1%	2%	-8%	0%	7%	-6%	-15%		-5%	9%	5%	8%
	Value	5%	5%	-2%	-6%	-3%	4%	-15%	-6%	4%	-17%	-5%		8%	-6%	6%
Equity	Carry	4%	-1%	-4%	1%	1%	4%	1%	14%	-5%	-14%	9%	8%		-30%	71%
	Trend	2%	8%	-1%	-2%	-8%	-14%	3%	-8%	0%	-3%	5%	-6%	-30%		-47%
	Value	-3%	-3%	-5%	3%	2%	0%	-1%	8%	2%	-8%	8%	6%	71%	-47%	

Source: BofA Merrill Lynch Global Research. Data: Jan-04 to Jan-16. *correlation of weekly returns over entire period.

Chart 6: Historical pair-wise correlations of cross asset Risk factors

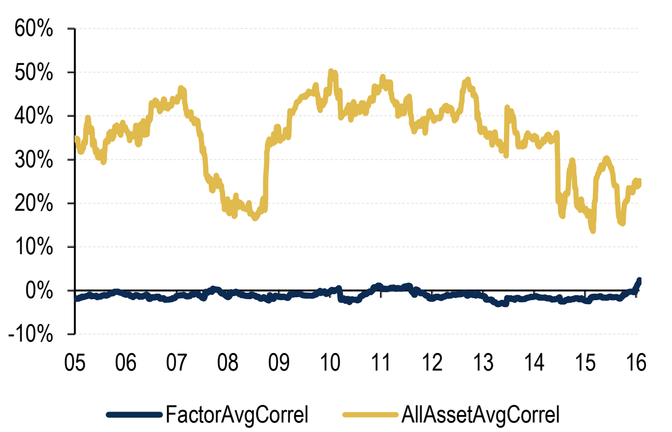


Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. *1y rolling average pair-wise correlation of weekly returns.

Chart 7 and Chart 8 show the average pairwise correlations of cross asset risk factor returns historically and the loadings from principal component analysis (PCA) of factor returns, respectively. We note that not only were long term correlations of the strategies low as shown in Exhibit 3, but that they were stable too, particularly when compared with the pair-wise correlations of traditional asset classes.

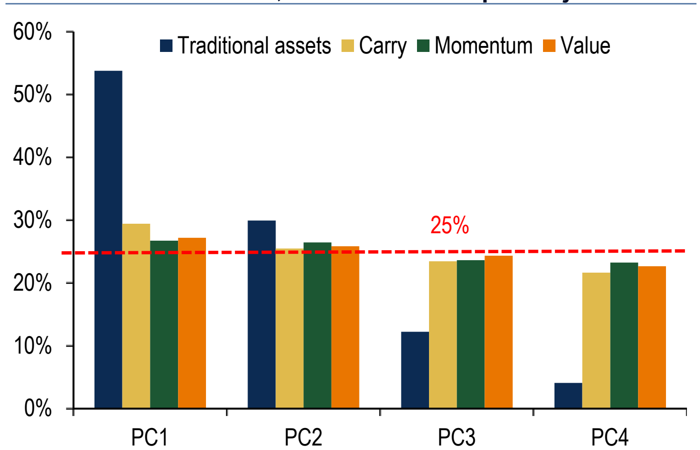
Furthermore, the near evenly distributed PCA loadings in Chart 8 suggest that the (long/short) expressions of each factor need not be further reduced to fewer variables as the variance in factor returns is more or less explained equally across each of the principal components.

Chart 7: Cross asset factor correlations were close to 0 and stable, unlike the pair-wise correlation of traditional asset classes*



Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. Rolling 1y correl of weekly returns. *Traditional assets are global equities (MXWO), global govt bonds (W0G1), global corporate bonds (GI00) and broad commodities (BCOM). Factors are 15 Carry, Momentum and Value strategies across 5 asset classes

Chart 8: Factor strategy PCA shows each principal component explained a similar amount of variance; no need for fewer explanatory variables



Source: BofA Merrill Lynch Global Research. Data: Jan-04 to Jan-16. We do PCA decomposition of weekly returns of each group of strategies (Carry, Momentum, Value & traditional assets)

Bank of America Merrill Lynch

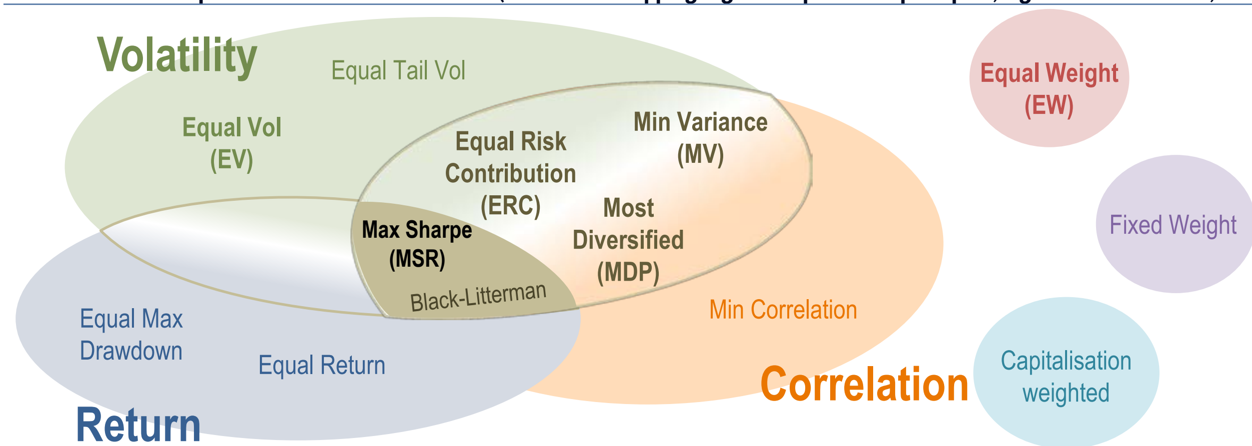
Building x-asset Risk factor portfolios

When considering return streams attributable to Risk factors across asset classes, which may have *very* different risk profiles, it is important to assess the pros and cons of different allocation/optimisation techniques before embarking on portfolio construction.

A bird's eye view of portfolio construction techniques

In Exhibit 4 we show a variety of portfolio allocation methods that are loosely grouped into regions depicting the nature of the inputs they require. The techniques range from the simple/requiring few or no inputs (e.g. Equal Weights (EW) or Equal Volatility (EV)) through to more complex optimisations that require a host of inputs (such as Maximum Sharpe Ratio, MSR).

Exhibit 4: A menu of portfolio construction methods (those in overlapping regions require multiple inputs, e.g. MSR needs return, volatility & correlation data)



Equal Weight (EW)	⇨ **1/N sizing:** Special case of fixed weight sizing where each asset/strategy is given equal weight ✓ Simplest, most straightforward method: does not rely on return/risk projections × Fails to differentiate between embedded leverage (risk) in different strategies
Equal Vol (EV)	⇨ Each asset is given **equal (marginal) volatility –** using tail event vol may make sense for some strategies ✓ Relatively simple method to account for different embedded leverage between strategies × Ignores diversification benefits different strategies offer; can result in significantly higher weight to low vol assets
Min Variance (MV)	⇨ **Targets a portfolio with lowest possible volatility** ✓ Includes the impact of correlation in addition to marginal vol ; targets an efficient (frontier) portfolio × Complex calculation; needs both vol & correl estimates; can result in significantly higher weight to low vol assets
Equal Risk Contribution (ERC)	⇨ **Equal total risk contribution from each asset**, i.e. for each asset, sum of covar vs all the others is equal ✓ Includes impact of correlation & vol, aims for equal risk exposure from each strategy × Complex calculation; needs both vol & correlation estimates
Most Diversified (MDP)	⇨ **Solves for maximum diversification ratio**, i.e. maximises ratio of weighted component vols vs portfolio vol ✓ One of the key motivations behind portfolio construction is diversification and this approach tries to maximise it × Complex calculation; needs both vol & correlation estimates
Maximum Sharpe Ratio (MSR)	⇨ **Targets a portfolio with the highest Sharpe ratio** ✓ Uses return, vol, correlation input to maximise portfolio risk adjusted return × Complex calculation; relies on both vol & correlation estimates – returns particularly hard to forecast ex-ante

Source: BofA Merrill Lynch Global Research

Each of these methods have ardent followers and detractors alike, particularly as they serve different purposes, are judged using different metrics and hence may be valued differently. Indeed as the names suggest, MV optimisation aims to minimise the total variance of the resulting portfolio, while MSR seeks to maximize its Sharpe ratio. MDP targets maximum diversification, an important aim of portfolio construction, while ERC tries to achieve equal risk contributions from the portfolio elements to overall risk. In our view, these objectives also need to be assessed in conjunction with broader considerations such as the stability of allocations (turnover) and concentration risk (eg if all/most of the allocation is directed to one strategy).

Ahead of delving deeper into this topic, we believe it is important to make two broad points that outline our philosophy when deciding on a portfolio allocation technique:

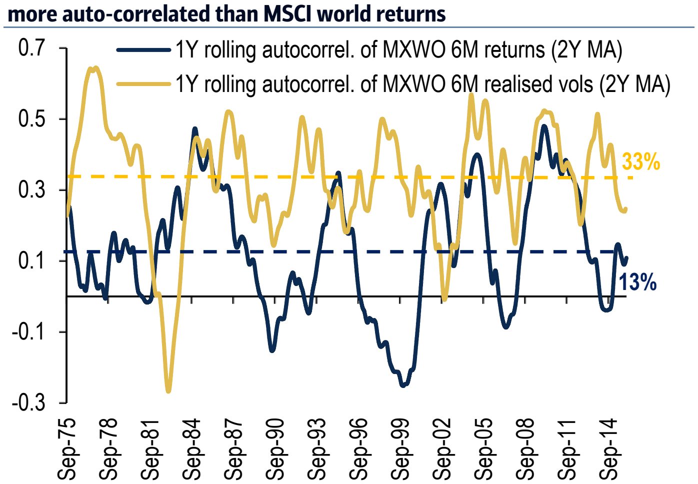
- **Trust Occam's razor; choose simplicity and not the 'best-of' back-tests**. In our view, Occam's razor is a good principle to abide by when making multi-layered decisions. In the context of portfolio allocation, the fewer the assumptions made, the more parsimonious the model used, the more likely we are to achieve stable results that are resilient to regime change. Consequently, we are biased against methods where additional complexity/assumptions are justified purely on the basis of historical performance.

- **Favour methods reliant on historical risk rather than return metrics**
  Quantitative portfolio allocation methods generally use past information for future forecasts. As we show next, we believe this is harder for asset returns than for the variability of those returns (volatility). When combining long/short factors, we are therefore biased towards methods that do not require historical return inputs.

Quantifying the difficulty of forecasting return vs risk based on historical data
Autocorrelation or serial correlation is a measure of the persistence of a trend. The higher the autocorrelation of a variable, the greater is its tendency to remain in the same state from one observation to the next. We note that:

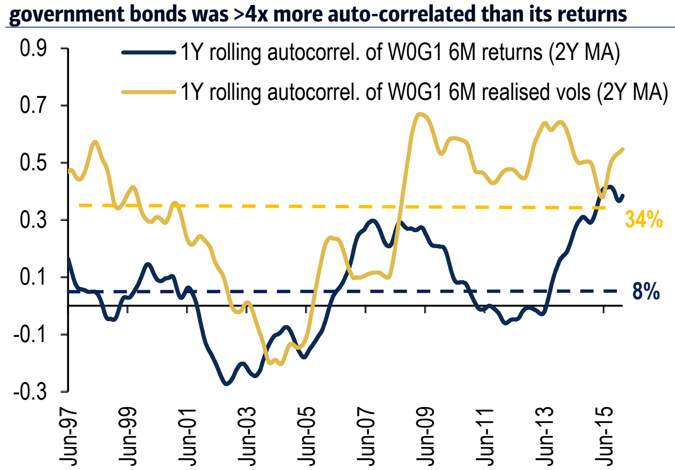
- **Returns are 2-4x harder to estimate ex-ante than risk**. Chart 9 and Chart 10 show that the 6m historical volatilities of global equities and bonds were more positively auto-correlated (2.5x and 4.3x, respectively) than their 6m returns. This suggests future returns are relatively harder to forecast than risk.

Chart 9: Since 1975, MSCI world realised vols were on average 2.5x more auto-correlated than MSCI world returns



Source: BofA Merrill Lynch Global Research. Data: Sep-75 to Jan-16.

Chart 10: Since 1997 (start of our data), the realised volatility of government bonds was >4x more auto-correlated than its returns



Source: BofA Merrill Lynch Global Research, Data: Jun-97 to Jan-16. W0G1: BofA Merrill Lynch Global Government Index

- **Mis-estimation can have greater impact when it comes to return vs risk**. Best and Grauer [1991] and Chopra [1993] show that slightly different return estimates may imply very different mean-variance optimized portfolios (eg MSR-based allocations). Michaud [1989] shows that mean-variance optimization tends to overweight assets with a large ratio of estimated risk premium to estimated variance; indeed it is such assets that are likely to have large estimation errors. Given this sensitivity of portfolios to return estimation errors, we believe it is more sensible to focus on risk-based allocation methods.

Applying portfolio allocation techniques to factors

We now assess the results of applying the 6 portfolio allocation/optimisation techniques detailed in Exhibit 4 to the universe of cross asset Risk factors we outlined earlier in ***Towards a universe of cross-asset Risk factors***. To keep things simple, we start by combining[5] the components of each Risk factor cluster (Momentum, Carry and Value) and evaluate allocation techniques based not only on historical (risk-adjusted) performance and strategy drawdowns, but also on broader considerations like annual turnover, concentration risk and diversifying power[6].

Constructing Momentum, Carry and Value portfolios

In Exhibit 5, Chart 11 and Table 2, we highlight the results, according to our hypothetical back-tested analysis, of using different allocation techniques when combining Momentum strategies across asset classes. We show similarly detailed analysis for the Carry and Value portfolios in the ***Appendix***. From a broad array of metrics outlined in Table 2, Table 6 (Appendix), Table 7 (Appendix) and Exhibit 6, we make the following observations about the different allocation methods:

- **What goes around may not come around**: While MSR-based allocations aim to maximise a portfolio's Sharpe, the technique would have ranked the worst historically on this objective for Momentum strategies. In our view, this is due to a combination of the relative difficulty in forecasting returns based on historical data (and hence Sharpe ratios) as well as higher strategy concentration risk (more below), which increases the risk of variable results across different strategies and time periods. Indeed, unlike for Momentum strategies, MSR would have generated the best Sharpe across allocation methods in the Carry portfolio (see Exhibit 8 in the Appendix). In contrast, EV, ERC and MDP portfolios would have yielded consistently high Sharpes across Risk factors.

- **Don't churn and burn:** High turnover as a result of the portfolio allocation method used may prove to be costly to implement when rebalancing a portfolio, particularly given that Risk factor strategies have variable cost structures. MV-optimisation and MSR-based allocations would consistently have led to the highest turnover across the different techniques and Risk factors, with MSR in particular leading to churning entire Risk factor portfolios more than twice in a year (>200% annual turnover). The simple EW method as well as the EV and ERC-based portfolios would have had the least turnover across Risk factors.

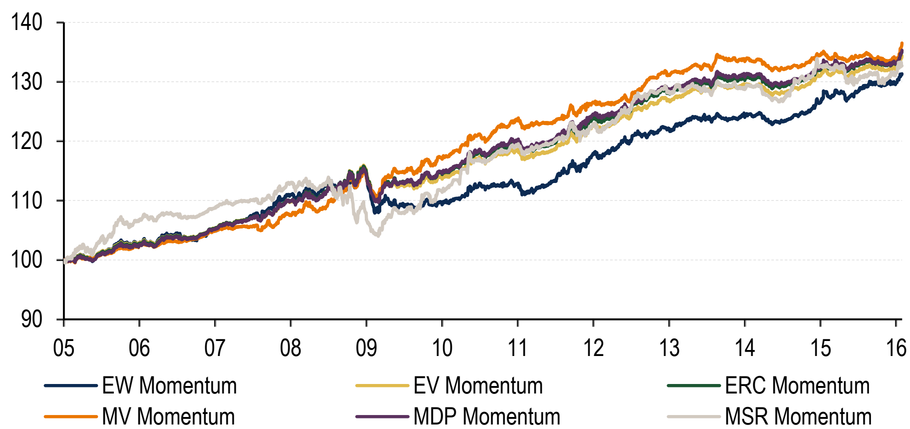
- **Beware of all your eggs in a basket**: High asset concentration risk poses a threat to real-world portfolios as exposure to the same (or similar) Risk factors brings with it idiosyncratic risk. For example, Exhibit 5 shows that MV-optimisation would have resulted in very high allocations to Credit Momentum in 2006-07 and an MSR-based allocation would have almost exclusively favoured Commodity Momentum in 2008-09. While such high allocations *may* lead towards optimal portfolios, any idiosyncratic shocks in the 'chosen' strategies may have outsized portfolio effects due to a lack of diversification. Indeed, MSR-based allocations would have experienced the highest risk and drawdowns in the Momentum and Value portfolios (Table 2 and Table 7). Furthermore, market capacity constraints for some Risk factors may make such concentrated portfolios infeasible, in our view.

[5] We use the last 1y of price, vol and correlation data as required in the different methods and rebalance every 3m.
[6] See footnote of Table 2 to see how these are defined.

- **Remember there is only one free lunch**: Diversification matters; indeed many would argue it is critical to the resilience and long-term success of portfolios. Notably, MDP-based allocations target maximum diversification itself (maximises the ratio of weighted strategy volatility to portfolio volatility). While our hypothetical back-tested analysis suggests MDP would have achieved among the highest diversification across Risk factors (along with EV & ERC-based allocations), MV and MSR portfolios would have achieved the least amount of diversification.
- **On balance, we favour Equal Risk Contribution-based allocations**: Exhibit 6 depicts a simple representation of the efficacy of different portfolio allocation methods across Risk factors by ranking them across 6 different criteria: (high) portfolio Sharpe, (high) Calmar (drawdown-adjusted return), (low) portfolio risk, (low) asset concentration risk, (low) asset turnover and (high) diversification ratio. While EW, MV-optimisation and MSR appear to have achieved their aims (low concentration, low risk and high Sharpe respectively), their scores across the remaining metrics were relatively poor. The Equal Risk Contribution (ERC) method generated consistently better ranks across these criteria.

The **Equal Risk Contribution (ERC)** method, which generates strategy weights with the aim of equating each strategy's total contribution to portfolio risk, ranked consistently well across Risk factor portfolios on a range of assessment criteria, according to our hypothetical back-tested analysis.

Chart 11: Cross asset Momentum strategies, using different allocation / optimisation methods



Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

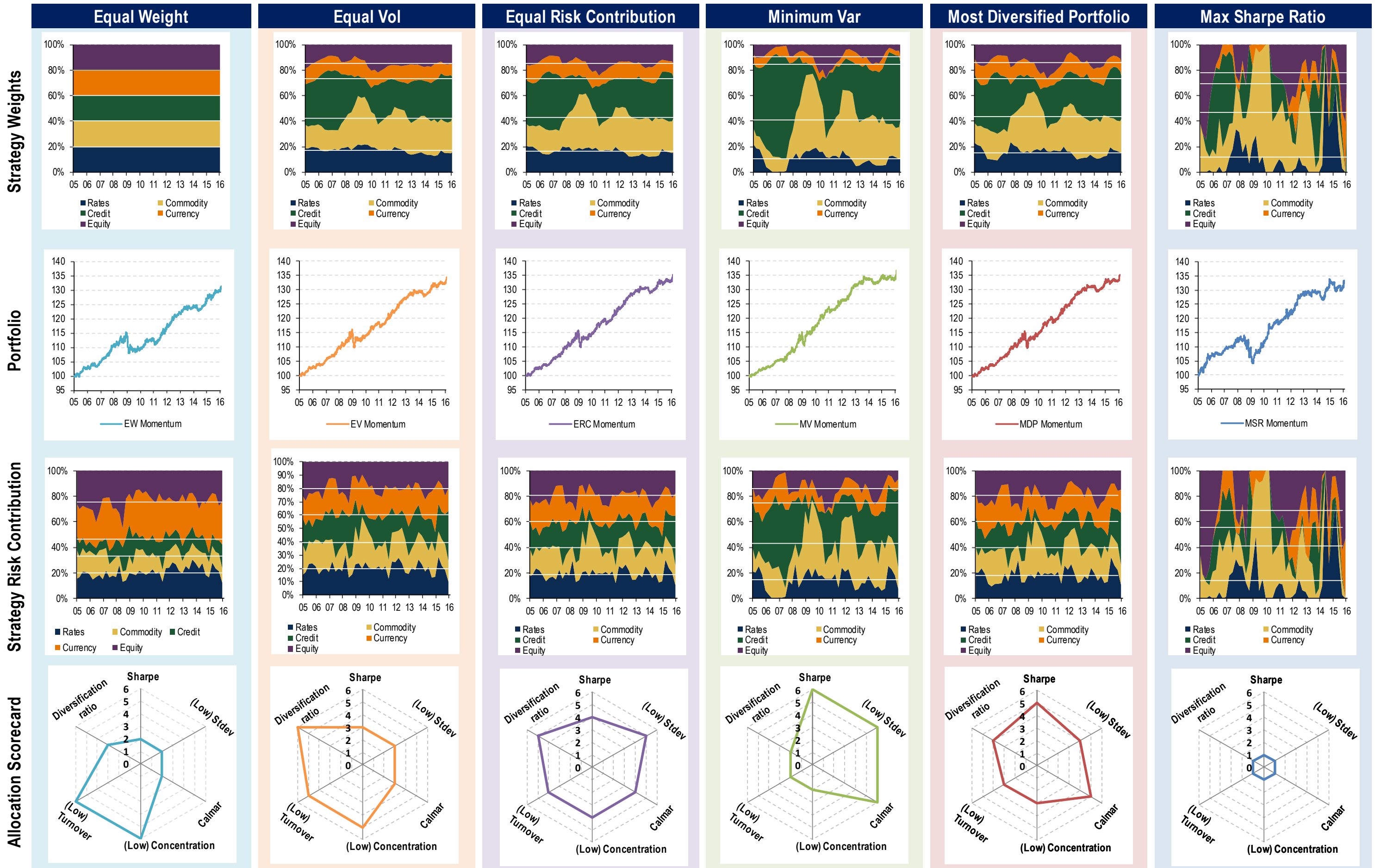
Table 2: Statistics to help evaluate pros/cons of different portfolio allocation methods applied to Momentum strategies

	Method	CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
Momentum	EW	2.5%	1.06	2.3%	-6.5%	-0.23%	-0.33%	15%	0%	1.98
	EV	2.7%	1.35	1.9%	-5.3%	-0.18%	-0.27%	37%	22%	2.06
	ERC	2.8%	1.39	1.9%	-5.0%	-0.18%	-0.27%	41%	23%	2.06
	MV	2.9%	1.49	1.8%	-4.2%	-0.16%	-0.25%	68%	48%	1.85
	MDP	2.8%	1.39	1.9%	-5.0%	-0.18%	-0.27%	54%	25%	2.04
	MSR	2.6%	0.93	2.7%	-8.7%	-0.26%	-0.40%	214%	56%	1.56

Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. **Turnover** = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). **Concentration** = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. **Diversification Ratio** = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

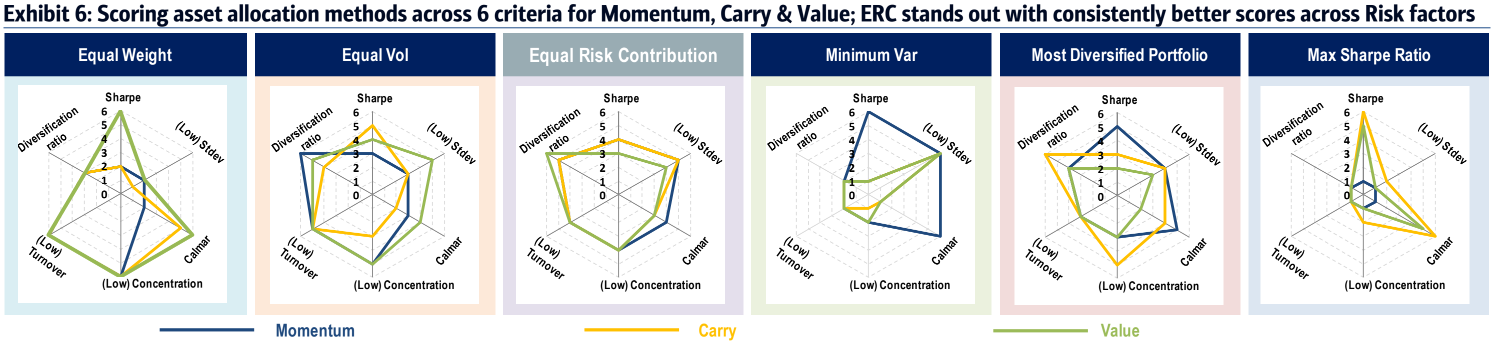
Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Exhibit 5: Portfolios of cross-asset Momentum strategies, using a variety of allocation techniques



Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates.
Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Exhibit 6: Scoring asset allocation methods across 6 criteria for Momentum, Carry & Value; ERC stands out with consistently better scores across Risk factors



Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates.
Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Bringing it all together… a cross asset portfolio of Risk factors

When building a multi Risk factor portfolio, investors may take different 'clustering' approaches to combine strategies:

1. **Risk factor clustering**: Group cross asset strategies under Carry, Value and Momentum and then combine them (i.e. a 2-step allocation) – see Chart 12, Table 3 and Exhibit 10.

2. **Asset class clustering**: Group strategies under their respective asset classes (e.g. equity Carry, equity Value & equity Momentum) and then combine the asset class clusters (again, a 2-step allocation) – see Chart 13, Table 4 and Exhibit 11.

3. **Kitchen-sink (no clustering)**, i.e. combine all the strategies in one step – see Chart 14, Table 5 and Exhibit 12.

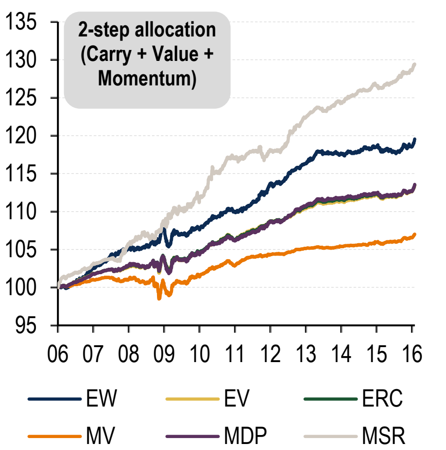
The kitchen-sink approach is operationally intensive as all possible pair-wise relationships (eg covariance matrices in ERC, MV, MDP and MSR) are used. In our case (of 15 cross asset strategies), this amounts to 15*14/2 = 105 pairs. Using all this information can be a positive in portfolio construction if the pair-wise relationships are stable, as it would make historical estimates more reliable going forward.

One way to ensure stable inter-relationships is to group strategies into clusters that share a common driving force (be it factor or asset-class based). The strategies within a cluster may then behave similarly in stressed market environments when broader historical trends become less reliable. A good example of such a cluster would be cross asset volatility. While we do not work with the volatility Risk factor in this piece, it has (by construction) predictable behaviour across asset classes in stressed market conditions. Moreover, a clustering approach is less operationally intensive and relies on fewer (ideally more stable) inter-relationships. For instance, we would only have 33 pair-wise relationships for 3 (factor) clusters of 5 strategies each.

Favour Risk factor clustering. The organisation of some investment teams (eg by asset class, geography or other Risk factors) will naturally tilt them towards their choice of clustering (usually asset class). However, we are inclined to adopt the factor clustering approach as asset class clusters often have multiple overlapping factors that drive performance. Indeed multi-asset investors may benefit most from factor clustering as it allows for the construction of (inherently cross asset) modules that could slot into an 'Alternative' allocation bucket.

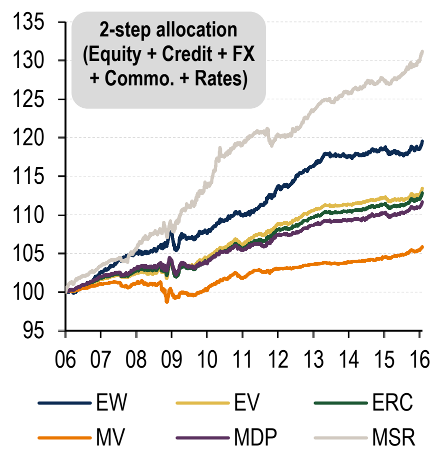
EV and ERC allocations would have had the most well balanced scores across the broad range of evaluation criteria we developed earlier to assess allocation techniques (Exhibit 7). On balance we still favour ERC as it takes into account historical correlations explicitly and may make a greater impact on portfolio performance if strategy correlations weren't as low (close to 0) as they are in our example. Indeed, this is also a reason why the factor-based and asset class-based clustering approaches did not yield very different historical results, in our back-tested analysis.

Chart 12: Cross asset Risk factor portfolio created using factor-based clustering



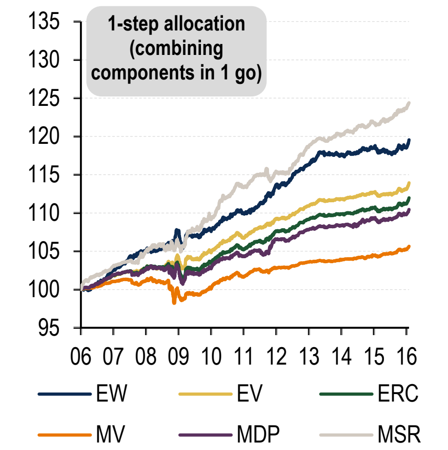
Source: BofA Merrill Lynch Global Research. Data: Jan-06-Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Chart 13: Cross asset Risk factor portfolio created using asset class-based clustering



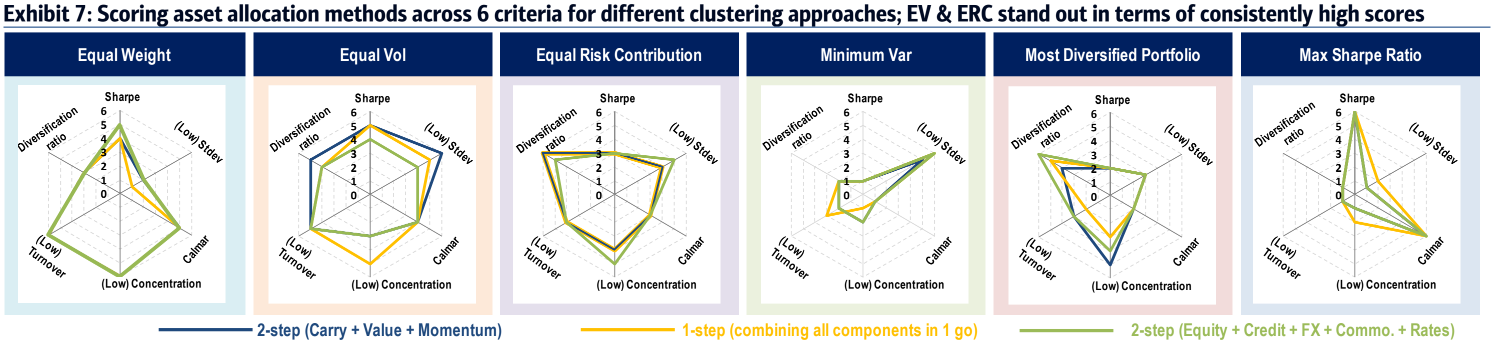
Source: BofA Merrill Lynch Global Research. Data: Jan-06-Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance

Chart 14: Cross asset Risk factor portfolio created without any clustering



Source: BofA Merrill Lynch Global Research. Data: Jan-06-Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Exhibit 7: Scoring asset allocation methods across 6 criteria for different clustering approaches; EV & ERC stand out in terms of consistently high scores



Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Table 3: Statistics for a cross asset Risk factor portfolio constructed using a factor-based clustering approach

	Method	CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
Carry + Momentum + Value	EW	1.8%	1.69	1.0%	-2.3%	-0.10%	-0.15%	7%	0%	3.94
	EV	1.3%	1.70	0.7%	-1.8%	-0.06%	-0.11%	37%	35%	4.04
	ERC	1.3%	1.68	0.7%	-2.0%	-0.06%	-0.11%	40%	32%	4.21
	MV	0.7%	0.92	0.7%	-2.9%	-0.06%	-0.11%	69%	63%	3.09
	MDP	1.3%	1.59	0.8%	-2.2%	-0.07%	-0.11%	55%	30%	3.98
	MSR	2.6%	2.05	1.2%	-1.6%	-0.11%	-0.17%	224%	67%	2.57

Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Table 4: Statistics for a cross asset Risk factor portfolio constructed using an asset class-based clustering approach

	Method	CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
Credit + FX + Commo. + Rates + Equity	EW	1.8%	1.69	1.0%	-2.3%	-0.10%	-0.15%	7%	0%	3.94
	EV	1.3%	1.67	0.7%	-2.0%	-0.06%	-0.11%	48%	36%	4.04
	ERC	1.2%	1.61	0.7%	-2.0%	-0.06%	-0.11%	54%	32%	4.25
	MV	0.6%	0.86	0.6%	-2.7%	-0.05%	-0.10%	82%	63%	3.24
	MDP	1.1%	1.39	0.8%	-2.2%	-0.07%	-0.11%	75%	32%	4.29
	MSR	2.7%	2.18	1.2%	-1.9%	-0.10%	-0.17%	188%	69%	2.16

Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. **Turnover** = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). **Concentration** = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. **Diversification Ratio** = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Table 5: Statistics for a cross asset Risk factor portfolio constructed using a kitchen sink approach (no clustering, all strategies are rebalanced together)

		CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
1-step allocation	EW	1.8%	1.69	1.0%	-2.3%	-0.10%	-0.15%	14%	0%	3.94
	EV	1.3%	1.78	0.7%	-1.8%	-0.06%	-0.10%	41%	35%	4.08
	ERC	1.1%	1.50	0.7%	-2.2%	-0.06%	-0.11%	63%	34%	4.19
	MV	0.5%	0.78	0.7%	-3.3%	-0.05%	-0.10%	89%	63%	3.35
	MDP	1.0%	1.12	0.9%	-2.5%	-0.07%	-0.13%	113%	38%	4.13
	MSR	2.2%	2.10	1.0%	-1.6%	-0.09%	-0.14%	191%	59%	2.71

Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. **Turnover** = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). **Concentration** = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. **Diversification Ratio** = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

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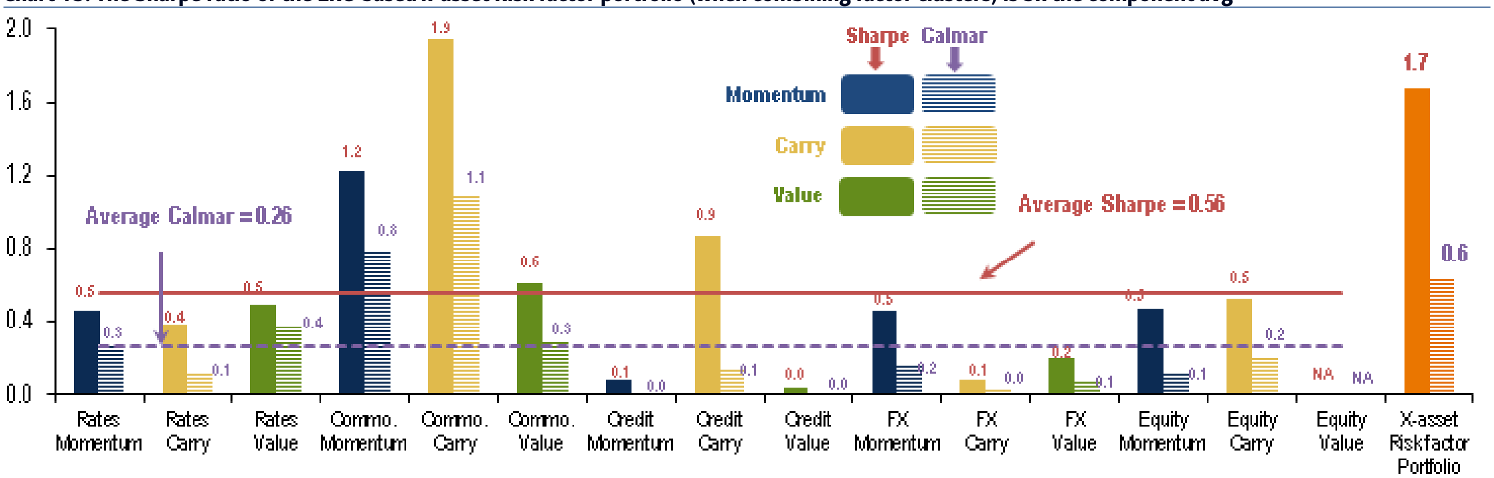
Chart 15 shows hypothetical back-tested statistics (Sharpe & Calmar ratio) for each of (15) cross asset factors and that of a portfolio created using a 2-step ERC-based allocation process which combines factor clusters. We note that the portfolio would have had 3x the Sharpe and 2.3x the Calmar ratio of the component averages.

> A cross asset Risk factor portfolio created using Equal Risk Contribution-based allocations applied to Carry, Value & Momentum factor clusters would have achieved 2-3x the average risk-adjusted return of its constituents.

Chart 15: The Sharpe ratio of the ERC-based x-asset Risk factor portfolio (when combining factor clusters) is 3x the component avg



Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

And finally, some important choices to think about…

Right through our analysis on portfolio allocation techniques, we have made a number of choices regarding historical observation windows, portfolio rebalance frequency, definitions of volatility, correlation, and so on. Here we present some thoughts on our choices.

To roll or not to roll (the observation window): At the risk of sparking a debate with risk managers by weighing in on this point, note that we decided to roll our (1Y long) historical observation window rather than growing it when using different portfolio allocation / optimisation techniques on the (linear) Risk factors Carry, Momentum and Value. In our view, this helps keep strategy allocations from stagnating in the long run (given that a growing window will lead to an ultimately static covariance matrix that corresponds to long run averages of volatility and correlation). The risk of doing this is that we 'forget' older (and potentially very violent) events like the 2008 GFC which conservative managers may not wish to do. Indeed such omissions can become particularly important for volatility-based alpha strategies (eg short variance). In our view, a compromise could involve growing the observation window but giving recent returns more weight (e.g. using Exponentially Weighted Moving Averages – EWMA).

A tale of tails: We have used the standard definition of volatility in our work here. In our view, it would be interesting to use extreme (tail) volatilities and correlations of different strategies to help make allocations more conservative, particularly when considering strategies linked to the Volatility factor. One way to do this would be to calculate the volatility of say the worst 10% of returns of a strategy. If used in conjunction with an expanding observation window, this may reduce the risk of stagnating portfolio weights as any new extreme events would get a higher representation than if we were using the traditional definition of volatility (which uses all return observations).

Why rebalance like clockwork? In our analysis, we have rebalanced all portfolios (ie run the allocation / optimisation engine) on a quarterly basis for simplicity and ease of calculation; however this isn't the only option. Aside more or less frequent rebalancing (which in itself is a function of the observation window), an alternative could be to rebalance based on pre-defined thresholds rather than periodically. For instance, the portfolio could rebalance if performance were to cause the weight of a strategy to deviate substantially from the last recommended weight. Note: This rebalancing is at a portfolio level and is different from rebalancing within a strategy, which could (and arguably should) be more frequent.

Biting off more than you can chew: One of the practical considerations when implementing Risk factor portfolios is that of market capacity, particularly in relation to alternative factors like volatility, correlation and dividends that are relatively less deep versus broader markets. In such circumstances, having multiple expressions of a Risk factor can help mitigate the risk of a strategy's weights hitting capacity constraints.

Tinkering with allocations: Some investors may wish to introduce (arbitrarily defined) caps and floors on strategy weights to explicitly limit strategy concentration risk. Any deviation from 'optimal' weights would be traded off for less concentration risk. One way to do this would be to use a simple ranking of strategies based on an investor's preferred portfolio allocation method. For instance, if an ERC-based allocation were to recommend weights of 60%, 30% and 10% respectively to three strategies A, B & C, a simple ranking would lead to A, B & C having weights of 3/(1+2+3) = 50%, 2/(1+2+3) = 33% and 1/(1+2+3) = 17%, respectively. Such a ranking would then cap the weight of any 3-asset portfolio at 50% and floor it at 17%.

Risks to our analysis

Our hypothetical back-testing analysis uses historical volatility, correlation and return data to forecast future trends. Should these variables for different factor strategies exhibit unstable relationships versus each other (e.g. 2 strategies are very uncorrelated normally and become very correlated or vice versa), then a number of portfolio allocation methods will be less able to meet their stated objectives.

Note that we have not included the impact of transaction or rebalancing costs in our hypothetical back-testing; their inclusion may reduce the hypothetical back-tested profitability of the overall portfolio.

Appendix

Cross asset Carry portfolio analysis

Exhibit 8 and Table 6 depict the historical component weights, hypothetical back-tested portfolio analysis, component risk contributions and evaluation scorecard for different allocation techniques applied to cross asset Carry strategies.

Exhibit 8: Portfolios of cross-asset Carry strategies, using a variety of allocation techniques

Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. **Turnover** = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). **Concentration** = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. **Diversification Ratio** = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates.

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Table 6: Statistics to help evaluate pros/cons of different portfolio allocation methods applied to Carry strategies

	Method	CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
Carry	EW	2.1%	1.22	1.6%	-3.3%	-0.15%	-0.24%	14%	0%	1.90
	EV	1.2%	1.38	0.9%	-3.6%	-0.07%	-0.13%	42%	43%	2.28
	ERC	1.2%	1.38	0.9%	-3.5%	-0.07%	-0.13%	43%	42%	2.30
	MV	0.6%	0.66	0.9%	-5.3%	-0.06%	-0.13%	60%	70%	1.81
	MDP	1.2%	1.36	0.9%	-3.4%	-0.07%	-0.13%	51%	42%	2.31
	MSR	2.7%	2.15	1.2%	-1.2%	-0.10%	-0.17%	167%	63%	1.59

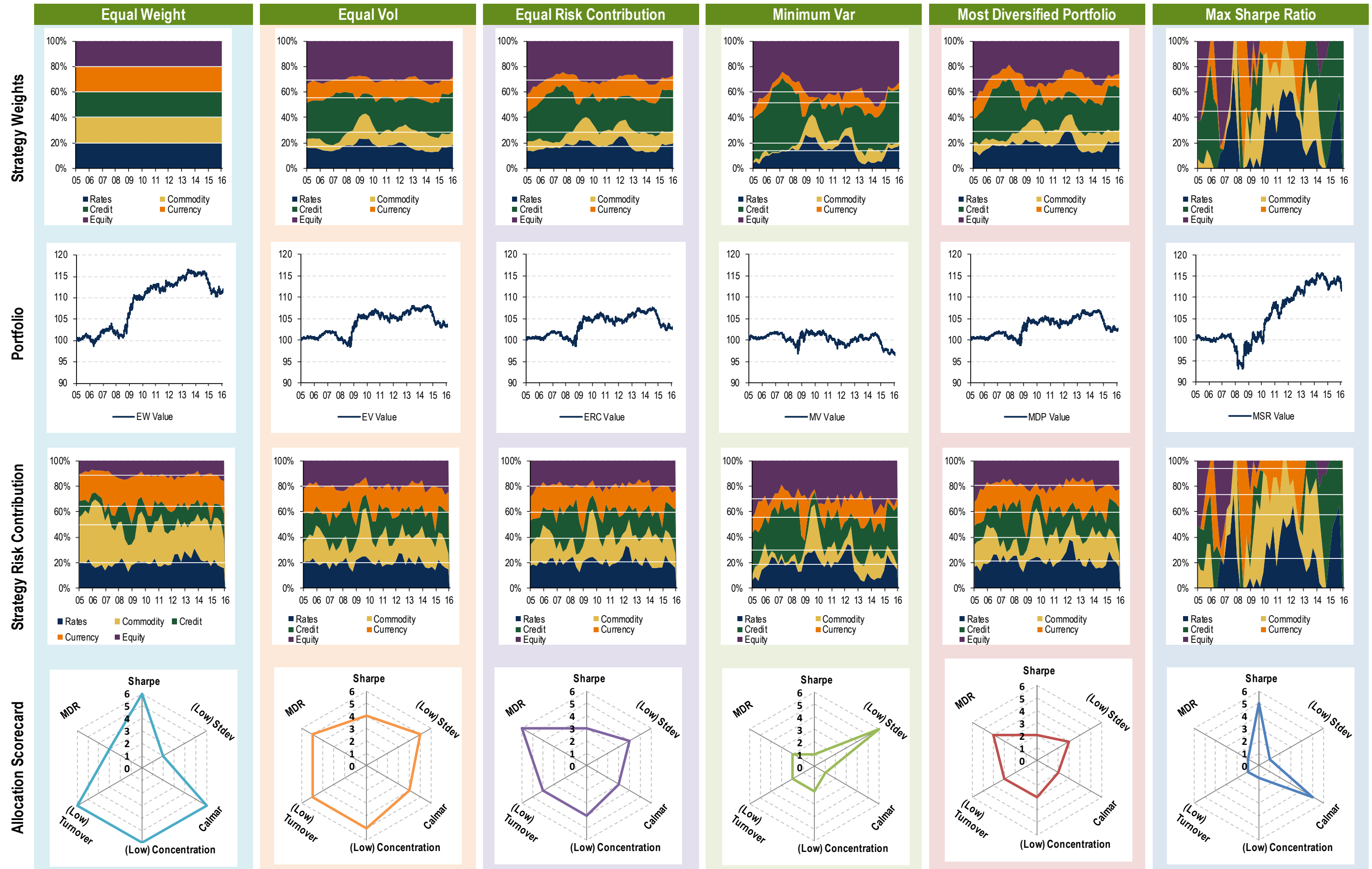
Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. **Turnover** = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). **Concentration** = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. **Diversification Ratio** = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Cross asset Value portfolio analysis

Exhibit 9 and Table 7 depict the historical component weights, hypothetical back-tested portfolio analysis, component risk contributions and evaluation scorecard for different allocation techniques applied to cross asset Value strategies.

Exhibit 9: Portfolios of cross-asset Value strategies, using a variety of allocation techniques



Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates.

Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

Table 7: Statistics to help evaluate pros/cons of different portfolio allocation methods applied to Value strategies

	Method	CAGR	Sharpe	Stdev	Max DrawDown	VaR	cVaR	Turnover	Concentration	Diversification Ratio
Value	EW	1.0%	0.47	2.2%	-5.5%	-0.20%	-0.29%	15%	0%	2.03
	EV	0.3%	0.18	1.9%	-4.9%	-0.17%	-0.26%	30%	23%	2.20
	ERC	0.3%	0.15	1.9%	-4.9%	-0.17%	-0.27%	36%	23%	2.20
	MV	-0.3%	NA	1.9%	-6.0%	-0.17%	-0.27%	57%	43%	2.00
	MDP	0.2%	0.13	1.9%	-4.8%	-0.17%	-0.27%	48%	24%	2.18
	MSR	1.1%	0.35	3.1%	-8.2%	-0.27%	-0.46%	234%	64%	1.50

Source: BofA Merrill Lynch Global Research. Data: Jan-05 to Jan-16. CAGR = compounded annual growth rate. VaR and cVaR are for a 95% confidence interval. Turnover = Strategy notional traded as a proportion of portfolio value on rebalancing dates (per annum). Concentration = Average absolute deviation of each strategy's weight versus an equal weight allocation, averaged across all rebalancing dates [Equal weight portfolio concentration = 0, Single strategy portfolio concentration = 100%]. Diversification Ratio = Weighted average strategy vol divided by portfolio vol averaged across all rebalancing dates. Green (red) indicates the best (worst) allocation method based on each assessment metric (column).

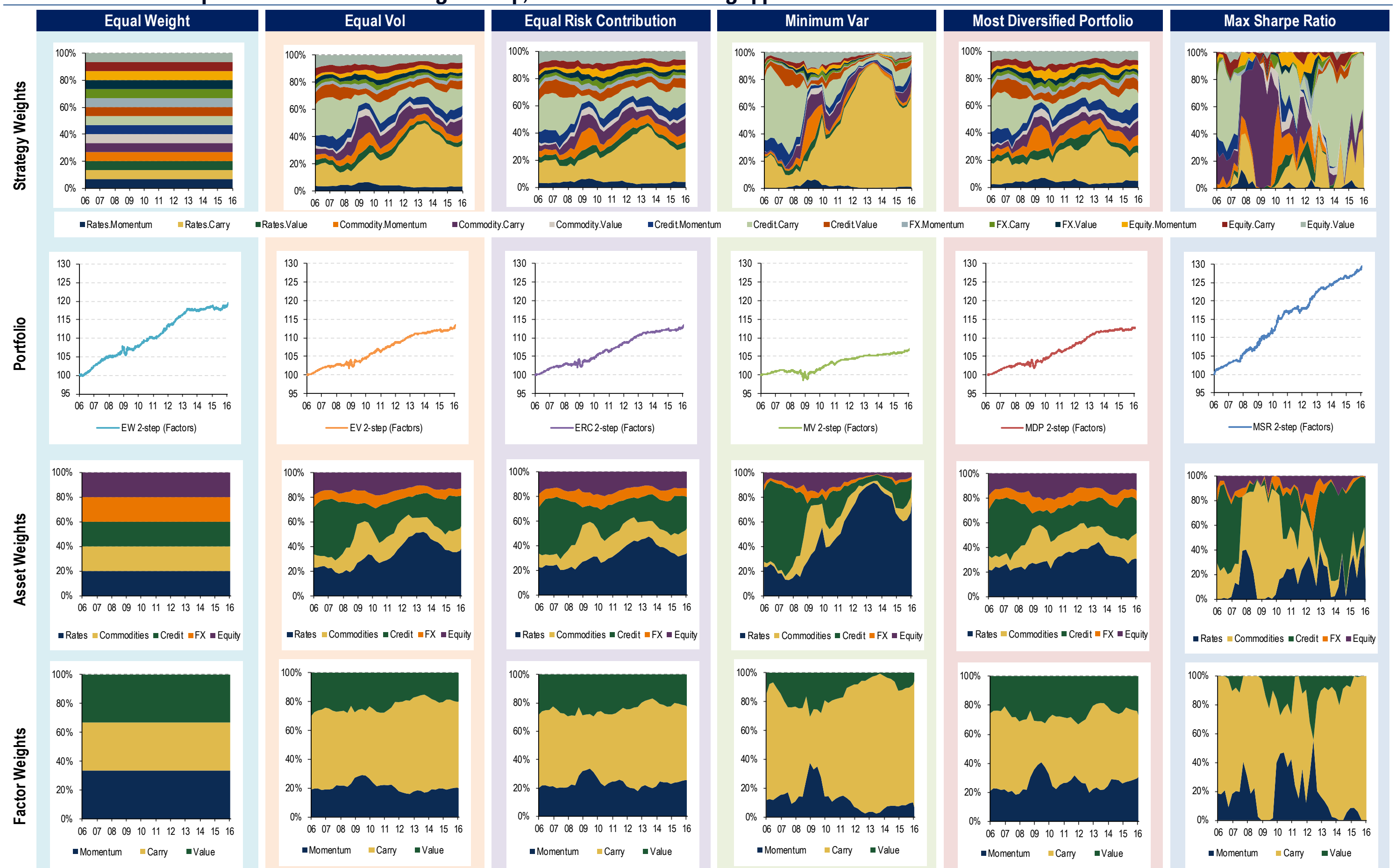
Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

2-step Risk factor-based clustering approach to portfolio construction

Exhibit 10 shows the component weights, hypothetical back-tested portfolio analysis, weights by asset class and by factor definitions for different allocation techniques applied to create a cross asset Risk factor portfolio using a 2-step factor-based clustering approach.

Note: The same technique is applied at both steps, e.g. for Equal Vol (EV), we combine 5 (asset class) strategies using EV to generate Carry, Value and Momentum clusters and then combine these 3 using EV.

Exhibit 10: Risk factor portfolio construction using a 2-step, factor-based clustering approach



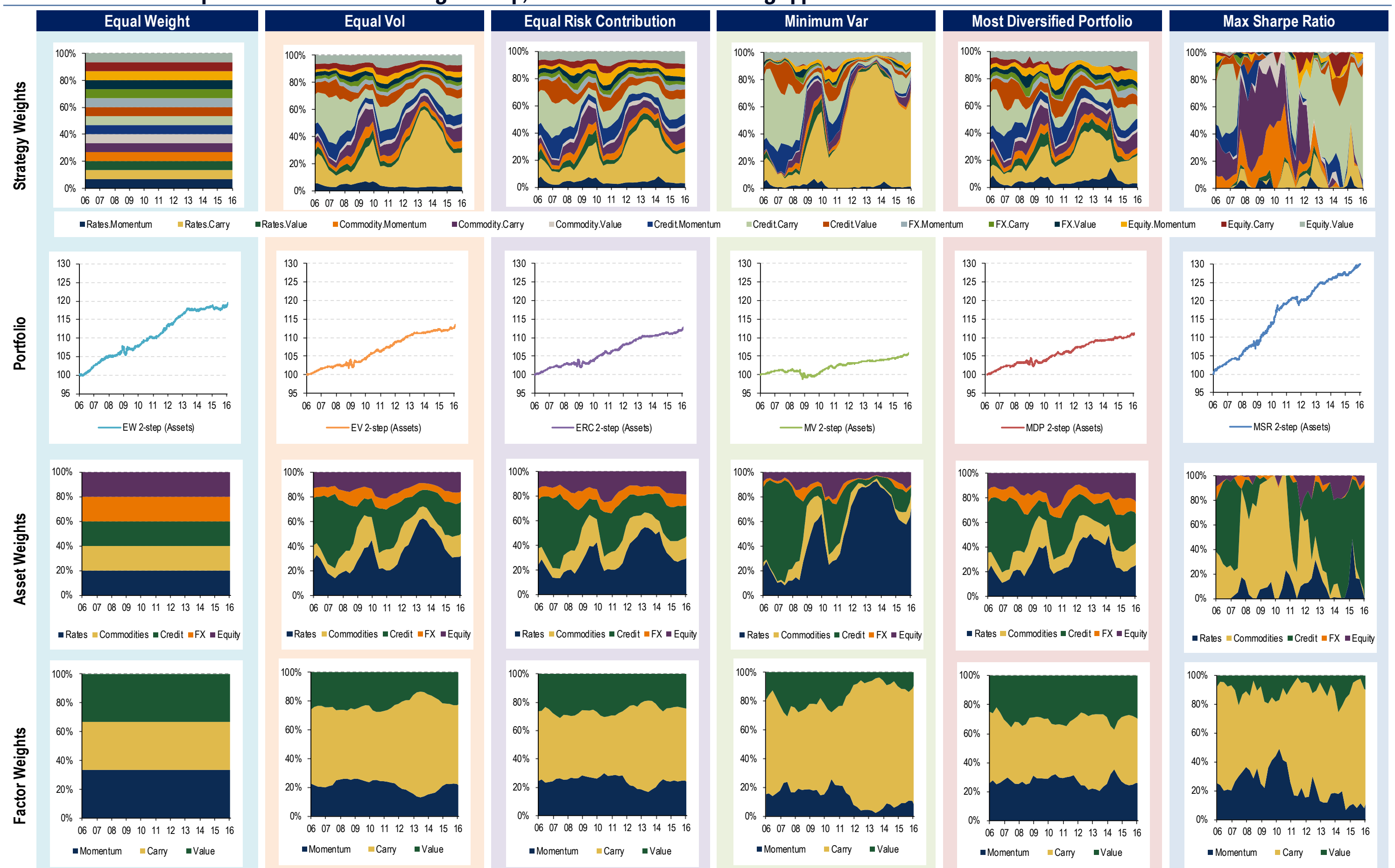
Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

2-step asset class -based clustering approach to portfolio construction

Exhibit 11 shows the component weights, hypothetical back-tested portfolio analysis, weights by asset class and by factor definitions for different allocation techniques applied to create a cross asset Risk factor portfolio using a 2-step **asset class**-based clustering approach.

Note: The same technique is applied at both steps, e.g. for Equal Vol (EV), we combine 3 (factor) strategies using EV to generate Equity, Rates, Credit, FX and Commodity clusters and then combine these 3 using EV.

Exhibit 11: Risk factor portfolio construction using a 2-step, asset class-based clustering approach

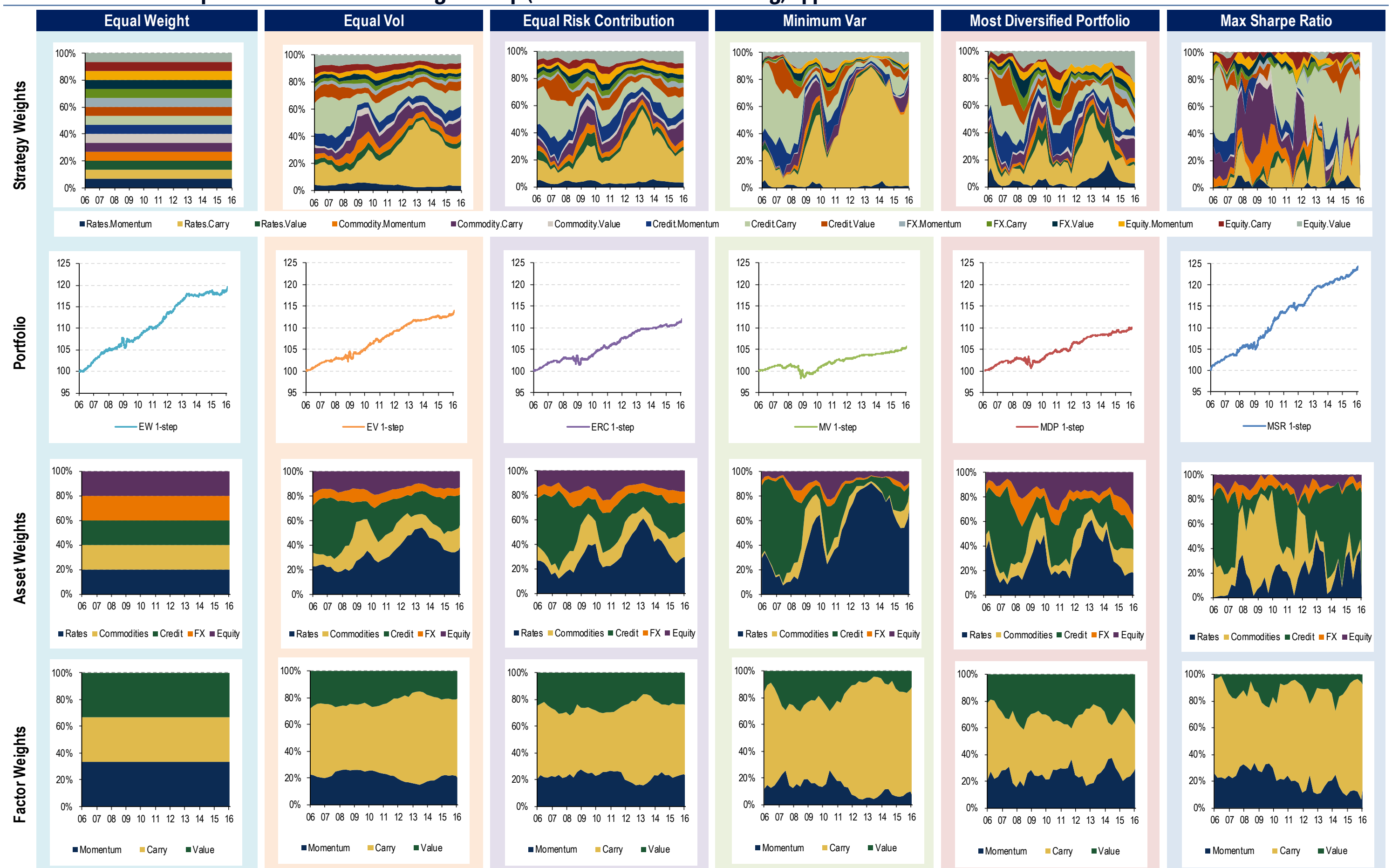


Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

1-step kitchen sink (no clustering) approach to portfolio construction

Exhibit 12 shows the component weights, hypothetical back-tested portfolio analysis, weights by asset class and by factor definitions for different allocation techniques applied to create a cross asset Risk factor portfolio using a 1-step approach (i.e. no clustering).

Exhibit 12: Risk factor portfolio construction using a 1-step (kitchen sink or no clustering) approach



Source: BofA Merrill Lynch Global Research. Data: Jan-06 to Jan-16. Back-testing is hypothetical in nature & reflects application of the strategy prior to its introduction. It is not actual performance & is not intended to be indicative of future performance.

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