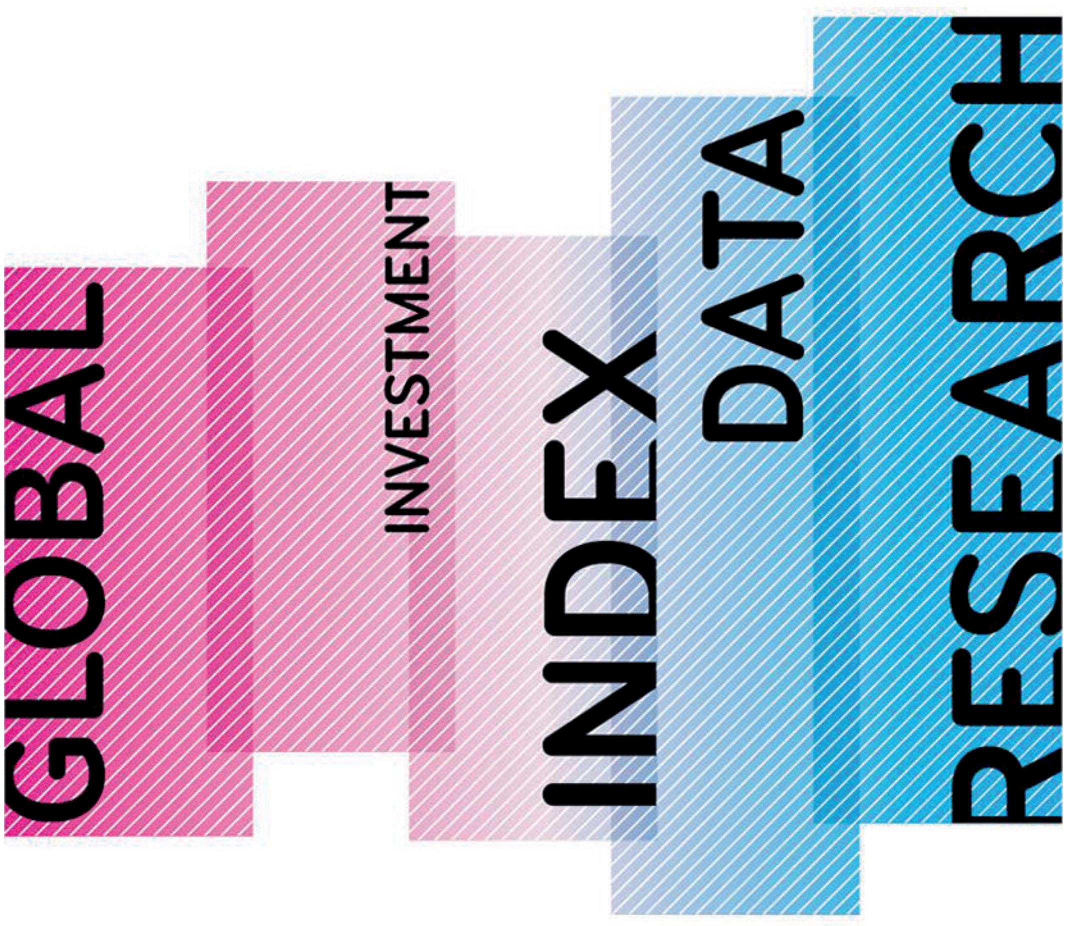
April 2019

THE LOW VOLATILITY PREMIUM – AN ANALYSIS OF FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Anand Venkataraman, Head of Product Management, STOXX Ltd.



STOXX

INNOVATIVE. GLOBAL. INDICES.

TABLE OF CONTENTS

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

INTRODUCTION

Minimum variance strategies have gained significant traction especially since the global financial crisis. They aim at reducing or minimizing variance, i.e. the square of volatility as measured by standard deviation, or, in this case, price fluctuations of portfolio prices around their mean. As such, they are of much interest to risk-aware and risk-averse investors. While assets linked to investments that follow such strategies increased substantially in recent years, the theoretical foundation underlying minimum variance concepts has been around for decades, going back to Markowitz [1952][1]. In the years following his work, a vast number of empirical studies looked into characteristics of minimum variance portfolios with a focus on how to best implement such strategies in practice[2]. In recent years, however, academia has shifted its focus to the explanation of the so-called low volatility factor.

The traditional Capital Asset Pricing Model (CAPM) explains asset returns in excess of the risk-free rate as compensation for systematic, i.e. non-diversifiable, risk[3]. In a market equilibrium, investors would hold risky assets only if they received a premium that is positively related to the extent of systematic risk they take on. Hence, the higher an asset's exposure to systematic risk, the higher the expected return. In violation of this explanation, however, empirical studies have found that stocks that exhibit comparatively low levels of risk tend to outperform riskier stocks[4]. This phenomenon is often referred to as the 'low volatility anomaly'.

Are minimum variance concepts that attempt to minimize variance, really a guarantee for outperformance relative to traditional market-capitalization-weighted benchmarks? We attempt to answer that question in this paper, by breaking down the performance of minimum variance strategies into the underlying systematic factors. We further isolate the performance contribution of the low-volatility premium, while simultaneously assessing contributions from other style factors[5] identified in the related literature that arise as a consequence of the minimum variance optimization.

Why minimum variance strategies and not low volatility strategies? Minimum variance strategies typically aim at minimizing the variance of a portfolio. The construction of such a portfolio considers both stock price volatility as well as correlations among stocks. Hence, the strategy does not directly target the low volatility factor, unlike low volatility concepts that simply select stocks based on their price volatility. However, over the last decade or so, minimum variance strategies have become more popular, in part driven by the fact that their risk-adjusted returns have been higher than those of low volatility strategies in many cases. Therefore, we focus on minimum variance strategies in our analysis, rather than on the more heuristic low volatility strategies.

Our empirical analysis reveals that, relative to market-capitalization-weighted benchmarks, minimum variance strategies not only reduce volatility but also enable investors to harvest positive and statistically significant low-volatility premia. This observation holds true even after controlling for industry and country factors as well as for other style factors. However, the empirical results further show that selecting and weighting stocks in order to minimize portfolio risk leads to statistically significant exposures to other style factors versus the benchmark, sometimes with persistent negative performance contributions over time, thereby cannibalizing parts of the low-volatility premium. This observation is found to exist across geographies.

[1] Markowitz, H. [1952].

[2] See e.g. Behr et al. [2009] and Chow et al. [2016] for an analysis of the impact of constraints on minimum variance portfolios.

[3] The CAPM goes back to William F. Sharpe, John Lintner and Jan Mossin, who developed the model independent from one another in the 1960s. See e.g., Sharpe [1964], Lintner [1965] and Mossin [1965].

[4] See e.g. Ramos and Hang [2013].

[5] All of the performance attribution analysis is carried out using Axioma's Portfolio Analytics system with attribution carried out using the Axioma AX-WW 2.1 World-Wide Equity Factor Risk Model.

These findings are likely of great importance for investors while implementing minimum variance strategies. Investors need to be aware of interactions among factors in order to apply appropriate countermeasures. In this context, the empirical findings indicate that applying constraints to limit unintended style factor exposures relative to the benchmark may help reduce the negative performance contribution and its statistical significance. However, this typically comes at the cost of a lower reduction in portfolio risk and a reduction in the low-volatility premium.

THE CAPM AND ITS EXTENSION TO MULTI-FACTOR MODELS

The traditional Capital Asset Pricing Model (CAPM), which goes back to the 1960s, hypothesizes that the majority of a portfolio's returns may be explained by one factor, the 'market factor', which is therefore the only risk factor to be systematically priced. Empirical studies have since endorsed the presence of this market factor that accounts for a majority – and in many cases all – of a portfolio's returns.

Over the following decades, further empirical research, carried out in the attempt to explain equity returns, observed the existence of additional risk factors. One of the first extensions of the CAPM was proposed by Fama and French [1992], who suggested the presence of two additional factors: size and value. The authors found that small-cap companies as well as companies that are undervalued relative to their book value outperform their respective counterparts.

The existence of these additional factors goes back to a variety of considerations. Small-cap stocks are often less liquid than their large-cap peers. Illiquidity is typically considered a risk for investors who want to trade freely in and out of stocks at low costs; they therefore expect a premium for investing in illiquid assets[6]. Also, there is less analyst and media coverage, and a corresponding lack of information, for small-cap compared to large-cap companies, which may be considered a risk factor for which investors demand compensation.

The presence of a value premium goes back to behavioral considerations. Value stocks, as opposed to growth stocks, are expected to have lower future growth rates. When growth rates mean-revert and expectations are not met, growth stocks typically fall out of favor with myopic investors, who prefer value stocks. Growth may also be referred to as a factor on its own. In fact, it is one of the oldest factors mentioned in academic and practitioner literature. Back in the 1930s, Thomas Rowe Price argued that companies are subject to a lifecycle of growth, maturity and decline. The best time for investing in a company would therefore be the growth period, when investors are able to participate in the expansion of the company. In this context, growth fulfills the characteristics of a risk factor, as a company's future growth trajectory is unknown. Hence, investors demand a premium as compensation for their exposure to this systematic source of risk.

In 1997, the three-factor 'Fama-French Model' was extended by Carhart's momentum factor as a fourth source of systematic risk. The intuition behind the existence of a momentum factor refers to investors' over- and underreaction to new information.[7] In 2015, Fama and French themselves extended their three-factor model by two additional factors that incorporate the variability in firm profitability and companies' investment policies – two measures of what is commonly referred to as the quality factor. Different explanations for the existence of a quality factor have been put forward. Hunstad [2013] argues that quality stocks earn a premium because of the difference in behavior between risk-averse and risk-seeking investors. While risk-averse investors look for companies with high profitability and low levels of debt, risk-seeking investors favor low-quality stocks in search of additional returns.

[6] Illiquidity may also be modeled as a separate factor.
[7] See Barberies et al. [1998] and Hong et al. [2000].

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

THE LOW VOLATILITY ANOMALY

In recent years, a sixth factor has attracted more and more attention: the low volatility factor. It was first observed in academic literature by Haugen and Baker [1991], who demonstrated that low volatility stocks in the U.S. outperformed their market-capitalization-weighted benchmarks. Other authors found empirical evidence in support of the existence of the low volatility anomaly also outside of the U.S.[8]. This observation is often referred to as the low volatility anomaly because its existence argues against the very foundation of the CAPM[9], which states that investors hold risky assets only if they receive adequate compensation for the non-diversifiable risk of the asset. If this assumption held true, why would investors demand a premium for stocks with lower risk? Ramos and Han [2013] drew upon investors' behavior in an attempt to explain this phenomenon. The underlying rationale is similar to the argument brought forward in support of the quality factor. The authors argue that risk-seeking investors that are willing to accept a moderate loss in pursuit of high returns tend to overpay for riskier assets.[10]

Hence, and assuming the existence of all of the factors described above, a stock's return may be decomposed as follows:

$$\mu_i = r_f + \beta_1 (r_m - r_f) + \beta_2 \, SIZE + \beta_3 \, VAL + \beta_4 \, GRW + \beta_5 \, MOM + \beta_6 \, QAL + \beta_7 \, VOL + \alpha \quad (1)$$

with:

» r_f: risk-free rate of return,
» r_m: market rate of return,
» SIZE, VAL, GRW, MOM, QAL, VOL: returns of factor indices for size, value, growth, momentum, quality and volatility respectively.

Under the assumption that global markets are fully integrated, country-specific risks should not be explicitly priced, as global investors are likely to diversify away any country-specific component. However, in practice, investors still encounter a variety of explicit and implicit, i.e. psychological, barriers. Hence, many risk models also include country, currency and sometimes even industry factors to account for corresponding deviations.

APPLICATION OF FACTOR MODELS AND MINIMUM VARIANCE CONCEPTS

The introduction of factor models has changed the understanding of, and approach to, investing. The extension of the single-factor CAPM to a multi-factor model has led to a steady decrease of what may traditionally be considered 'alpha'. What was initially assumed to be the skill of active management may now largely be explained by, or decomposed into, premia arising from the exposure to systematic sources of risk.

[7] See Barberies et al. [1998] and Hong et al. [2000].

[8] See e.g. Ang et al. [2006], Blitz and Vliet [2007], Blitz et al. [2012], Baker and Haugen [2012], Carvalho et al. [2012], Clarke et al. [2006].

[9] Low volatility, low risk and low beta are typically used interchangeably. CAPM specifically uses 'beta' and the anomaly, therefore, would technically be 'low beta', since beta includes correlation.

[10] Besides this explanation, often referred to as the 'lottery ticket' effect, additional rationale for the existence of a low volatility premium have been put forward. E.g. arbitrage aversion of institutional investors, confusion of relative with total risk, and agency pricing (Baker and Haugen [2012]); leverage-constrained investors using high-beta stocks to instead drive prices up (and premia down), career risk/aversion to deviate from benchmark (low beta stocks causes higher tracking error and underperformance in bull market), (Brennan and Li [2008], Baker and Wurgler [2011], Blitz and van Vliet [2007]); principal-agent problem: portfolio managers hold "call options" so favor high vol strategies, aiming for higher return through high risk/overconfidence (Black [1972], Black [1992], Asness and Pedersen [2012]).

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

While factor models were initially used primarily in a passive context to explain returns, they are now increasingly being applied to portfolio construction. The capturing of risk premia in systematic index-based solutions may be achieved by selecting and/or weighting stocks based on their factor exposures derived from heuristic models, or based on optimizations that consider relationships among and between assets or underlying factors in order to control for potentially unintended risks. Optimizations may be derived from variance-covariance matrices, either on a stock-return level or based on a risk factor.

In our analysis, we follow a factor-based optimization approach. Optimizations, as compared to heuristic low volatility concepts, allow for a relatively easy introduction of controls for unintended sources of risk. Furthermore, factor-based optimizations, as compared to stock-level optimizations, lead to more stable risk forecasts as they are less influenced by 'noise'[11].

The construction of minimum variance strategies based on risk models further allows us to pursue our research target: the assessment of the interaction of risk factors. In theory, risk factors are often constructed based upon long-short portfolios. Correlations among such portfolios are found to be very low, indicating independence or orthogonality. In practice, however, investors are often constrained to benchmarks and subject to short-selling restrictions, which has consequences for the interaction of risk factors, as our empirical results indicate.

EMPIRICAL FRAMEWORK

Our empirical analysis is based on two broad investable universes:
» a global developed markets equity portfolio; and,
» a global emerging markets equity portfolio

The investable developed markets equity universe consists of 1,800 stocks made up of the largest 600 stocks each in the North America, Europe and Asia/Pacific regions, respectively.[12]

The investable emerging markets equity universe consists of 800 stocks derived from the STOXX® Emerging Markets 1500 Index. This liquidity-optimized version covers about 80% of emerging equity markets' free-float market cap, offering liquid access to emerging markets and thereby ensuring easy tradability.

Within global developed markets, we additionally study regional universes that make up the North America, Europe and Asia/Pacific regions, respectively as well as a separate universe consisting of the largest 900 securities from USA and a separate universe consisting of the largest 600 securities by market capitalization from Japan. Within emerging markets, we additionally study the investable China A securities universe represented by 900 securities classified as China A securities derived from the STOXX Greater China Total Market Index (TMI). These securities represent the largest Chinese H-shares, B-shares and Red Chips, as well as the largest companies from Hong Kong and Taiwan.

As stocks with low liquidity may easily be confused with those of low return volatility, we consider only those stocks that display a minimum average daily traded value (ADTV) of 1 million US dollars within the above universes.

[11] See, e.g. Chan et al. [1999].

[12] STOXX classifies countries based on rules-based and transparent methodology that excludes any subjective decisions from the process. Details may be found here: https://www.stoxx.com/country-classification

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Two variants of minimum variance strategies are typically constructed based on the universes as well as on each applicable individual regional subset[13].

- The first minimum variance strategy, which we term 'constrained', aims at minimizing portfolio variance while simultaneously being restricted to certain characteristics of its benchmark, which typically is the free-float market-capitalization-weighted portfolio composed of all stocks from the respective region. Constraints applied are based on country and industry allocations as well as style exposures relative to the benchmark. Country and industry weights are not allowed to deviate by more than 5 percentage points versus the benchmark, while style factor exposures other than volatility and size are not allowed to deviate by more than 0.25 standard deviations relative to the benchmark.[14]

- The second strategy is the unconstrained minimum variance strategy. Unconstrained minimum variance optimizations are found to typically lead to highly concentrated portfolios[15]. In order to prevent excessive concentration, a capping at constituent level is introduced: while the weight of a single constituent is restricted to 8%, the aggregated weight of all stocks exceeding a weight of 4.5% is restricted to 35%[16].

A point to note about emerging markets is that only a constrained version of the minimum variance strategy is constructed and therefore analyzed. An unconstrained version of the minimum variance portfolio resulted in extreme allocations to illiquid securities, making the portfolio non-investable.

METHODOLOGY AND CONSTRAINTS

Minimum variance optimizations are also typically prone to selecting large numbers of stocks, sometimes with insignificant weights. In order to prevent this from happening, an additional constraint in the form of an inverse Herfindahl index is applied. The constraint is defined as follows:

$$H_{MinVar} \geq H_{Benchmark} \times 30\% \tag{2}$$

where: $H = \frac{1}{\sum w^2}$

The variable H may be interpreted as a measure of the number of assets effectively influencing a portfolio. Hence, we ensure that the number of effective assets is at least 30% of that of the benchmark.

Recognizing that minimum variance concepts may sometimes tend to hold stocks with less liquidity, a minimum liquidity requirement ensures that there is no material build-up of illiquid securities in certain segments of the portfolio. The weighted average days-to-trade (d_S) for a given group of holdings (S) is defined as:

$$d_S = \sum_{i \in S} w_i \times \frac{h_i}{ADV_i} \tag{3}$$

[13] The optimization and the related performance analyses are conducted using the Axioma Optimizer and Axioma Portfolio Analytics, respectively. The factor model applied is the cross-sectional World-Wide Equity Factor Risk Model as provided by Axioma Inc.

[14] We do not constrain for size as the market-capitalization-weighted benchmark may be considered to have a size, i.e. large-cap, bias in itself, which we do not want to incorporate into the minimum variance strategy.

[15] See Green and Hollifield [1992], Chopra [1993] and Chopra and Ziemba [1993] for evidence concerning this point.

[16] We have selected this capping methodology as it is often applied in practice, referred to as UCITS capping. UCITS is an EU directive that facilitates the distribution of funds to retail investors.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Where $h_i = w_i \times N$ represents the holdings for stock i and ADV_i represents its average 20-day average daily volume. Stocks in the benchmark index are ranked by trading volume, and liquidity constraints are imposed on stocks in the two least liquid quintiles. For each of these quintiles (Q), the weighted average days-to-trade value of the overall positions is required to be no more than 10 times the weighted average days-to-trade of the same stocks held at corresponding benchmark weights:

$$\Sigma_{i \in Q} w_i \times \frac{w_i \times N}{ADV_i} \leq \gamma \times \Sigma_{i \in Q} b_i \times \frac{b_i \times N}{ADV_i} \quad (4)$$

A last constraint relates to portfolio turnover. As variance minimizations react very sensitively to changes in input parameters as they happen over time, it is important to keep turnover at bay. We achieve this by constraining the maximum one-way turnover allowed to 7.5% per quarterly rebalancing (versus 5% on monthly basis for the unconstrained strategy), which results in a maximum turnover of 30% per annum (the same for the unconstrained strategy). The optimization is rerun on a quarterly basis (monthly basis for unconstrained version). Emerging markets and China A securities universes have two additional constraints: tracking error constraint and a cap on the maximum number of names due to the specific characteristics of these markets.

Figure 1: Summary of constraints on minimum variance strategies

Dimension	**Constrained**		**Unconstrained**
	Developed Markets	Emerging Markets	
Weighting caps			
Single constituent	8%	8%	8%
Aggregate of all constituents with individual weights > 4.5%	35%	35%	35%
Effective number of assets	30% of benchmark	30% of benchmark	30% of benchmark
Rebalancing and max. turnover	Quarterly, 7.5%	Quarterly, 7.5%	Monthly, 5%
Country/industry exposure	Within 5% of benchmark	Within 5% of benchmark	No constraints
Factor exposures to all non-targeted factors	Within 0.25 × [standard deviation] of benchmark	Within 0.25 × [standard deviation] of benchmark	No constraints
Tracking error	No constraints	Within 5% of benchmark	No constraints
Max. number of names	No constraints	≤ Max{Min[(Names in benchmark /4), 500], 80}	No constraints

Source: STOXX

Our empirical analysis is conducted over a long period of history as noted in the figures in the respective sections.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

EMPIRICAL RESULTS

The discussion of empirical results primarily focuses on the characteristics of minimum variance strategies based upon the global developed markets universe and the emerging markets universe. Results that are specific to the North America, the Europe and Asia/Pacific regional subsets, Japan, USA and the China A securities market are discussed towards the end of the respective sections.

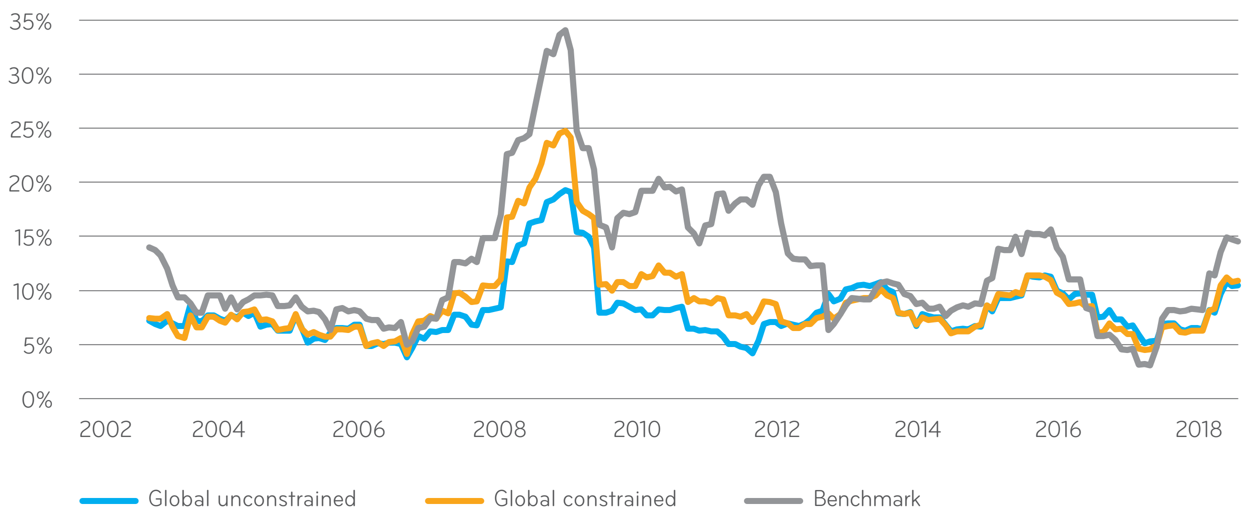
GLOBAL DEVELOPED MARKETS UNIVERSE

In this section, we discuss the results from the unconstrained and constrained versions of the developed markets minimum variance strategies.

Global developed markets unconstrained minimum variance strategy

As minimum variance strategies primarily aim at reducing total risk rather than increasing returns, we start with an analysis of volatility levels. Figure 2 shows that minimum variance strategies, constrained and unconstrained as applicable, lead to volatility levels persistently below those of the respective market-capitalization-weighted benchmark. When volatility increases across markets, the unconstrained approach reduces total risk even further compared to the constrained strategy. This observation is quite intuitive as the specification of benchmark constraints restricts the solution space available for the optimization process in its attempt to find the optimal, i.e. minimum variance, solution.

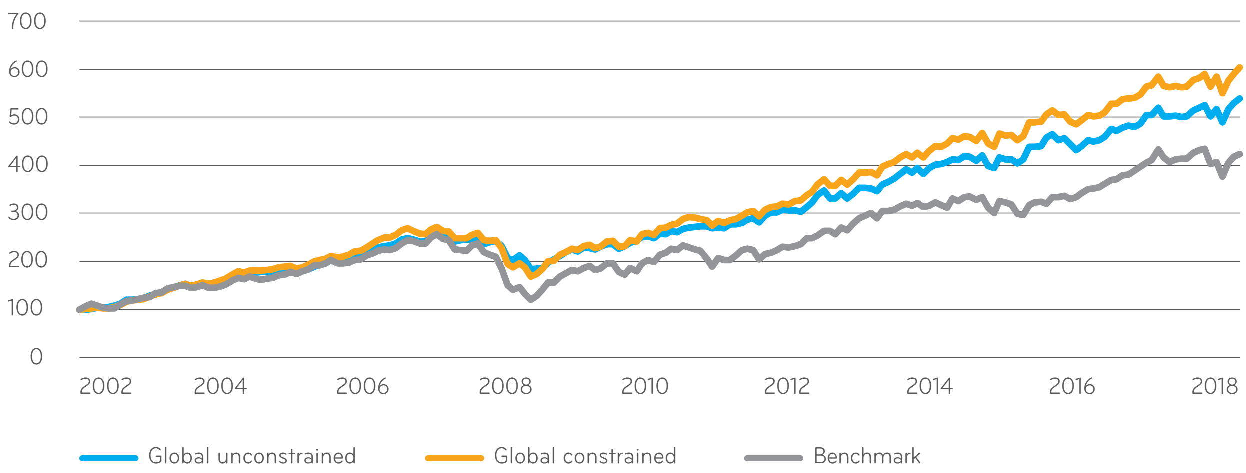
Figure 2: Rolling one-year standard deviation based on monthly returns for the global developed markets minimum variance strategies and the global developed markets benchmark.



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

A backtest of both minimum variance strategies, constrained and unconstrained, displays a consistent outperformance relative to their respective market-capitalization-weighted benchmark (see Figure 3). While the global developed markets benchmark generates a total return of 323.83% over the entire period from Oct. 2002 to Mar. 2019, the unconstrained minimum variance strategy generates a cumulative return of 438.73%. At 503.67%, the constrained strategy generates the highest overall cumulative return. Hence, one may conclude at this point that minimum variance strategies are able to capture and profit from the low volatility premium.

Figure 3: Historical performance of global developed markets minimum variance strategies and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

In order to understand the observed outperformance, we neutralize the effect of the benchmark and concentrate on the decomposition of the performance difference between the selected minimum variance strategies and their respective market-capitalization-weighted benchmark. Figure 4 provides the corresponding factor-based performance breakdown for the global developed markets unconstrained minimum variance strategy against the global developed markets benchmark for our observation period.

Figure 4: Factor-based performance attribution of global developed markets unconstrained minimum variance strategy versus the global developed markets benchmark

Source of return	Return	Risk	Information ratio	T-stat
Unconstrained MV index	438.73%	8.92%		
Benchmark	323.83%	14.35%		
Active	114.90%	9.59%	0.17	0.68
Specific return	92.75%	3.79%	0.34	1.38
Factor contribution	22.15%	10.17%	0.03	0.12
Style	7.14%	6.53%	0.02	0.06
Country	−57.18%	3.15%	−0.25	−1.03
Industry	14.74%	3.54%	0.06	0.24
Currency	58.57%	2.11%	0.39	1.57
Market	−1.12%	0.07%	−0.21	−0.87

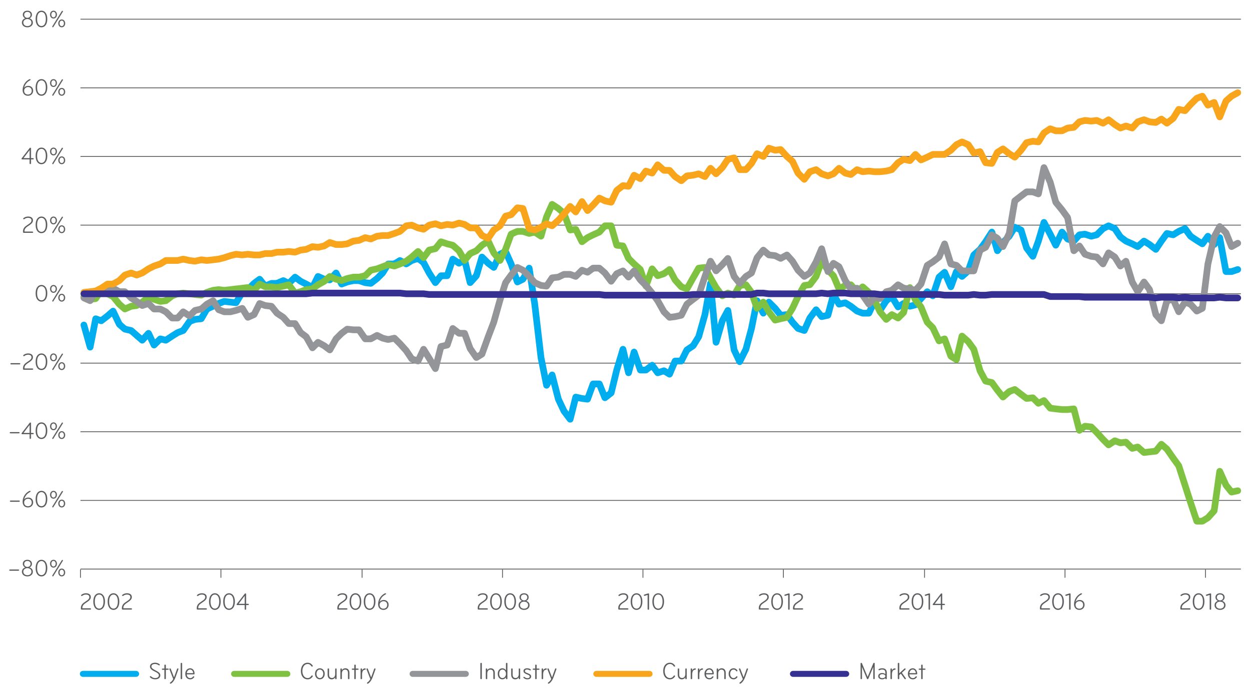
The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

The outperformance of the global developed markets unconstrained minimum variance strategy of 114.90% over its benchmark can be decomposed into a specific return and a factor-related component. Factor contribution, in turn, is further decomposed into an aggregate style factor, as well as country, industry, currency and market factors. At 92.75%, the specific return component dominates the total active return while the factor contribution only accounts for 22.15%. However, neither the specific return nor the aggregate factor contributions are found to be statistically significant at reasonable confidence levels (see t-statistic in Figure 4).

To better understand the evolution of factor contributions to active return over time, Figure 5 provides a graphical representation of cumulative sub-factor returns.

Figure 5: Cumulative return contribution of factors explaining the performance difference between the global unconstrained minimum variance index and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

Surprisingly, the overall performance impact of the style factor, of which volatility is a component, is relatively low. In fact, it is the currency factor that appears most prominent, with a cumulative return of 58.57%. The country factor has an equally significant contribution as the currency factor but in the other direction. As can be observed in Figure 5, the low net cumulative effect of the style factor over the entire period has mainly been driven by a significant negative performance contribution during the peak of the global financial crisis as well as in the recent 1.5 years. This negative impact therefore cannibalizes most of the positive contribution put together in all the other periods.

To further isolate the effect of the low volatility factor, we further decompose the aggregate style factor into its underlying components (see Figure 6).[17]

[17] Please refer to Figure A1 of the appendix for a detailed description of the Axioma Style factors used for this analysis.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

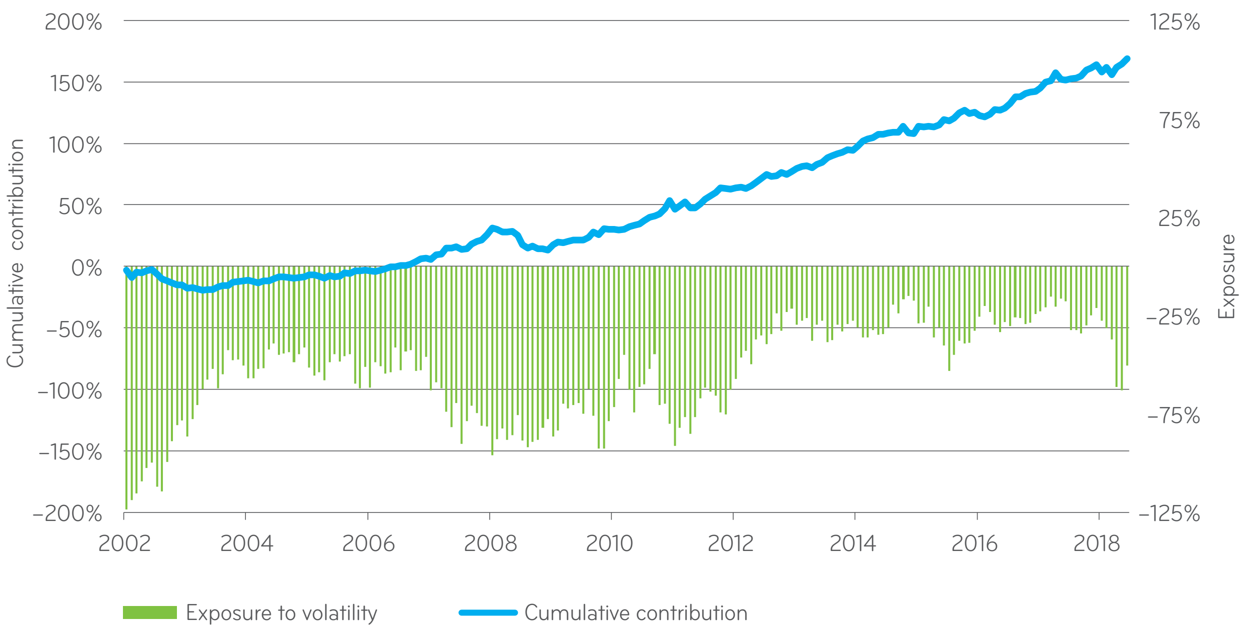
Figure 6: Style-factor-based return decomposition of performance difference between the global unconstrained minimum variance index and the global developed markets benchmark

Source of return	Return	Risk	Information ratio	T-stat
Style	7.14%	6.53%	0.02	0.06
Volatility	169.15%	4.32%	0.54	2.21
Growth	2.14%	0.21%	0.14	0.57
Leverage	−12.21%	0.40%	−0.43	−1.74
Liquidity	−38.59%	0.67%	−0.80	−3.26
Medium-term momentum	−89.76%	1.78%	−0.70	−2.85
Short-term momentum	−36.75%	1.38%	−0.37	−1.50
Size	25.58%	1.84%	0.19	0.79
Value	−12.58%	0.49%	−0.35	−1.44
Exchange-rate sensitivity	0.18%	0.14%	0.02	0.07

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

The decomposition reveals that the volatility factor is indeed highly significant (t-statistic of 2.21) and contributed 169.15% cumulatively, by far the highest return contribution among all style factors. The significance of the volatility factor is further supported by a persistently negative exposure to volatility over time (see Figure 7), which translates into the observed positive contribution to active returns.

Figure 7: Exposure to volatility factor over time and resulting cumulative return contribution to the performance difference between the global unconstrained minimum variance index and the global developed markets benchmark



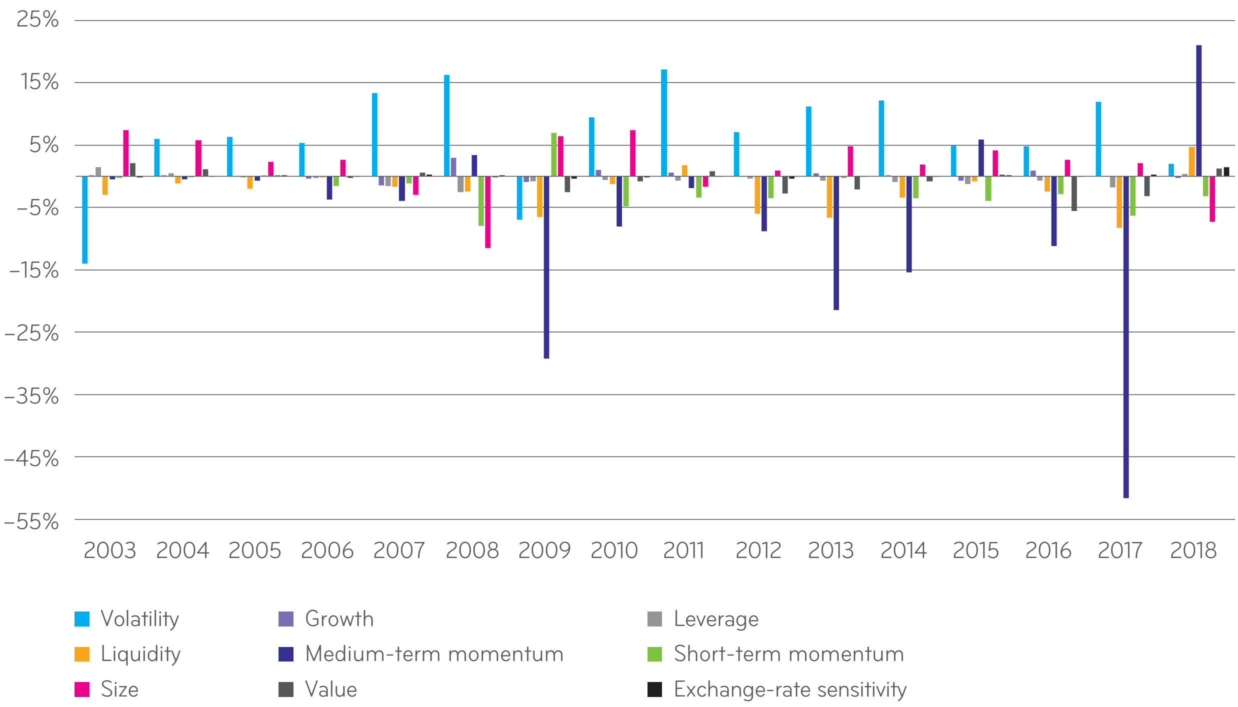
The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

However, we also find that the return contribution from exchange-rate sensitivity, leverage, liquidity, momentum and value all contribute negatively over the entire period of study. The highest negative contributions were from medium- and short-term momentum, with an aggregate of –126.52%, and from a negative exposure to liquidity (–38.59%). In fact, the statistical significance of liquidity (t-stat of –3.26) and medium-term momentum (t-stat of –2.85) is even higher than that of the volatility factor. Only size and growth style factors had a positive overall contribution; however, they were statistically insignificant.

A historical annual breakdown of style-factor returns reveals that the negative exposure to liquidity translated into a negative performance contribution persistent in 14 out of 16 calendar years (see Figure 8). Interestingly, the negative impact of medium-term momentum intensified substantially during the peak of the global financial crisis, as well as in other annual periods subsequently. It was also the primary reason for the negative impact of style on performance in 2009 and in 2017, as observed above. The volatility factor however, contributed positively in all years, with the exception of the periods of sharp recovery after the 'dot-com' bust and the global financial crisis.

Figure 8: Annual return contribution of style factors explaining the performance difference between the global unconstrained minimum variance index and the global developed markets benchmark

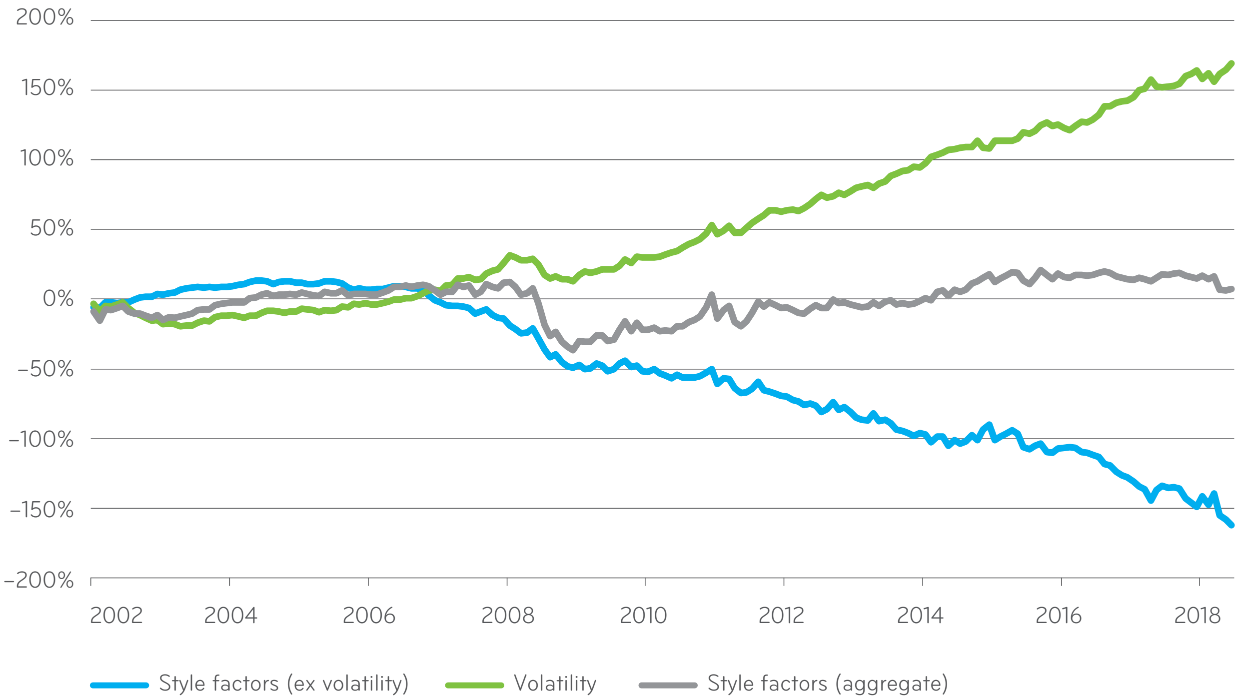


The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

In aggregate and over the entire period of observation, however, we may conclude that the net impact of the non-volatility style factors on performance was extremely negative, as can be seen in Figure 9.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 9: Cumulative return contribution of style factors explaining the performance difference between the global unconstrained minimum variance index and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

This negative impact almost completely offset the benefits accruing from the low volatility premium, resulting in a very low style factor contribution cumulatively over the observation period.

Global developed markets constrained minimum variance strategy

Having analyzed the unconstrained minimum variance strategy, we shall now investigate whether the negative performance contribution stemming from unintended sources of risk changes when we constrain the minimum variance optimization to achieve factor exposures closer to those of the benchmark. Figure 10 provides the return decomposition of the global developed markets constrained strategy.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 10: Factor-based return decomposition of performance difference between the global constrained minimum variance index and the global developed markets benchmark

Source of return	Return	Risk	Information ratio	T-stat
Unconstrained MV strategy	503.67%	10.09%		
Benchmark	323.83%	14.35%		
Active	179.83%	7.05%	0.34	1.36
Specific return	25.77%	2.93%	0.12	0.47
Factor contribution	154.07%	6.92%	0.29	1.19
Style	79.02%	4.51%	0.23	0.94
Country	–1.10%	1.57%	–0.01	–0.04
Industry	44.28%	2.75%	0.21	0.86
Currency	31.82%	1.13%	0.37	1.50
Market	0.04%	0.05%	0.01	0.05

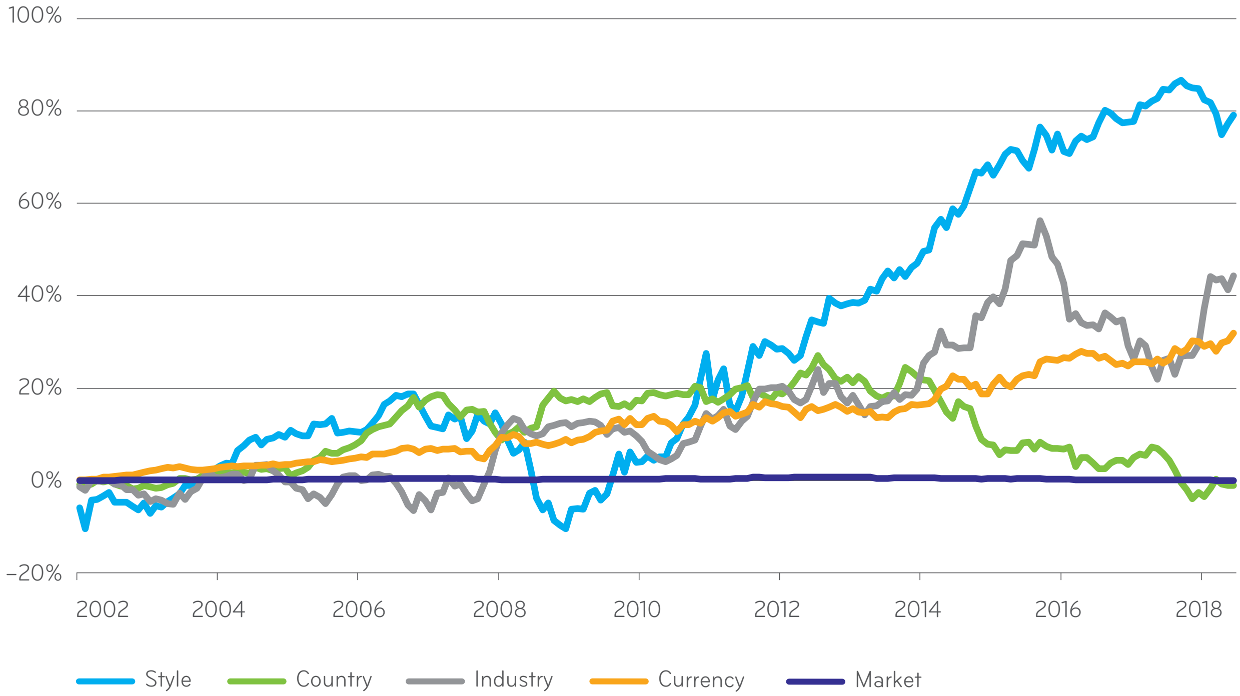
The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

At first glance, it may be observed that at 503.67%, the constrained strategy generates higher overall returns compared to the unconstrained version (438.73%). Another interesting difference between the two approaches is that the cumulative active return of the constrained strategy (179.83%) is now substantially tilted towards factors. Of the total active return, 154.07% may be attributed to systematic factors (style, country, industry, currency and market), while only 25.77% is attributable to specific return. This is hardly surprising as the optimization approach now has limited room for deviations from the specified benchmark (see Figure 10).

Unlike the unconstrained strategy, the aggregated impact of style returns over time is now by far the highest among all other factor groups (see Figure 11).

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 11: Cumulative return contribution of factors explaining the performance difference between the global constrained minimum variance index and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

A performance attribution to the underlying style factors explains this shift (see Figure 12).

Figure 12: Style-factor-based return decomposition of performance difference between the global unconstrained minimum variance index and the global developed markets benchmark

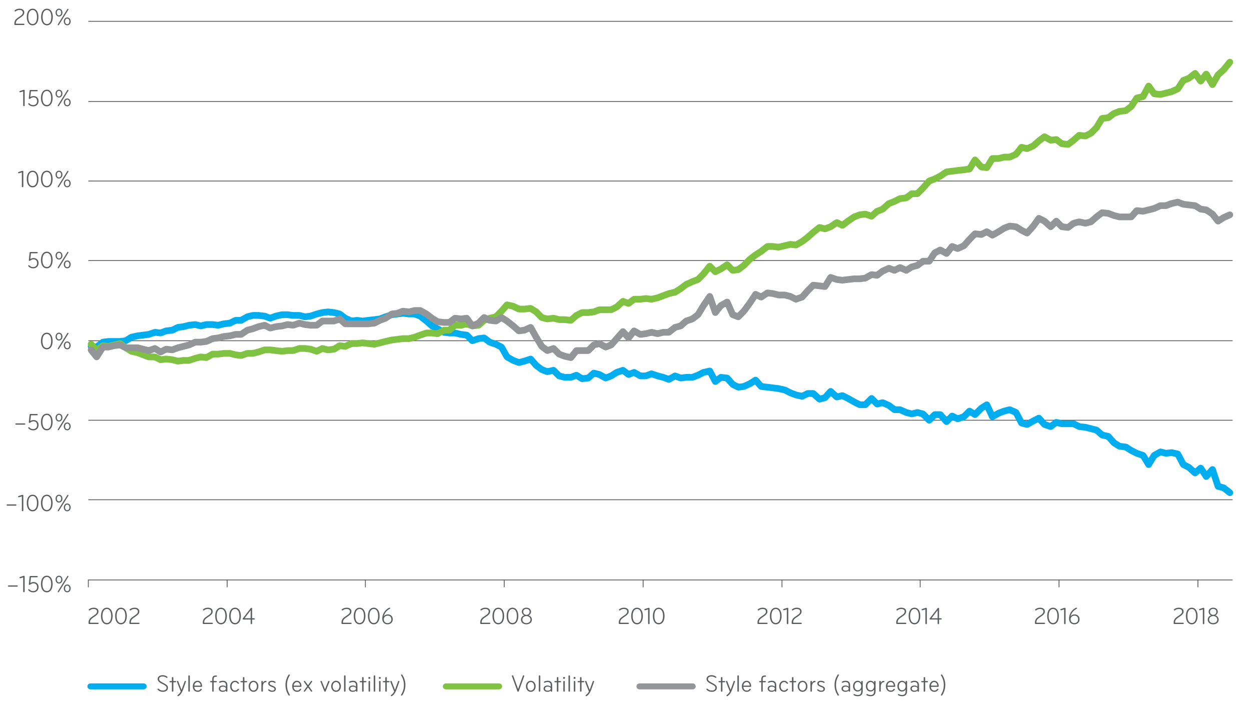
Source of return	Return	Risk	Information ratio	T-stat
Style	79.02%	4.51%	0.23	0.94
Volatility	174.43%	3.11%	0.74	2.99
Growth	1.71%	0.18%	0.13	0.52
Leverage	−12.44%	0.24%	−0.69	−2.82
Liquidity	−17.18%	0.34%	−0.66	−2.69
Medium-term momentum	−38.55%	0.84%	−0.61	−2.46
Short-term momentum	−41.08%	0.87%	−0.62	−2.52
Size	21.78%	1.75%	0.16	0.66
Value	−9.24%	0.32%	−0.38	−1.56
Exchange-rate sensitivity	−0.41%	0.14%	−0.04	−0.16

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

While the aggregated low volatility premium (174.43%) remains at similar levels compared to that within the unconstrained strategy, the negative contribution from medium-term momentum and liquidity is now noticeably less negative (see also Figure 13)[18], though the negative short-term momentum contribution is marginally higher. The aggregate momentum contribution in the constrained strategy is −79.63%, significantly less negative compared with the unconstrained strategy; the liquidity factor's contribution is also significantly less negative at −17.18%. The other style factors were more or less at similar levels to the unconstrained strategy, and, consequently, the net impact from all style factors is vastly positive at 79.02% over the entire period (see Figure 13).

Figure 13: Cumulative return contribution of style factors explaining the performance difference between the global constrained minimum variance index and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

We may therefore conclude that for the global developed markets portfolio, applying constraints to the minimum variance relative to its benchmark would have been beneficial in containing the offsetting effect on performance from unintended sources of risk.

Regional developed markets subsets

For the three regional subsets – North America, Europe and Asia/Pacific – the empirical results are qualitatively similar compared to those of the global developed markets minimum variance strategies (see Figure 14, Figure 15 and Figure 16). Although Japan is included within Asia/Pacific, we analyze Japan separately to see if the empirical results show similarities to other regional and global strategies.

[18] Please refer to Figure A2 of the appendix for a graphical representation of volatility exposure and resulting cumulative relative performance over time for the constrained global developed markets minimum variance index. Cumulative factor returns over time are displayed graphically in Figure A3.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

In all cases, minimum variance strategies outperformed their market-capitalization-weighted benchmarks. Hence, the empirical results confirm the existence of the low volatility premium also across regions. Unlike the global minimum variance strategies however, the unconstrained strategies for Europe and Asia/Pacific show better overall returns than their constrained counterparts. This is partially driven by high specific returns, i.e. systematic returns unexplained by the defined set of factors, that contribute substantially to the overall returns of the unconstrained strategies.

Figure 14: Style-factor-based return decomposition of performance difference between the North America minimum variance indices (constrained and unconstrained) and the North America benchmark

North America	**Unconstrained**				**Constrained**			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	437.62%	9.70%			464.93%	10.37%		
Benchmark	369.71%	13.66%			369.71%	13.66%		
Active	67.91%	8.22%	0.11	0.45	95.22%	6.43%	0.19	0.78
Specific return	38.19%	4.08%	0.12	0.51	7.07%	3.51%	0.03	0.11
Factor contribution	29.72%	7.83%	0.05	0.20	88.16%	5.43%	0.21	0.86
Style	34.09%	5.65%	0.08	0.33	79.62%	3.96%	0.26	1.06
Volatility	216.04%	3.89%	0.74	3.00	192.15%	2.84%	0.88	3.56
Style ex volatility	–181.95%				–112.53%			
Country	–16.59%	1.37%	–0.16	–0.65	–8.05%	0.45%	–0.23	–0.94
Industry	-8.90%	3.29%	–0.04	–0.15	11.82%	2.41%	0.06	0.26
Currency	25.47%	1.28%	0.26	1.07	4.96%	0.44%	0.15	0.60
Market	–4.34%	0.22%	–0.27	–1.09	–0.20%	0.14%	–0.02	–0.08

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

Figure 15: Style-factor-based return decomposition of performance difference between the Europe minimum variance indices (constrained and unconstrained) and the Europe benchmark

Europe	**Unconstrained**				**Constrained**			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	552.92%	12.89%			389.63%	14.74%		
Benchmark	278.45%	17.94%			278.45%	17.94%		
Active	274.47%	8.92%	0.41	1.66	111.19%	6.36%	0.27	1.09
Specific return	135.14%	4.42%	0.41	1.65	4.38%	3.66%	0.02	0.07
Factor contribution	139.33%	8.21%	0.23	0.92	106.80%	5.17%	0.32	1.29
Style	19.31%	6.46%	0.04	0.16	54.43%	3.94%	0.21	0.86
Volatility	145.39%	4.22%	0.46	1.86	97.64%	2.41%	0.62	2.53
Style ex volatility	–126.08%				–43.21%			
Country	–9.96%	2.22%	–0.06	–0.24	–20.59%	0.95%	–0.33	–1.35
Industry	92.82%	2.70%	0.46	1.85	67.01%	2.00%	0.51	2.09
Currency	36.45%	1.95%	0.25	1.01	5.51%	0.56%	0.15	0.61
Market	0.70%	0.02%	0.48	1.94	0.43%	0.02%	0.34	1.39

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 16: Style-factor-based return decomposition of performance difference between the Asia/Pacific minimum variance indices (constrained and unconstrained) and the Asia/Pacific benchmark

Asia / Pacific	Unconstrained				Constrained			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	505.81%	9.79%			333.85%	11.59%		
Benchmark	233.31%	15.08%			233.31%	15.08%		
Active	272.50%	10.43%	0.38	1.55	100.54%	7.20%	0.24	0.98
Specific return	235.90%	6.24%	0.55	2.24	38.86%	4.73%	0.14	0.58
Factor contribution	36.60%	9.56%	0.06	0.23	61.68%	5.68%	0.19	0.76
Style	26.27%	6.39%	0.06	0.24	46.84%	4.07%	0.20	0.80
Volatility	208.53%	4.24%	0.72	2.91	122.61%	2.66%	0.80	3.23
Style ex volatility	–182.26%				–75.77%			
Country	–116.32%	5.62%	–0.30	–1.22	–37.08%	1.17%	–0.54	–2.21
Industry	57.02%	3.93%	0.21	0.86	40.33%	2.86%	0.24	0.99
Currency	70.46%	3.03%	0.34	1.37	11.55%	0.60%	0.33	1.34
Market	–0.82%	0.04%	–0.27	–1.11	0.04%	0.02%	0.04	0.17

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

Even with the regional strategies, we find that the aggregate of the style factors other than the volatility factor is highly negative, which cannibalizes a lot of the low volatility premium. This drag on the low volatility premium may be 'limited' by constraining allowed style factor exposure deviations relative to the benchmark. However, the constrained approach not only limits the negative impact from unintended sources of style risk but also reduces the extent of the intended low volatility premium, albeit to a different extent for the three separate regions.

USA minimum variance strategy

Although securities from the USA is included within the North America universe that we reviewed earlier, we nonetheless analyze the USA 900 minimum variance strategy separately to study any similarities in the empirical results to the regional or global minimum variance strategies.

Even in the case of USA, minimum variance strategies outperformed their market-capitalization-weighted benchmarks, confirming the existence of the low volatility premium. Much like the global and regional (Europe and Asia/Pacific) minimum variance strategies, the unconstrained strategy for USA shows better overall returns than the constrained strategy, is primarily driven by higher specific returns.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 17: Style-factor-based return decomposition of performance difference between the USA minimum variance indices (constrained and unconstrained) and the USA benchmark

USA	**Unconstrained**				**Constrained**			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	339.27%	12.08%			290.08%	12.36%		
Benchmark	147.23%	14.72%			147.23%	14.72%		
Active	192.05%	12.15%	0.30	1.23	142.85%	8.89%	0.32	1.33
Specific return	132.84%	8.43%	0.30	1.23	71.07%	6.12%	0.23	0.96
Factor contribution	59.20%	9.07%	0.12	0.51	71.78%	6.05%	0.24	0.98
Style	4.01%	6.45%	0.01	0.05	27.90%	3.78%	0.15	0.61
Volatility	171.83%	4.06%	0.80	3.30	97.51%	2.47%	0.79	3.26
Style ex volatility	–167.83%				–69.61%			
Country	0.79%	0.07%	0.21	0.86	0.41%	0.07%	0.13	0.53
Industry	52.96%	4.43%	0.23	0.93	42.38%	3.54%	0.24	0.99
Currency	0.00%	0.00%	–0.15	–0.63	0.00%	0.00%	0.18	0.75
Market	1.44%	0.08%	0.34	1.41	1.09%	0.07%	0.29	1.21

The analysis is conducted for the period from Jan. 2003 to Mar. 2019. Returns are measured in USD total return.

The low volatility premium is significantly higher in the unconstrained strategy compared with the constrained version (see Figure 17). This may partly be explained by the limited scope in the optimization process for the constrained strategy. Just like the empirical results from the other minimum variance strategies studied earlier, the aggregate of the style factors other than volatility factor is highly negative in both strategies, thereby cannibalizes a lot of the low volatility premium and resulting in a very low style factor return contribution. The drag on the low volatility premium is 'limited' in the constrained minimum variance strategy approach, although this strategy simultaneously reduces the extent of the intended low volatility premium, with an overall style factor contribution that marginally better than the unconstrained strategy.

Japan minimum variance strategy

Although Japan is included within Asia/Pacific which we reviewed above, we analyze the Japan minimum variance strategy separately to see if the empirical results show similarities to other regional and global strategies. Even in the case of Japan, minimum variance strategies outperformed their market-capitalization-weighted benchmarks, confirming the existence of the low volatility premium. Much like Europe and Asia/Pacific minimum variance strategies, the unconstrained strategy for Japan shows better overall returns than the constrained strategy. This is primarily driven by higher specific returns, i.e. systematic returns unexplained by the defined set of factors, with a simultaneous reduction in the factor contribution.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 18: Style-factor-based return decomposition of performance difference between the Japan minimum variance indices (constrained and unconstrained) and the Japan benchmark

Japan	Unconstrained				Constrained			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	339.27%	12.08%			290.08%	12.36%		
Benchmark	147.23%	14.72%			147.23%	14.72%		
Active	192.05%	12.15%	0.30	1.23	142.85%	8.89%	0.32	1.33
Specific return	132.84%	8.43%	0.30	1.23	71.07%	6.12%	0.23	0.96
Factor contribution	59.20%	9.07%	0.12	0.51	71.78%	6.05%	0.24	0.98
Style	4.01%	6.45%	0.01	0.05	27.90%	3.78%	0.15	0.61
Volatility	171.83%	4.06%	0.80	3.30	97.51%	2.47%	0.79	3.26
Style ex volatility	−167.83%				−69.61%			
Country	0.79%	0.07%	0.21	0.86	0.41%	0.07%	0.13	0.53
Industry	52.96%	4.43%	0.23	0.93	42.38%	3.54%	0.24	0.99
Currency	0.00%	0.00%	−0.15	−0.63	0.00%	0.00%	0.18	0.75
Market	1.44%	0.08%	0.34	1.41	1.09%	0.07%	0.29	1.21

The analysis is conducted for the period from Apr. 2002 to Mar. 2019. Returns are measured in USD total return.

The low volatility premium is quite pronounced in the unconstrained version compared with the constrained version (see Figure 18), as can perhaps be expected due to the limited scope in the optimization process for the constrained strategy. Nonetheless, like in the global and regional minimum variance strategies, the aggregate of the style factors other than the volatility factor is highly negative. This cannibalizes a lot of the low volatility premium, thereby resulting in a very low style factor return contribution. The drag on the low volatility premium is 'limited' in the constrained minimum variance strategy approach, although this strategy simultaneously reduces the extent of the intended low volatility premium.

EMERGING MARKETS UNIVERSE

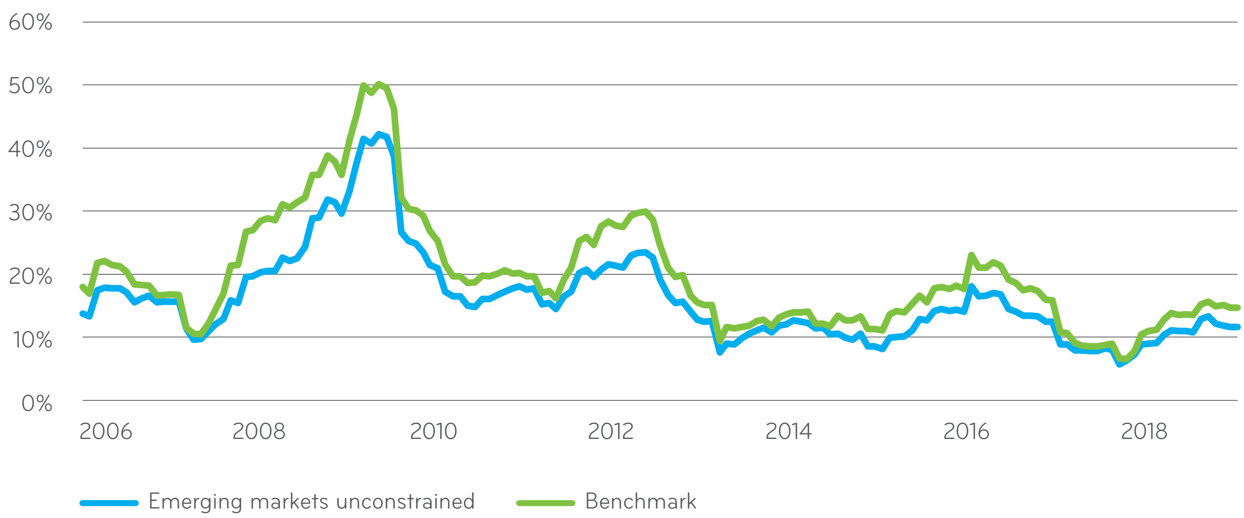
In this section, we discuss the results from the constrained version of the emerging markets minimum variance strategy, followed by a discussion on the China A securities minimum variance strategies (constrained and unconstrained).

Emerging markets minimum variance strategy

Beginning with an analysis of volatility levels, Figure 19 shows that the constrained minimum variance strategy reduces volatility to levels persistently below the benchmark. When volatility increases across markets, the minimum variance strategy behaves as intended by reducing the total risk of the portfolio. However, in the absence of an unconstrained version of the emerging markets minimum variance strategy, it is not possible to evaluate the efficacy of the constraints in the total risk reduction.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

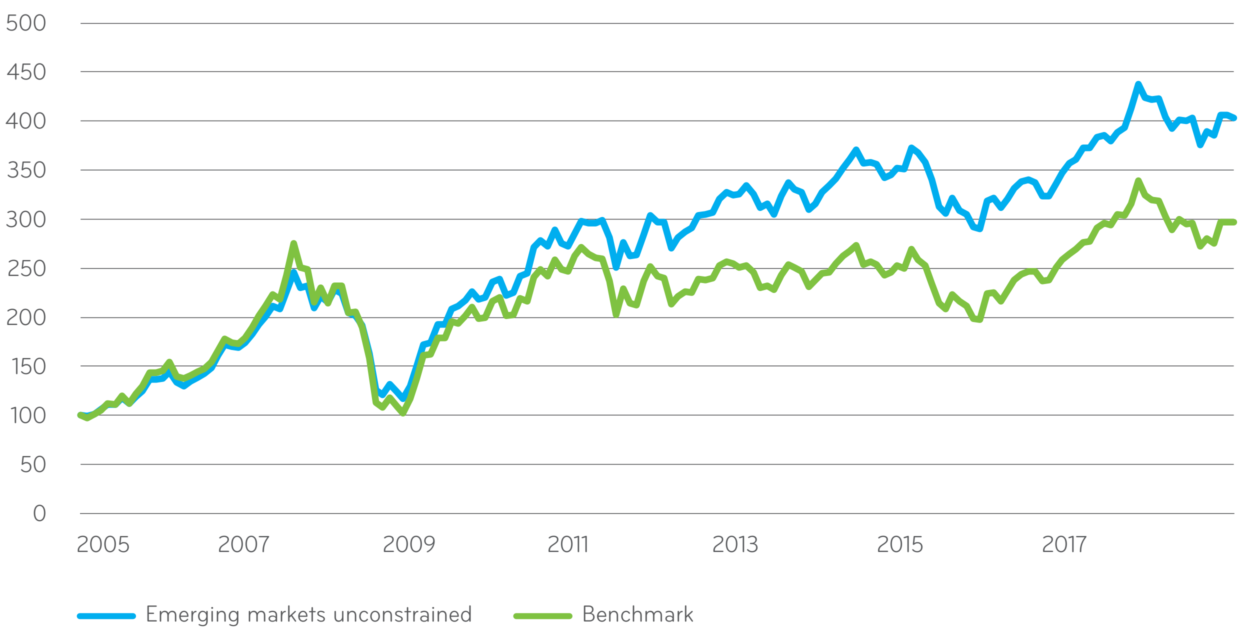
Figure 19: Rolling one-year standard deviation based on monthly returns for the emerging markets minimum variance strategy and the emerging markets benchmark



The analysis is conducted for the period from Apr. 2006 to Mar. 2019. Returns are measured in USD total return.

A backtest of the minimum variance strategy displays a consistent outperformance relative to the market-capitalization-weighted benchmark (see Figure 20) from the time of the onset of the financial crisis. While the emerging markets benchmark generated a total return of 196.55% over the entire period between Mar. 2005 and Mar. 2019, the minimum variance strategy generated a cumulative return of 303.32%.

Figure 20: Historical performance of the emerging markets minimum variance strategy and the emerging markets benchmark



The analysis is conducted for the period from Apr. 2005 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

One may therefore conclude that the emerging markets minimum variance strategy is able to capture and profit from the low volatility premium.

In order to understand the observed outperformance, we neutralize the effect of the benchmark and concentrate on the decomposition of the performance difference between the minimum variance strategy and its benchmark. Figure 21 provides the corresponding factor-based performance breakdown for the emerging markets 800 liquidity optimized minimum variance strategy for our observation period.

Figure 21: Factor-based performance attribution of emerging markets minimum variance strategy versus the emerging markets benchmark

Source of return	Return	Risk	Information ratio	T-stat
Constrained MV strategy	303.32%	17.85%		
Benchmark	196.55%	21.93%		.
Active	106.77%	5.53%	0.43	1.62
Specific return	−5.65%	3.15%	−0.04	−0.15
Factor contribution	112.42%	5.50%	0.46	1.72
Style	51.00%	2.45%	0.47	1.75
Country	6.77%	1.88%	0.08	0.30
Industry	36.26%	2.20%	0.37	1.38
Currency	7.73%	1.41%	0.12	0.46
Local	10.39%	0.72%	0.32	1.21
Market	0.27%	0.02%	0.25	0.93

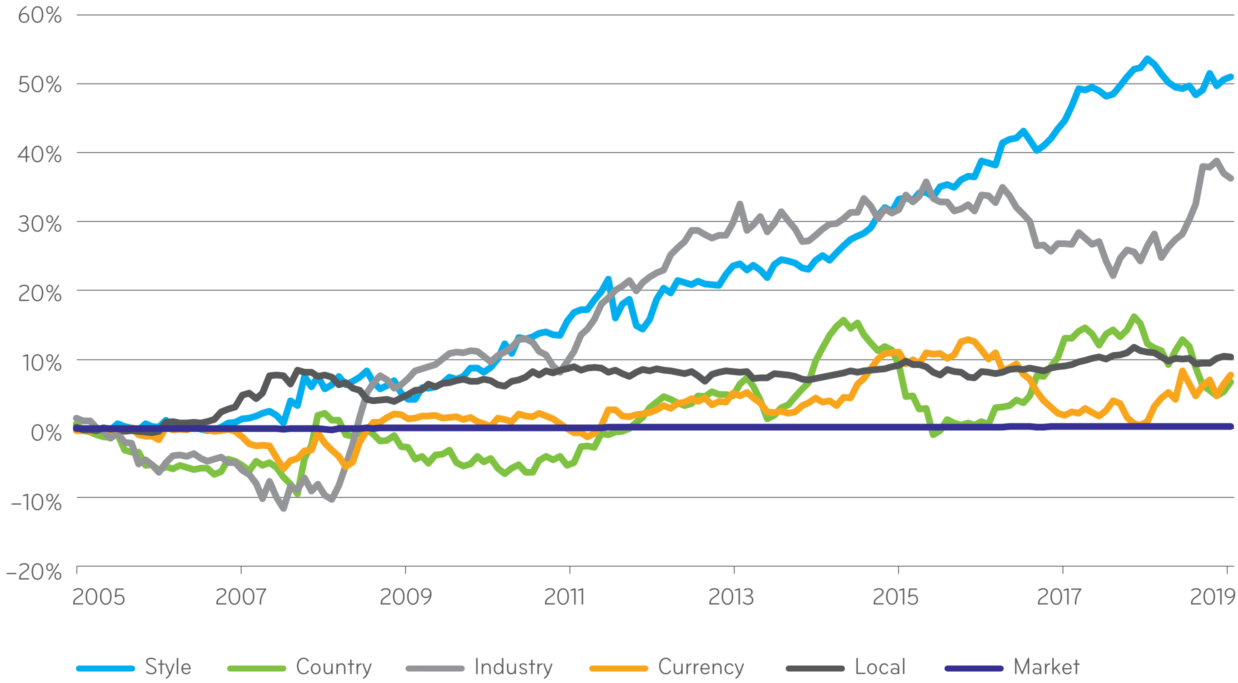
The analysis is conducted for the period from Apr. 2005 to Mar. 2019. Returns are measured in USD total return.

The cumulative outperformance of the minimum variance strategy of 106.77% over its benchmark can be decomposed into a specific and a factor-related component. Factor contribution, in turn, is further decomposed into an aggregate style factor, as well as country, industry, currency and market factors. At −5.65%, the contribution of specific returns, albeit negative, may well be considered immaterial, whereas the factor contribution of 112.42% explains all of the active return (and more). However, neither the specific return factor nor the aggregate of factor contributions is found to be statistically significant at reasonable levels (see t-statistic in Figure 21).

To better understand the development of factor contributions to excess return over time, Figure 22 provides a graphical representation of cumulative factor returns.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 22: Cumulative return contribution of factors explaining the performance difference between the global unconstrained minimum variance index and the emerging markets benchmark



The analysis is conducted for the period from Apr. 2005 to Mar. 2019. Returns are measured in USD total return.

The overall style factor contribution, of which volatility is a component, to the overall factor contribution is relatively substantial; it is also statistically significant at reasonable levels (see Figure 21). The industry factor is the second-largest contributor with a cumulative return of 22.96% and is also statistically significant.

We further decompose the aggregate style factor into its underlying components (see Figure 23).[19] The decomposition reveals that the volatility factor is, in fact, statistically highly significant (t-statistic of 5.06) and contributed 100.91%, by far the highest return among all style factors. The significance of the volatility factor is further supported by a persistently negative exposure to volatility over time (see Figure 24), which translated into the observed positive contribution to active return.

[19] Please refer to Figure A1 of the appendix for a detailed description of the Axioma Style factors used for this analysis.

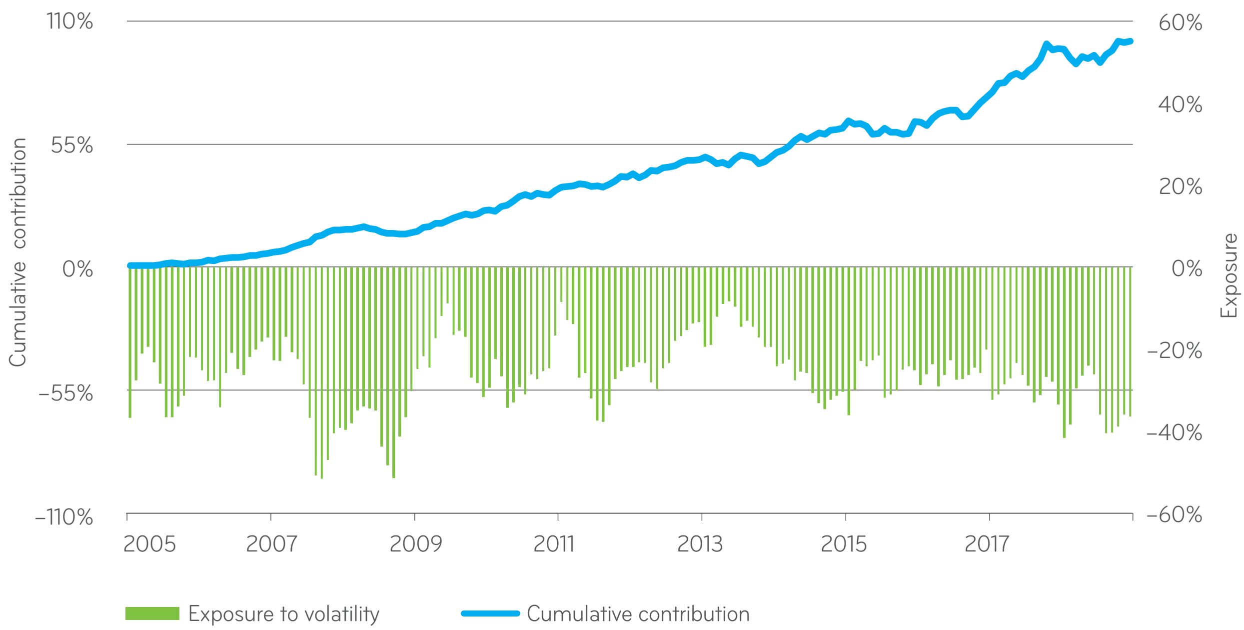
FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure 23: Style-factor based return decomposition of performance difference between the emerging markets minimum variance strategy and the emerging markets benchmark

Source of return	Return	Risk	Information ratio	T-stat
Style	51.00%	2.45%	0.47	1.75
Volatility	100.91%	1.68%	1.35	5.06
Growth	−4.27%	0.18%	−0.54	−2.01
Leverage	2.48%	0.10%	0.56	2.11
Liquidity	−3.06%	0.23%	−0.29	−1.10
Medium-term momentum	−13.60%	0.53%	−0.58	−2.15
Short-term momentum	−12.23%	0.75%	−0.37	−1.37
Size	−8.64%	0.62%	−0.31	−1.17
Value	−10.26%	0.36%	−0.63	−2.36
Exchange-rate sensitivity	−0.33%	0.09%	−0.08	−0.30

The analysis is conducted for the period from Apr. 2005 to Mar. 2019. Returns are measured in USD total return.

Figure 24: Exposure to volatility factor over time and resulting cumulative return contribution to the performance difference between the global unconstrained minimum variance index and the emerging markets benchmark



The analysis is conducted for the period from Apr. 2005 to Mar. 2019. Returns are measured in USD total return.

We also find that growth, liquidity, momentum, size, value and exchange-rate sensitivity contribute negatively to the active returns with the value factor being the only one with a statistically significant contribution. These six style factors act as a drag on the low volatility premium, with only leverage offering some positive contribution.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

China A securities minimum variance strategy

China A securities are not included within the global emerging markets universe that we reviewed above. We therefore analyze China A securities minimum variance strategies separately in this section. Even in the case of China A Securities, minimum variance strategies outperformed their market-capitalization-weighted benchmarks, confirming the existence of the low volatility premium. However, a large contribution to active returns arises from specific return in both minimum variance strategies (see Figure 25). Much like Europe and Asia/Pacific minimum variance strategies, the unconstrained strategy for the China A securities universe shows better overall returns than the constrained strategy, which, besides specific returns, is additionally driven by a healthy factor contribution.

Figure 25: Style-factor-based return decomposition of performance difference between the China A securities minimum variance indices (constrained and unconstrained) and the China A securities benchmark

China A securities	**Unconstrained**				**Constrained**			
Source of return	**Return**	**Risk**	**IR**	**T-stat**	**Return**	**Risk**	**IR**	**T-stat**
Minimum variance	861.78%	25.93%			668.94%	28.78%		
Benchmark	374.24%	28.98%			374.24%	28.98%		
Active	487.54%	9.13%	0.58	2.25	294.70%	6.88%	0.52	2.02
Specific return	214.29%	8.40%	0.28	1.07	266.12%	6.67%	0.48	1.88
Factor contribution	273.26%	3.94%	0.75	2.92	28.58%	2.70%	0.13	0.50
Style	162.75%	2.84%	0.62	2.41	−9.85%	2.03%	−0.06	−0.23
Volatility	209.13%	1.70%	1.32	5.17	19.67%	0.95%	0.25	0.98
Style ex volatility	−46.38%				−29.52%			
Country	−1.14%	0.04%	−0.31	−1.22	−0.15%	0.02%	−0.10	−0.38
Industry	116.57%	2.28%	0.55	2.15	44.92%	1.79%	0.30	1.19
Currency	0.00%	0.00%	−0.28	−1.09	0.00%	0.00%	−0.27	−1.07
Local	−5.40%	0.25%	−0.24	−0.92	−6.38%	0.22%	−0.35	−1.36
Market	0.48%	0.03%	0.15	0.59	0.04%	0.01%	0.03	0.12

The analysis is conducted for the period from Jan. 2004 to Mar. 2019. Returns are measured in USD total return.

The low volatility premium is quite pronounced in the unconstrained version compared with the constrained version (see Figure 25), driving the large overall style factor returns. The aggregate of the style factors other than volatility factor is fairly negative, much like the other minimum variance strategies seen earlier. However, the large contribution from the style factors disappears completely, and, in fact, turns marginally negative in the constrained version. Even the low volatility premium is quite insignificant compared to the active return, suggesting that the constraints on unintended risk exposures prevent the extraction of the low volatility premium in the case of China A securities. This is an important empirical observation that investors should most certainly keep in mind whilst considering constrained minimum variance approaches to not just China A securities, but elsewhere.

CONCLUSION

In this paper, we have analyzed the performance of minimum variance strategies for the developed and emerging markets universes, as well as selected regional subsets separately, and further decomposed the performance of these strategies into their underlying systematic factors. We isolated the performance contribution stemming from the low volatility anomaly while simultaneously assessing contributions arising from other style factors identified in the related literature.

The empirical analysis reveals that, relative to market-capitalization-weighted benchmark portfolios, minimum variance strategies not only enable investors to reduce the risk of their portfolios, but also assist in harvesting positive and statistically significant low volatility premia. This observation holds true even after controlling for industry and country factors across geographies and market classifications. However, the empirical results further show that unconstrained minimum variance strategies typically lead to statistically significant exposures to other style factors with persistent and sometimes negative performance contributions over time, thereby cannibalizing parts of the low volatility premium. This observation again is found to exist across geographical regions.

Empirical findings indicate that applying constraints to limit unintended style factor exposures relative to the respective benchmarks may help reduce the negative performance contribution from such style factors, and in many cases also their statistical significance. However, this outcome is achieved at the cost of a lower reduction in portfolio volatility and a reduction in the low volatility premium. Investors therefore need to be mindful of these ‘drags’ on performances due to intended style factor risk exposures for implementing appropriate countermeasures in their portfolios and/or benchmarks.

REFERENCES

Ang, A, R. J. Hodrick, Y. Xing, and X. Zhang [2006]. "The Cross-Section of Volatility and Expected Returns." Journal of Finance, 61 (1), 259-299.

Baker, M., B. Bradley, and J. Wurgler [2011]. "Benchmarks As Limits To Arbitrage: Understanding The Low-Volatility Anomaly." Financial Analysis Journal, 67 (1), 40-54.

Baker, N.L., and R.A. Haugen [2012]. "Low Risk Stocks Outperform Within All Observable Markets Of The World." Social Science Research Network. Retrieved from https://ssrn.com/abstract=2055431.

Barneris, N., A. Ahleifer, and R. Vishny [1998]. "A model of investor sentiment." Journal of Financial Economics, 49 (3), 307-343.

Behr, P., A. Güttler, and F. Miebs [2008]. "Is Minimum-Variance Investing Really Worth the While? An Analysis with Robust Performance Inference." Working paper. http://www.cfr-cologne.de/download/kolloquium/2009/behr_et_al.pdf

Blitz, D., and P.V. Vliet [2007]. "The volatility effect." Journal of Portfolio Management, 34 (1), 102-113.

Blitz, D., J. Pang and V.V. Pim [2013]. "The volatility effect in emerging markets." Emerging Market Review, 16, 31-45.

Chan, K.C.L., J.J. Karceski, and J. Lakonishok [1999]. "On portfolio optimization: Forecasting Covariances and choosing the risk model." Review of Financial Studies, 12 (5), 937-974.

Carhart, M. M. [1997]. "On persistence in Mutual Fund Performance." Journal of Finance, 52 (1), 57-82.

Carvalho, R.L.D., L. Xiao, and P. Moulin [2012]. "Demystifying Equity Risk-Based Strategies: A Simple Alpha Plus Beta Description." The Journal of Portfolio Management, 38 (3), 56-70.

Chopra, V. K. (1993). "Improving Optimization." Journal of Investing, 2 (3), 51-59.

Chopra, V. K., and W. T. Ziemba [1993]. "The Effects of Errors in Means, Variances, and Covariances on Optimal Portfolio Choice." Journal of Portfolio Management, 19 (2), 6-11.

Chow, T. M., E. Kose, and F. Li [2016]. "The Impact of Constraints on Minimum-Variance Portfolios." Financial Analysts Journal, 72 (2), 52-70.

Clarke, R., H. D. Silva, and S. Thorley (2006). "Minimum-Variance Portfolios In The U.S. Equity Market." Journal of Investing, 33 (1), 108-118.

Fama, E. F., and K. R. French [1992]. "The Cross-Section of Expected Stock Returns." Journal of Finance, 47 (2), 427-465.

Fama, E. F., and K. R. French [2015]. "A Five-Factor Asset Pricing Model." Journal of Financial Economics, 116 (1), 1-22.

Green, R., and B. Hollifield [1992]. "When Will Mean-Variance Efficient Portfolios Be Well Diversified." Journal of Finance, 47 (5), 1785-1809.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Haugen, R.A., and N.L. Baker [1991]. "The Efficient Market Inefficiency of Capitalization-Weighted Stock Portfolios." Journal of Portfolio Management, 17 (3), 35-40.

Hong, H., T. Lim, and J.C. Stein [2000]. "Bad News Travels Slowly: Size, Analyst Coverage, and the Profitability of Momentum Strategies." Journal of Finance, 55 (1), 265-295.

Hunstad, M. [2014]. "What is Quality." Northern Trust.

Lintner, J. [1965]. "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets". Review of Economics and Statistics, 47 (1), 13-37.

Mossin, J. [1965]. "Equilibrium in a Capital Asset Market." Econometrica, 34 (4), 768-783.

Ramos, E., and J. Hans [2013]. "Finding Opportunities Through the Low Volatility Anomaly." BMO Global Asset Management.

Sharpe, W. [1964]. "A Theory of Market Equilibrium Under Conditions of Risk." Journal of Finance, 19 (3), 425-442.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

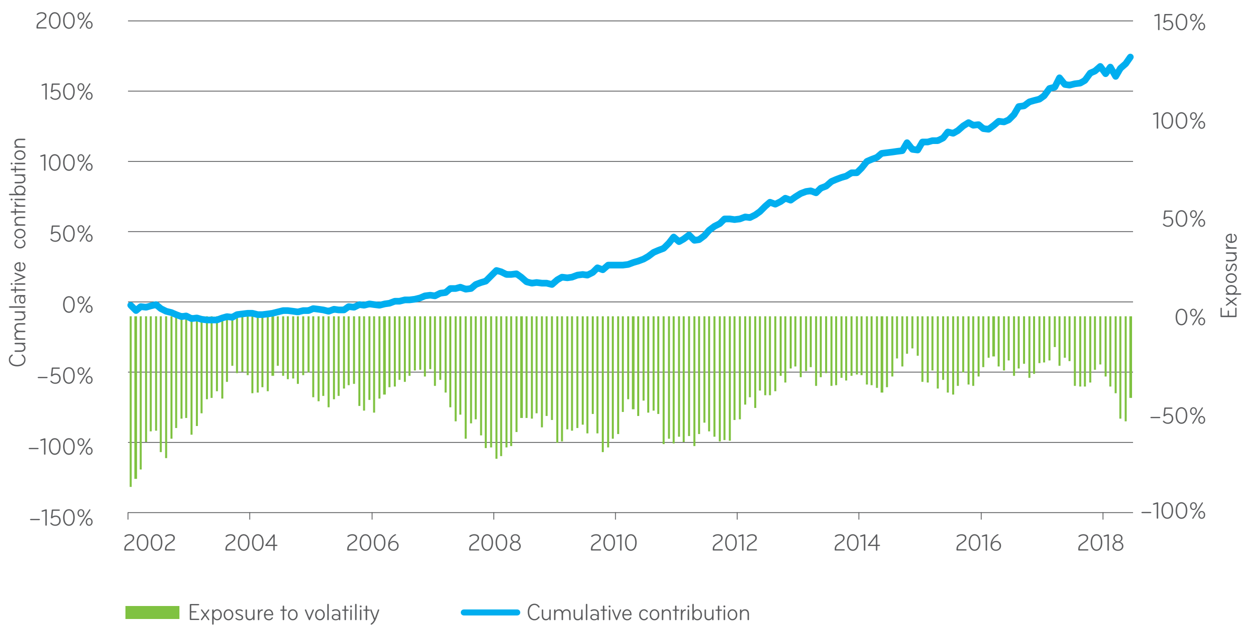
APPENDIX

Figure A1: Definitions of style factors

Style factor	Definition
Volatility	3-month average of absolute return over cross-sectional standard deviation
Growth	Sustainable growth rate, historical earnings growth, historical sales growth
Leverage	Debt-to-assets ratio
Liquidity	1-month average daily volume over market capitalization
Medium-term momentum	Cumulative return over past year excluding most recent month
Short-term momentum	Cumulative return over past month
Size	Natural logarithm of total issuer market capitalization
Value	Book-to-price ratio, earnings-to-price ratio
Exchange-rate sensitivity	6-month beta to returns of a currency basket containing USD, EUR, GBP, JPY

Source: Axioma World-Wide Equity Factor Risk Models

Figure A2: Exposure to volatility factor over time and resulting cumulative return contribution to performance difference between the global constrained minimum variance index and the global developed markets benchmark



The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

Figure A3: Annual return contribution of style factors explaining the performance difference between the global unconstrained minimum variance index and the global developed markets benchmark

The analysis is conducted for the period from Oct. 2002 to Mar. 2019. Returns are measured in USD total return.

FACTOR EXPOSURES OF MINIMUM VARIANCE STRATEGIES

About STOXX Ltd.

STOXX Ltd. is a global index provider, currently calculating a global, comprehensive index family of over 10,000 strictly rules-based and transparent indices. Best known for the leading European equity indices EURO STOXX 50, STOXX Europe 50 and STOXX Europe 600, STOXX Ltd. maintains and calculates the STOXX Global index family, which consists of total market, broad and blue-chip indices for the regions Americas, Europe, Asia/Pacific and sub-regions Latin America and BRIC (Brazil, Russia, India and China), as well as global markets.

To provide market participants with optimal transparency, STOXX indices are classified into three categories. Regular "STOXX" indices include all standard, theme and strategy indices that are part of STOXX's integrated index family and follow a strict rules-based methodology. The "iSTOXX" brand typically comprises less standardized index concepts that are not integrated in the STOXX Global index family, but are nevertheless strictly rules-based. While indices that are branded "STOXX" and "iSTOXX" are developed by STOXX for a broad range of market participants, the "STOXX Customized" brand covers indices that are specifically developed for clients and do not carry the STOXX brand in the index name.

STOXX indices are licensed to more than 500 companies around the world as underlyings for Exchange-Traded Funds (ETFs), futures and options, structured products and passively-managed investment funds. Three of the top ETFs in Europe and approximately 25% of all assets under management are based on STOXX indices. STOXX Ltd. holds Europe's number one and the world's number two position in the derivatives segment.

STOXX is part of Deutsche Börse Group, and markets the DAX indices.

www.stoxx.com

Theilerstrasse 1a
CH-6300 Zug
P +41-(0)43 430 71 01
stoxx@stoxx.com
www.stoxx.com

London: +44 (0) 207 862 7680
Frankfurt: +49 (0) 69 211 0
New York: +1 646-876-2030
Hong Kong: +852 2530 7862
Tokyo: +81-3-4578-6688

STOXX

INNOVATIVE. GLOBAL. INDICES.

STOXX Ltd. is part of Deutsche Börse Group.