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Low-Volatility Investing: Empirical evidence of the defensive properties of low volatility enhanced portfolios

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Low-Volatility Investing: Empirical evidence of the defensive properties of low volatility enhanced portfolios

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Abstract

Our study provides further insights into the evidence of excess returns of low volatility enhanced portfolios. Based on the framework presented by Campbell and Vuolteenaho (2003), we analyze through-the-cycle as well as stress periods to provide an insight into which portfolio construction technique is most beneficial in enhancing portfolio returns on a risk-adjusted basis. Analyzing a new data set from 2000 through 2015, we find that low volatility enhanced portfolios exhibit extraordinary excess returns during stressed market conditions. Empirically, we find that enhancing portfolios with low volatility building blocks produces on average an excess return between 5.6% and 17.2% for US equity and 1.8% and 16.7% for European equity portfolios during strong market corrections. We provide evidence that across different portfolio construction techniques, relative excess returns become more pronounced the more severe the market correction becomes. While equal weight techniques contribute very steadily to the overall excess return in down cycles, switching techniques show more relative outperformance towards the deeper end of market down cycles.

Keywords: *factor investing, factor premia, low-volatility investing, low beta, low risk, downside properties, Calmar ratio, modified Sharpe ratio*

JEL Classification: *C12, G11, G12, G14*

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1. The Paradox of Low Risk Investing

The most important axiom of the market risk-reward theorem (MRRT) is that riskier assets deliver on average higher returns as a compensation for holding more risk[1]. The MMRT has been used for many decades as the main underlying principle that, inter alia , resulted in the proposition of the Capital Asset Pricing Model (CAPM). Originally formulated by Treynor (1961), Sharpe (1964), Linther (1965) and Mossin (1966) and further developed via various multi-factor approaches by Merton (1969, 1973), Ross (1976) and Fama and French (1992, 1993), the model is based on the principle that the factors behind assets should be seen as the primary driver of what are commonly known as risk premia. This model is still broadly accepted in finance both in academia as well as in financial markets (Levy and Roll 2012). According to the model, investors do interpret the linear relationship between an asset's expected return and its market beta so that they are compensated for taking on systematic (non-diversifiable) risk. If this interpretation holds, the following relationship should be empirically observable: the riskier the asset in relation to the respective market portfolio, the more market participants discount that asset's expected cash flows. To put this another way: rational investors expect higher returns from assets with higher non-diversifiable risk.

Nevertheless, Black, Jensen and Scholes (1972) and Scholes (1972) reported abnormally higher returns for low systematic risk portfolios of US equities measured by the asset's beta coefficient vis-a-vis the market. More recently, Baker, Bradley and Wurgler (2011), Baker and Haugen (2012) and Frazzini and Pedersen (2014) reported similar observations in most of the world's equity markets including emerging market equities. Looking at our sample of daily low volatility returns, we also report similar findings where the low volatility portfolio exhibits a significant outperformance over the broad market portfolio (see Figure 1). Our data shows an excess return of around 3% for US low volatility stocks and considerably over 3% for European low volatility stocks on an annualized basis. Notably, these excess returns are delivered with lower risk levels. While the broad market portfolio exhibits annualized volatility of 20.0% and 21.8% for the USA and Europe respectively, the low volatility portfolios have volatility levels of just 15.4% and 14.0% respectively.

[FIGURE 1 ABOUT HERE]

When providing an explanation for the observed pricing anomaly which is shown in Figure 1, answers can be broken down into a) rationally-based explanations and b) behavioral-based explanations. With regards to the rational explanations, there are primarily two aspects to this which had first been put forward by Black and Scholes (1973) and others, and is a consequence of what is referred to as the 'delegated asset pricing phenomena'. The main observation is that asset owners delegate the task of managing these assets to asset managers whose performance is measured against a predefined benchmark. The given guidelines for those asset managers are often restrictive with regards to the use of leverage that can be applied to their portfolios. As a consequence, low beta stocks are viewed as an

[1] See Markowitz (1952), specifically the findings which lead to the modern portfolio theory (MPT). In order to avoid any misunderstanding, the MPT states that only the systematic risk is priced.

inferior choice. In other words, to hold low beta stocks raises the risk that asset managers could miss their return targets due to the perception that these stocks offer too little compensation in return. Ang, Hodrick, Xing and Zhang (2006) examined the pricing of aggregate volatility risk and found that stocks with high sensitivities to innovations in overall market volatility have low average returns. They estimate that the reduction in average returns of highly volatile stocks vis-à-vis low volatile stocks is on average 1% annualized.

An explanation relating to the behavioral explanations is offered by Barberis and Huang (2001). They argue that investors systematically underestimate the risk of 'high volatility stocks' and thus by bidding up prices of high beta stocks on average, returns are therefore subsequently reduced. A similar explanation is given by Barber, Odean and Zhu (2009). They find that stocks that consistently received the most media attention typically were stocks with higher volatility. These stocks tend to be generally overbought and hence deliver a lower average return over longer periods due to the fact that valuations mean revert to their long-term averages. An additional explanation has been put forward by Clarke, De Silva and Thorley (2011). In their recent study, they argue that minimum variance, low volatility and low beta can be interpreted as very closely related strategies. They provide an analytical framework which shows that a minimum variance portfolio subject to a long-only constraint when stock returns can be attributed to a single factor model consists only of low beta stocks. Specifically, these are stocks whose beta is less than the threshold beta and which are weighted in inverse proportion to their idiosyncratic volatility. They argue that theses portfolios have more robust properties in turbulent market situations and hence can offer higher returns in the long-run. Baker, Bradley and Wurgler (2011) tested these results in their own study using the largest 1000 stocks in the US equity universe and indeed found almost no differences to clearly separate the three portfolio construction approaches. Regardless of whether they defined risk as volatility of beta or whether they used the entire stock universe or only large cap stocks, the low risk or beta portfolio consistently outperformed the high risk or beta portfolio over the studied period from 1963 to 2008.

In our study here, we follow the arguments provided by Clarke, De Silva and Thorley (2011) as well as Baker, Bradley and Wurgler (2011) and specifically investigate the behavior of low volatility enhanced portfolio returns under varying market conditions. Fostering a true practitioner's view on how low volatility returns can be beneficial to the overall portfolio risk and return relationship, we enhanced our study in the following respect: we tested how a specific portfolio construction technique changes the level of excess returns under different market assumptions. While there is a long list of empirical evidence to explain the low volatility puzzle using standalone factor portfolios, there is limited literature available which uses a more practitioner-skewed framework. To extend the scope of this study to a more realistic portfolio framework is in our view even more important as the assumption of running a single factor portfolio is quite unrealistic for many asset allocators who typically manage a number of different portfolios. We therefore examine daily returns of five different portfolio construction processes (model portfolios)[2] for i) the existing unconditional data sample and ii) conditional data for all documented down-market cycles. Each model portfolio

[2] long switch (lsw), long/short (lsh), equally weighted daily (eqw_daily), equally weighted (eqw) and equally weighted January (eqw_jan). All switch strategies are based on a risk-on/risk-off model using levels of bipower variation (5-minute) of the volatility for S&P500 and DAX index. Further details about each strategy is outlined in section 3.

follows a specific portfolio construction technique which is implementable using passive portfolio building blocks (see Figure 2 for details about each model portfolio).

[FIGURE 2 ABOUT HERE]

We test all strategies against the broad market equity portfolio on a risk-adjusted basis. The basic assumption for this study design accounts for the fact that in reality, some practitioners use low volatility factor building blocks solely on a tactical basis where others prefer their portfolio to be exposed to low volatility returns without trying to time the market cycles. To accommodate the requirements from the first group of investors, we define a risk-on/risk-off switching model which provides an indication as to the most favorable point at which to add or remove the low volatility factor from the broad market portfolio. For accommodating the requirements from the latter group of investors, we test the existence of harvestable low volatility premia by using an equal weighting technique. For all portfolios, daily returns and risk figures are than calculated and compared to the broad market exposure. Additionally, for each portfolio, two risk measurement ratios are derived to quantify the level of added value of each portfolio construction process using two risk adjusted measures: these being the Calmar Ratio (CR)[3] and the Modified Sharpe Ratio (MSR)[4].

2. Data and Methodology

We obtained daily index level data from MSCI for the broad market exposures as well as for the regional low volatility building blocks[5] (MSCI USA Select Dynamic 50% Risk Weighted Index and MSCI EMU Select Dynamic 50% Risk Weighted indices) for May 31, 1999 through December 7, 2015. This indices select stocks with below median volatility. This formation process of this low volatility portfolio is carried out on a semi-annual bases and hence, is an equivalent for the low volatility ranking procedure used in literature[6]. Returns are calculated based on daily index level changes using a log return calculation. The performance figures for the five model portfolios are calculated using the framework described in section 2.1 and 2.2 and the market portfolio is represented by the index performance of the MSCI USA and EMU respectively. In total, the sample includes 3901 daily observations for US and 3826 for EMU. The difference in the number of observations is simply due to the difference in the so called 'index holiday schedules' so that the two regional data samples do not contain the exact same number of daily index level data.

To better understand the two data sets, Figure 3 provides a summary of distribution for the key return and risk characteristics of the five tested portfolio construction techniques as well as for the broad market portfolio.

[3] For further details see Young 1991
[4] For further details see Sharpe 1970
[5] Index level data accessible via the MSCI website (www.msci.com)
[6] For further information on the index methodology we refer to the MSCI website (www.msci.com)

[FIGURE 3 ABOUT HERE]

For both regional exposures, we observe excess returns for all tested low volatility enhanced model portfolios over the market portfolios regardless of the construction technique applied. All of these excess returns have been generated using less risk compared to the market portfolio. While all US portfolios exhibit negative skewness, European portfolios show more variations for 3rd moments, where some are slightly positive and others are slightly negative. With regards to 4th moments we observe relatively high numbers across all tested portfolios regardless of the region. Based on the summary statistics we conclude that our data set of daily returns are not normally distributed which is confirmed by the JB test results.

Finally, to quantify the factor premia added to each model portfolio on a risk-adjusted basis, we calculate the Calmar Ratio (CR) as well as the Modified Sharpe Ratio (MSR) and compare the results with the ratio of the market portfolios. The higher the CR, the better the performance on a risk-adjusted basis. For the MSR, we use a modification to the original Sharpe Ratio as our data sample exhibits non-normal distributed returns[7]. We conclude that the model portfolio with a higher MSR than the broad market is able to add value on a risk-adjusted basis. Furthermore, we understand that the higher the MSR value the higher the level of benefit a particular portfolio construction technique is able to add. The highest MSR value indicates which of the tested construction techniques should be the preferred choice for a portfolio manager managing a low volatility enhancing portfolio.

2.1. Portfolios Using Switch Signals for Low Volatility Enhancing

The switching model in this study uses volatility levels of liquid stock markets to represent US and European portfolios, in particular it uses the realized volatility levels of the S&P500 and DAX universe[8]. In order to accommodate time variations in volatility levels, we use the upper confidence band around the 30 day moving average of the realized volatility levels. A risk-off signal[9] appears when the observed volatility on a particular day exceeds the 1.5 standard deviation upper bound on three consecutive days and then subsequently disappears when the observed volatility on a particular day undercuts the 1.5 standard deviation lower bound on three consecutive days. Figure 4 provides a graphical overview of the risk-on and risk-off days for US and European models where the crossing indicates a potential kick-in or kick-out switching signal.

[FIGURE 4 ABOUT HERE]

While the total number of risk-off days for both models is very similar (752 for US, 728 for Europe), the single periods with consecutive risk-off days differ heavily between the two

[7] We therefore use the Cornish-Fisher expansion, which adjusts the VaR in terms of asymmetric distribution and above-average frequency of returns at both ends of the distribution, see Cornish and Fisher (1937)
[8] The 5-minute bi-power variation of S&P500 and DAX were downloaded from Bloomberg data service.
[9] In this study a risk-off rebalance trade is understood as a reduction in the level of market cap exposure and an increase in the level of low volatility exposure.

markets. The longest risk-on period is observed within the European market from 19th March, 2009 to 17th March, 2010, hence 244 days (almost the length of an entire trading year) without a single switching signal. For the US model, the longest risk-on period is documented from 9th August, 2002 to 5th February, 2003; this accounts for 120 days without a rebalance trade activity.

Two out of the five model portfolios in our study design use the switch signals from the volatility model described. The long switch (lsw) strategy uses factor return long positions fully financed by the broad market position for all risk-off periods where the long/short (lsh) strategy uses factor return long positions financed by selling short the broad market position for all risk-off periods (for more details about the construction technique see Figure 2).

2.2. Portfolios Using Strategic Tilts for Low Volatility Enhancing

Three out of five model portfolios are exposed to low volatility factor returns strategically. They use an equal weight technique either on a buy and hold or a rebalancing basis. The equal weighted daily (eqw_daily) strategy uses factor return and broad market long positions equally weighted on a daily basis. The equal weighted (eqw) strategy uses low volatility and broad market long positions with an equal split on a buy and hold basis. The equal weighted January (eqw_jan) strategy uses factor return and broad market long positions equally weighted where the rebalancing is executed on the first day of each individual calendar year (for more details about the construction technique see Figure 2).

3. Empirical Estimates for the Low Risk Premia in a Portfolio Context

The results from May 2000 through November 2015 daily return data support the findings from academic literature in that the low volatility premia is persistent over time and produces an excess return over the broad market portfolio. On a single factor portfolio basis, we report a significant annualized outperformance for US and European portfolios (recall Figure 1).

In this section, we discuss the findings from the unconditional and the conditional analysis. The unconditional study design looks at the returns from five different model portfolios and assesses whether these model portfolios produce higher risk-adjusted returns over the entire period. The conditional analysis looks in particular into the behavior of these five model portfolios when markets are in downside mode. Of particular interest is how the differently constructed low volatility enhanced portfolios are able to cope with very difficult market conditions and the defensive properties which they provide. Such characteristics have been laid out in some studies (see for example Campbell and Vuolteenaho 2003), and are also empirically observable in a more recent data sample.

3.1. Unconditional Findings

The time series data over the above described period shows that both regional universes outperform on all tested model portfolios vis-à-vis the broad market portfolio. Nevertheless, the levels of outperformance differ quite significantly from strategy to strategy depending on the market analyzed. Panel A of Figure 5 shows the cumulative relative (over the broad market) portfolio returns for US exposures while Panel B highlights the results from the

European perspective. To provide a relative orientation of the overall market conditions throughout the time series, we show the market levels on both charts.

[FIGURE 5 ABOUT HERE]

Overall, the most beneficial portfolio construction technique is the non-rebalanced equal weighted strategy (eqw) which yields an outperformance over the full period of 46.22% (2.99% annualized) in the case of the US and 57.34% (3.78% annualized) for European portfolios. The data in Figure 5 reveals a fundamental difference when looking at the two different types of construction techniques. While the strategic allocation to the low volatility factor for US portfolios adds only limited value (except during the first period), we find a consistent positive contribution for European portfolios from using equally weighted techniques. Our data provides evidence, that at least for European portfolios, a strategic allocation to low volatility returns is beneficial regardless of business cycle conditions, and hence, an active timing component of low volatility returns seems less important.

In contrast to the findings for European portfolios, for US portfolios, the cyclicality is much more apparent. For example, the switching model using long/short portfolio construction techniques (lsh) exhibits superior returns over all other strategies for longer periods (for example in 2000 or 2011-2014) while underperforming quite significantly in other periods (2004-2008 or 2015). However, in both cases, the relative return analysis also exhibits very notable behavior even though the effect is less pronounced for US portfolios. If markets show strong corrections, we find that these portfolios outperform the broad market quite significantly. When we look at the switching model portfolios, the findings for the two regional implementations are very different. For US portfolios, the long/short (lsh) construction technique works quite well and even exhibits the highest relative outperformance between 2011 and 2014. Also, the long switch (lsw) approach produces an almost identical outperformance of 84.8% over time which translates into an annualized excess return of 5.5%. However, for European portfolios, both switching techniques produce limited to almost no outperformance and hence do not add value with an annualized outperformance of just 0.4%.

This raises the question of how effective market downside protection properties of low volatility enhanced portfolios are and if there is evidence that low volatility enhanced techniques are able to reduce the draw down risks compared to the broad market portfolio. As the results in Figure 6 illustrate, we find that all construction techniques were able to reduce the maximum draw down, and in some cases quite significantly. Moreover, across all model portfolios, the number of days above water mark (WM) are significantly higher compared to the market portfolio. When we look at the recovery time of all model portfolios and compare the number of days it takes to reach the previous water mark levels within a particular bottom-to-peak market cycle, we find that the model portfolios report around half as many days as the market portfolio and sometimes even less (for example EMU eqw with 947 vs 2295 days). This indicates that not only are these model portfolios able to reduce the downside risk versus the market but they also recover much more quickly than the market portfolio.

[FIGURE 6 ABOUT HERE]

When adjusting the aforementioned outperformance by the inherent risk levels, we find substantial added value for all the low volatility enhanced portfolios. Figure 7 shows CR and MSR values derived from daily returns from 2000 through 2015 for all model - as well as for the broad market portfolios. Overall we find that low volatility enhanced portfolios exhibit higher risk-adjusted returns than the market portfolio. With the exception of the US lsw portfolio, this holds true across regions as well as risk measures applied.

The most added value comes from the non-rebalanced equal weighting technique in both regions. Similar values are reached by the other equal weight portfolios. On average, the group of equal weight portfolios produce slightly superior results. However, in the case of the US lsw portfolio, the contribution is almost identical. Almost no added value comes from lsh US portfolio as well as from the lsw European portfolio. Both model portfolios fail to produce risk-adjusted excess returns.

We conclude that low volatility enhanced portfolios using the equal weight technique are best in delivering excess returns for the level of risk involved. Furthermore, from the group of equal weight techniques, we prefer the non-rebalancing construction process due to the following: a) it delivers the highest risk-adjusted returns, b) the non-balancing set-up does not add additional costs which would need to be weighed up against the returns and c) it does not require advanced allocation modelling techniques to detect the risk-on and risk-off regime switches.

[FIGURE 7 ABOUT HERE]

3.2. Conditional Findings

Based on the findings in the previous section and based on the understanding that this outperformance potentially comes from the fact that these portfolios show better risk behaviors we also analyzed all portfolios using a conditional framework. That is to say, we quantified returns and risk values across all model portfolios for all market conditions in contracting market scenarios. Our hypothesis assumes low volatility enhanced portfolios benefit not only from substantially smaller maximum drawdowns compared to the broad market but also from better tail hedge properties and hence, should exhibit outperformance in various conditional market down cycles.

[FIGURE 8 ABOUT HERE]

When looking at how the tested model portfolios behave in conditional market down cycles, we looked at a Peak-to-Bottom (PtoB) and a Bottom-to-Peak (BtoP) scenario, and found a common pattern across regions and also to a lesser extent across the construction techniques applied. While the cumulative excess returns becomes bigger the more severe the market down turn becomes, this effect does not revert when markets are moving back up to their historical WM. This indicates that low volatility enhanced portfolios cumulate excess return on the way down while not losing the entire cumulated excess return on the way up. As shown in Panel A and C in Figure 8, the cumulative excess returns of the model portfolios through a full market down cycle (PtoB) are skewed towards the positive values the more negative the drawdown figures grow. In Panel B and D, almost all BtoP plots across regions show an almost vertical shape of cumulative excess returns which are centered around zero. Similar but less conclusive is the situation for the lsh portfolios where the behavior of the cumulated excess return figures are quite different for each individual BtoP cycle. However, on the way down (PtoB cycle), this construction technique shows the best tail hedging properties. The lsh portfolios work best at the very deep end of the market down cycle with cumulative excess returns moving almost horizontally towards higher positive values. Overall we find firm evidence that the tested portfolio construction techniques using low volatility returns provide an increasing relative down side hedge the bigger the drop from the historical WM becomes. This is also confirmed by very high R^2 values of around 90% for US and between 40-78% for European portfolios.

On average, we find that the annualized excess returns in contracting market cycles for the tested model portfolios range between 5.48% and 17.16% for US and between 1.84% and 16.7% for European portfolios (median values). As the data in Figure 9 exhibits, the best results in terms of returns are shown for the lsh portfolios while the lsw portfolios show the smallest excess returns. Not only do we find that the model portfolios gain excess returns with lower risk levels than the market portfolio, but the longer the contraction in the cycle becomes the larger the excess returns become. At least for most US portfolios, this relationship is observable across different construction techniques.

[FIGURE 9 ABOUT HERE]

In the last section of the conditional findings we look at whether a universal pattern across all model portfolios is observable and which portfolio construction technique offers the best tail hedging properties in down market periods. We therefore calculate annualized excess returns for predefined conditional down cycle periods for which we define threshold levels at -10%, -20%, -30%, -40% and full PtoB. Each down cycle ends when the threshold is reached for the first time.

Almost all model portfolios were able to produce annualized excess returns for a market down period with thresholds of -10% and -20% regardless of the construction technique or the regional breakdown applied. The exception here being the second PtoB cycle in Europe where only the lsh portfolio was able to gain excess return momentum. A very similar pattern occurs for a drop down to -30% where on average, all portfolios show significant outperformance. The biggest annualized excess return exhibited is the US lsh portfolio in the market PtoB cycle 2 with 44.01%. It's only for the first 10% that this construction technique produces a negative excess return. For all other down periods, substantially higher excess returns are exhibited. This indicates that lsh portfolios, in particular the US portfolios, offer a substantial relative down side hedge across almost at all tested levels.

When looking across the -10% threshold figures, in most scenarios, the relative downside hedge holds even though individual results differ quite substantially. A similar situation occurs when extending the period out to the -20% threshold. In most scenarios, excess returns are positive across all model portfolios and no clear preference exists over the construction techniques. At the -30% level, the equal weight construction produces slightly better results on average. Within the group of equal weight portfolios, the differences are minimal and no clear advantage is shown. For the -40% threshold we conclude that the equal weight portfolios perform slightly better in relative terms. We further find strong relative tail hedge properties for full down market cycles where all model portfolios exhibit positive excess returns. The strongest excess returns for this period are produced by the lsh portfolios.

We conclude that for a given market down scenario the most suitable construction technique depends on the severity of the market contraction. For smaller market down cycles, in particular up to -20%, we find no clear preference with regards to the enhancement technique used in the reported data. However, in more severe market down scenarios, on average we find that the equal weight technique offers a stronger and more robust relative tail hedge. For severe market drops we prefer model portfolios using an lsh allocation technique.

[FIGURE 10 ABOUT HERE]

4. Conclusions and Key Findings

This study confirms that low volatility formed portfolio returns exhibit a clearly observable outperformance over longer periods. In our sample of daily data from 31st May, 2000 through to 7th December, 2015, we find an outperformance of approximately 3 percent annualized using low volatility and broad market portfolio building block returns. This paper provides guidance as to which portfolio construction technique is most beneficial in enhancing portfolio returns (see Figure 5). Furthermore, we provide evidence that the excess returns of low volatility enhanced portfolios are not based on any kind of additionally incurred risk levels. We demonstrate this by reduced unconditional maximum drawdown levels as well as higher CR and MSR values across construction techniques and regions. Together with significantly reduced time-to-recovery values, our results indicate that not only are low volatility enhanced portfolios able to reduce the downside risk versus the market but they also recover much more quickly than the market portfolio.

By using a practitioner-skewed study design, we find further evidence of the rationales which have been put forward by Campbell and Vuolteenaho (2004) for actively managed portfolios. Our results support the hypothesis that the reported long-term excess return of low volatility enhanced portfolios is mainly a result of significant excess returns generated in market down cycles. Empirically, we find that enhancing portfolios with low volatility building blocks during strong market corrections produces excess returns on average of between 5.6% and 17.2% for US and 1.8% and 16.7% for European portfolios (see Figure 9). We provide evidence that across different portfolio construction techniques, the relative excess returns grow larger the more severe the market correction is. While equal weight techniques contribute very steadily to the overall excess returns in market down cycles, switch techniques show more relative outperformance towards the deeper end (see Figure 8).

When considering a portfolio construction technique over smaller market corrections, there is no clear preference over the different construction techniques. However, equal weight portfolios provide a more robust relative tail hedge for more severe market corrections up to drawdown level of -40%. In cases where market corrections go beyond these levels, we find that switch techniques, in particular the lsh portfolios show the strongest relative tail hedge properties (see Figure 10). Averaging across different down market scenario levels, equal weighted portfolio construction techniques proof to exhibit the most robust down side hedging properties.

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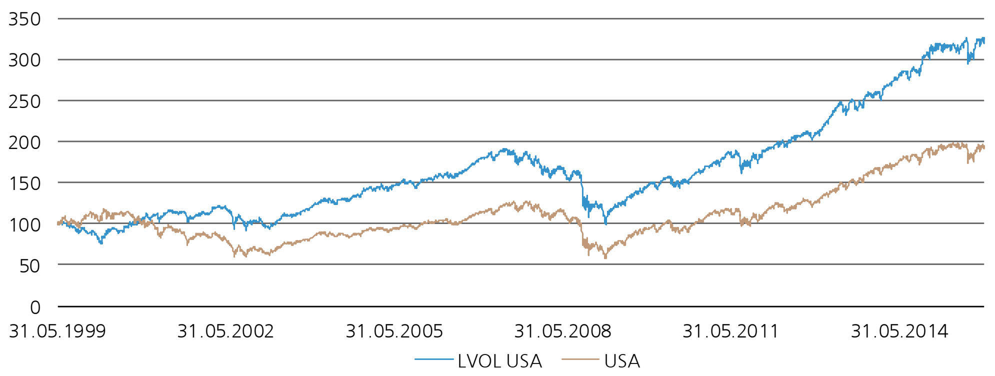
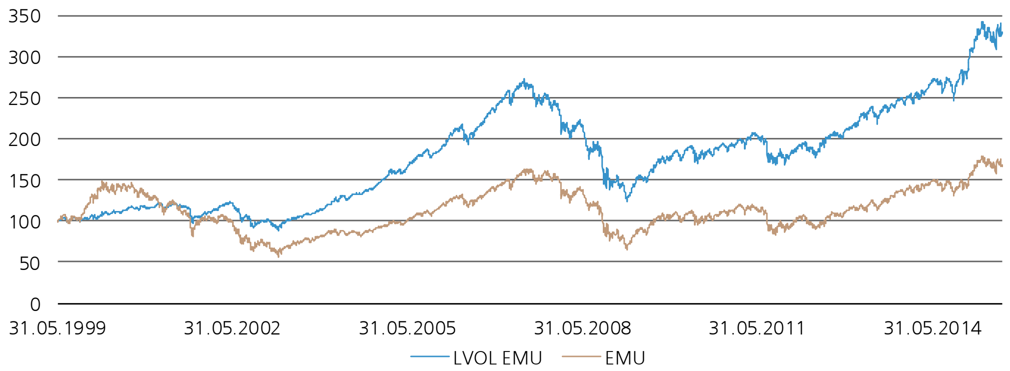
Figure 1: **The performance of low volatility stocks**

Single factor and broad market portfolio returns indexed to 100 at May 31, 1999. Daily index level data are obtained from MSCI. The low volatility stock are represented by the daily log returns of the MSCI USA Select Dynamic 50% Risk Weighted Index and the MSCI EMU Select Dynamic 50% Risk Weighted Index respectively. The broad market portfolio is represented by the daily log returns of the MSCI USA and the MSCI EMU respectively. All return data are calculated in local currency terms. Panel A reports the cumulative return of US portfolios, Panel B reports the cumulative return of the European portfolios.

Panel A:



Panel B:



Source: MSCI, UBS Asset Management

Figure 2: **Portfolio construction techniques**

Overview of the different portfolio construction techniques and its characteristics. Overall there are five different model portfolios, two using the switch signal technique and three using the equal weight technique. The lsw model portfolio uses factor return long positions fully financed by the broad market position for all risk-off periods. The lsh model portfolio uses factor return long positions financed by selling short the broad market position for all risk-off periods. The eqw_daily model portfolio uses factor return and broad market long positions equally weighted on a daily basis where the eqw model portfolio uses factor return and broad market long positions with an equal split on a buy and hold basis, and finally the eqw_jan model portfolio uses factor return and broad market long positions equally weighted where the rebalancing is executed on the first day of each individual calendar year.

Characteristics	Switching models		Tilting models		
Symbol	lsw	lsh	eqw-daily	eqw	eqw-jan
Construction	long-switch	long-short	equally weighting	equally weighting	equally weighting
Rebalance signal	realized volatility[1]	realized volatility[1]	day	n/a	calendar
Rebalance frequency	based on signal	based on signal	daily	n/a	yearly
Allocation style	factor timing	factor timing	buy-and-hold	buy-and-hold	buy-and-hold
Finance low vol. returns	long pos. market	short pos. market	long pos. market	long pos. market	long pos. market
Directional constraints	long only	none	long only, reb. freq.	long only, reb. freq.	long only, reb. freq.
Leverage	none	none	none	none	none

1 Calculated using the bipower variation (5-minute) data for the given stock universe (S&P500 and DAX)

Source: UBS Asset Management

Figure 3: **Summary statistics model and broad market portfolios**

Summary statistics on the daily return data for US and European portfolios. All returns are based on daily index levels from April 5, 2000 through November 13, 2015 in local currency and are calculated using the log return method. Based on the p-values we can reject the null-hypothesis of normally distributed return data for our data sample. Panel A reports the return and risk values for all US model as well as for the broad market portfolios. Panel B reports the return and risk values for all European model as well as for the broad market portfolios.

Panel A

	USA					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Observations (n)	3901	3901	3901	3901	3901	3901
Return (full period)	84.83%	83.83%	92.95%	100.50%	96.47%	54.28%
Return p.a.	5.48%	5.42%	6.00%	6.49%	6.23%	3.51%
Return max (daily)	9.47%	6.75%	10.26%	9.98%	10.21%	11.04%
Return min (daily)	-9.40%	-9.40%	-8.48%	-8.11%	-8.42%	-9.51%
Stdev p.a.	18.70%	16.76%	17.28%	16.53%	17.19%	20.08%
Skewness	-0.14	-0.18	-0.22	-0.21	-0.22	-0.21
Kurtosis	9.92	9.66	12.56	12.72	12.49	11.29
JB p-values	0.000	0.000	0.000	0.000	0.000	0.000

Panel B:

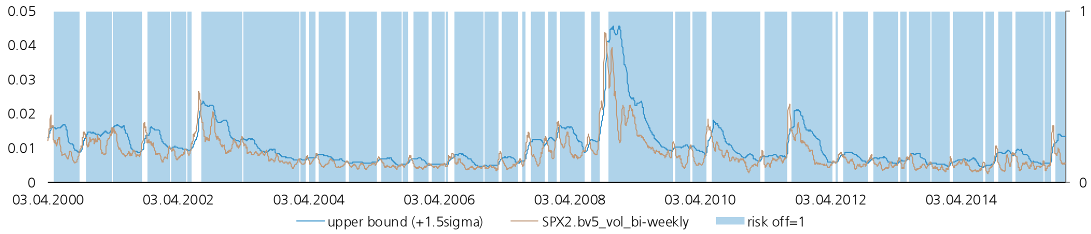
	EMU					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Observations (n)	3826	3826	3826	3826	3826	3826
Return (full period)	6.31%	32.73%	53.12%	63.33%	55.17%	5.99%
Return p.a.	0.42%	2.16%	3.50%	4.17%	3.63%	0.39%
Return max (daily)	9.93%	9.93%	9.31%	9.08%	9.29%	9.93%
Return min (daily)	-8.18%	-8.18%	-7.55%	-7.32%	-7.53%	-8.18%
Stdev p.a.	20.36%	19.92%	17.98%	16.79%	17.81%	22.14%
Skewness	0.02	0.03	-0.13	-0.15	-0.13	-0.06
Kurtosis	8.19	8.58	8.67	9.11	8.70	7.35
JB p-values	0.000	0.000	0.000	0.000	0.000	0.000

Source: MSCI, UBS Asset Management

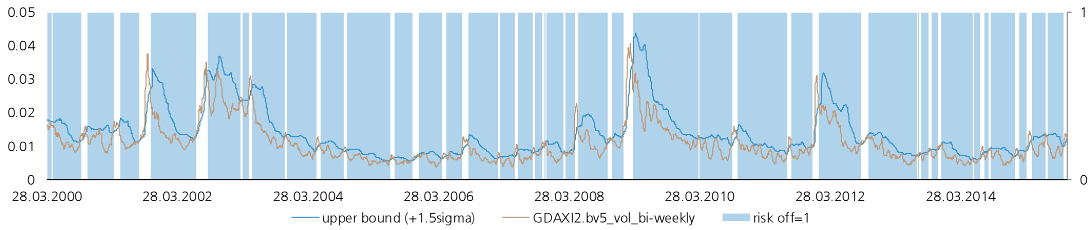
Figure 4: **Risk-on/risk-off switch models**

Risk-on and risk-off signal using the realized volatility of S&P500 for US portfolios and DAX for European portfolios. In order to accommodate time variation of volatility levels, we use the upper confidence band around the 30 day moving average of the realized volatility levels. A risk-off signal appears when the observed volatility of a particular day exceeds the 1.5 standard deviation upper bound on three consecutive days and disappears in case the observed volatility of a particular day undercuts the 1.5 standard deviation lower bound on three consecutive days. Figure 4 provides a graphical overview of the risk-on and risk-off days for US and European model where the crossing indicates a potential kick-in or kick-out switching signal. The bipower variation (5-minute) levels of the volatility for S&P500 and DAX index are downloaded from Bloomberg data service. The upper bound is calculated using 30day moving average calculation on the observed realized volatility of S&P500 and DAX. Panel A reports all figures for US portfolios and Panel B reports all figures for European portfolios.

Panel A: USA signal



Panel B: European signal

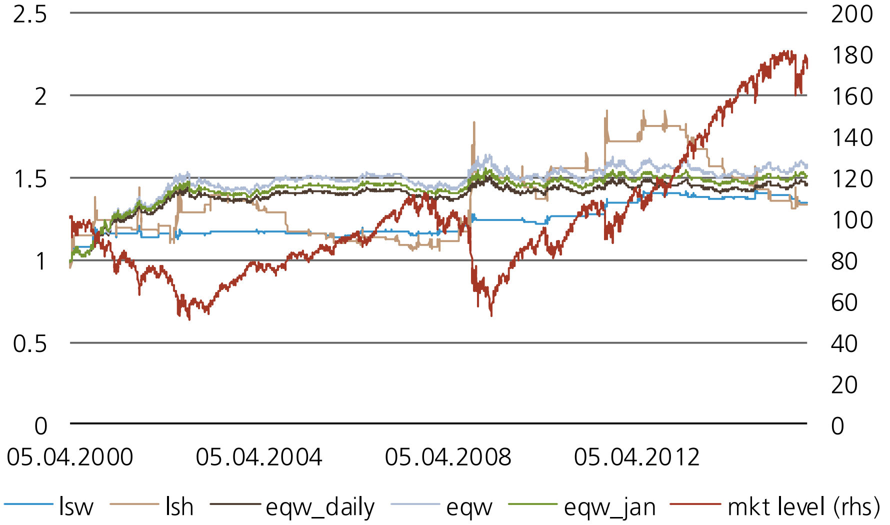


Source: Bloomberg, UBS Asset Management

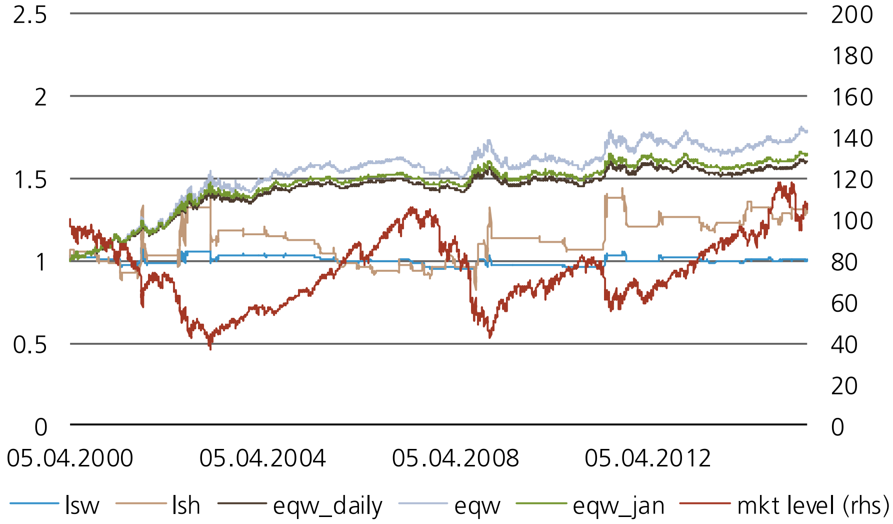
Figure 5: **Time series of cumulated relative (over market) returns**

Cumulated excess return for all model portfolios indexed to 1 at 05.04.2000 for US portfolios and indexed to 1 at 28.03.2000 for European portfolios and calculated through November 13, 2015. Broad market index levels indexed to 100 at 05.04.2000 for US portfolios and indexed to 100 at 28.03.2000 for European portfolios and calculated through November 13, 2015. All returns are calculated as log returns in local currency. For details about the switch model see Section 2.1 and 2.2 for equal weight models. Panel A reports all figures for US portfolios and Panel B reports all figures for European portfolios.

Panel A: USA equity universe



Panel B: Europe equity universe



Source: MSCI, UBS Asset Management

Figure 6: **Maximum drawdown vs. market**

Maximum drawdown values for all model as well as for the broad market portfolios. The maximum drawdown values are based on the daily return data from April 5, 2000 through November 13, 2015 in local currency and are calculated using the log return method. Below WM reports on how many days a specific model or market portfolio exhibits performance levels which are above the previously observed water mark (WM). Panel A reports all figures for US portfolios and Panel B reports all figures for European portfolios.

Panel A:

	USA					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Maxdd	-50.4%	-44.7%	-49.7%	-48.4%	-49.5%	-53.6%
Below WM (n)	3620	3697	3580	3552	3572	3715
Above WM (n)	281	204	321	349	329	186
D-to-recovery (avg)	723	646	452	426	430	913

Panel B:

	EMU					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Maxdd	-60.2%	-56.0%	-58.1%	-57.1%	-58.0%	-63.1%
Below WM (n)	3789	3737	3663	3636	3657	3791
Above WM (n)	37	89	163	190	169	35
D-to-recovery (avg)	1223	1064	1004	947	1001	2295

Source: MSCI, UBS Asset Management

Figure 7: **Risk-adjusted values**

Calmar Ratio (CR) and Modified Sharpe Ratio (MSR) are calculate using daily log return data of each model as well as for the market portfolio over the entire data history from April 5, 2000 through November 13, 2015 in local currency. The reported values are derived using the commonly used formula. For CR values we calculated the 3yrs rolling annualized returns in local currency as well as the 3yrs rolling relative draw down levels. CR values reported here represent the median over the entire data history. The MSR values are calculated the Cornish-Fisher expansion, which adjusts the VaR in terms of asymmetric distribution and above-average frequency of returns at both ends of the distribution. Panel A reports all values for US portfolios and Panel B report the values for European portfolios.

Panel A:

	USA					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
n (trading days)	3901	3901	3901	3901	3901	3901
CR	0.43	0.24	0.40	0.42	0.40	0.28
MSR	0.16	0.18	0.19	0.21	0.20	0.11

Panel B:

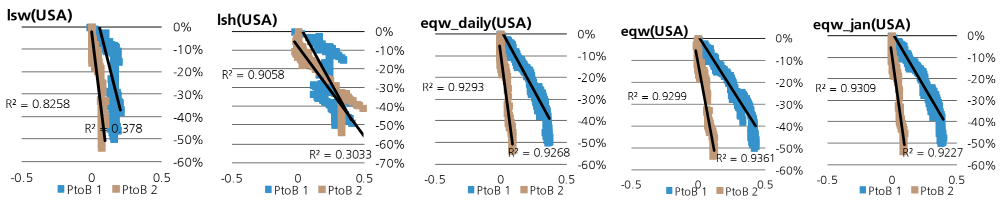
	EMU					
	lsw	lsh	eqw_daily	eqw	eqw_jan	market
n (trading days)	3826	3826	3826	3826	3826	3826
CR	0.08	0.13	0.10	0.12	0.11	0.06
MSR	0.01	0.07	0.11	0.14	0.12	0.01

Source: MSCI, UBS Asset Management

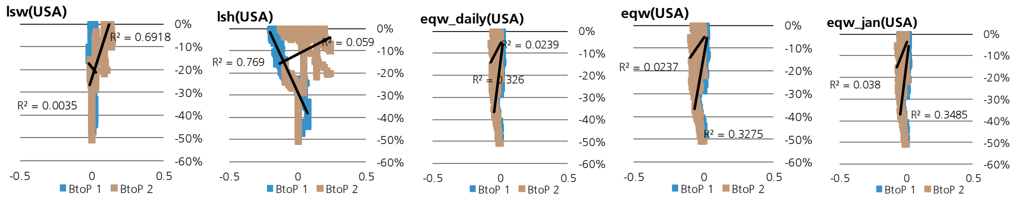
Figure 8: **Peak-to-bottom (PtoB) and Bottom-to-peak (BtoP) performance behavior**

The scatter plots in this Figure show the cumulated excess return for all model portfolios on the horizontal axes (x-values) and the draw down levels on the vertical axes (y-axes) for different market down cycles. The cumulated returns are calculate using daily log return data of each model portfolio over the entire data history from April 5, 2000 through November 13, 2015 in local currency. For US portfolios we report two main market down cycles (PtoB1, PtoB 2) while for the European portfolios we report three market down cycles (PtoB 1, PtoB 2 and PtoB 3). A market down cycle starts at the very peak of a previous up market trend and ends on the very bottom of a market correction. The cumulated excess returns therefore are normalized to zero at the very start of a PtoB cycle. Panel A reports the market down cycle results for US portfolios and Panel C reports the market down cycle results for European portfolios. Panel B and D reports the results of US and European portfolios in rebounding market conditions respectively, hence the cycle starts at the very bottom and ends at the very peak of a rebound market development. For US portfolios we report two main market up cycles (BtoP 1, BtoP 2) and for European portfolios we report three market up cycles (BtoP 1, BtoP 2 and BtoP 3).

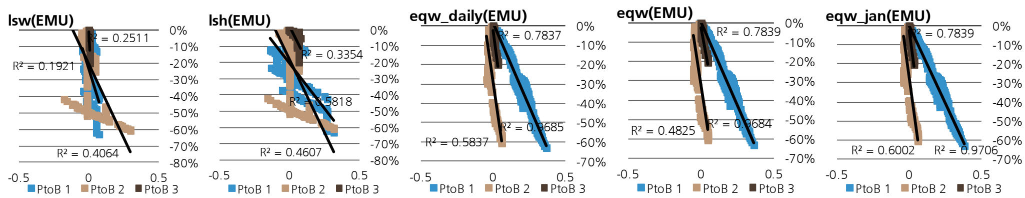
Panel A: PtoB US portfolios



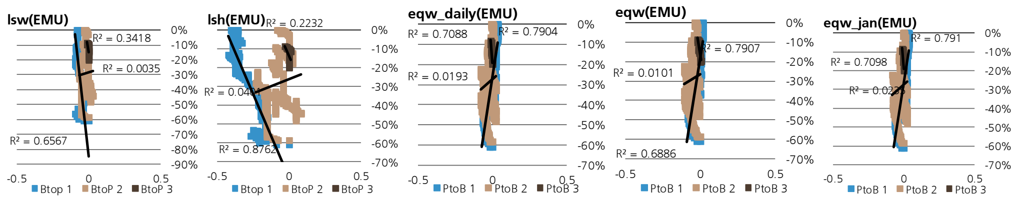
Panel B: BtoP US porfolios



Panel C: PtoB European portfolios



Panel D: BtoP European portfolios



Source: MSCI, UBS Asset Management

Figure 9: **Annualized return and volatility in downside market conditions**

Annualized returns and risk values are calculate using daily log return data of each model as well as for the market portfolio over the entire data history from April 5, 2000 through November 13, 2015 in local currency. The number of trading days for each contraction cycle is reported in the column n. Each market contraction cycle is defined as the number of trading days which span from the very peak level to the very bottom. Panel A reports all values for US portfolios and Panel B report the values for European portfolios.

Panel A:

USA

	n	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Annualized returns							
Contraction 1	618	-21.62%	-16.83%	-13.48%	-10.93%	-12.33%	-27.75%
Contraction 2	348	-50.78%	-32.19%	-49.71%	-47.67%	-49.49%	-55.60%
Median	*483*	*-36.20%*	*-24.51%*	*-31.59%*	*-29.30%*	*-30.91%*	*-41.68%*
Annualized volatility							
	n	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Contraction 1	618	20.94%	20.17%	18.11%	17.26%	17.87%	23.18%
Contraction 2	348	35.03%	29.11%	34.02%	32.63%	33.83%	38.26%
Median	*483*	*27.99%*	*24.64%*	*26.06%*	*24.95%*	*25.85%*	*30.72%*

Panel B:

EMU

	n	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Annualized returns							
Contraction 1	711	-32.39%	-23.74%	-21.98%	-19.82%	-21.48%	-35.02%
Contraction 2	334	-54.96%	-36.48%	-52.82%	-51.37%	-52.64%	-56.49%
Contraction 3	111	-49.04%	-34.18%	-43.11%	-39.75%	-43.02%	-50.88%
Median	*385*	*-49.04%*	*-34.18%*	*-43.11%*	*-39.75%*	*-43.02%*	*-50.88%*
Annualized volatility							
	n	lsw	lsh	eqw_daily	eqw	eqw_jan	market
Contraction 1	711	22.60%	23.27%	19.21%	17.77%	18.61%	26.89%
Contraction 2	334	30.48%	28.37%	28.74%	27.48%	28.64%	32.29%
Contraction 3	111	22.83%	21.67%	21.30%	20.60%	21.29%	23.07%
Median	*385*	*22.83%*	*23.27%*	*21.30%*	*20.60%*	*21.29%*	*26.89%*

Source: MSCI, UBS Asset Management

Figure 10: **Stepwise downside periods**

Annualized returns and risk values are calculate using daily log return data of each model as well as for the market portfolio over the entire data history from April 5, 2000 through November 13, 2015 in local currency. Returns are annualized based on the daily average return for the length of the market down cycles up to the pre-defined thresholds of -10%, -20%, -30%, -40% and for the full drop from PtoB. Each segment down to the pre-defined thresholds is defined as the number of trading days up to when the threshold is reached the first time during the PtoB market down cycle for each region. The number of trading days for each threshold cycle is reported in column n. For US portfolios we report two main market down cycles (PtoB1, PtoB 2) while for the European portfolios we report three market down cycles (PtoB 1, PtoB 2 and PtoB 3). Panel A reports the results for US portfolios and Panel B reports the results for European portfolios.

Panel A:

			USA			
% drop	n	lsw (USA)	lsh(USA)	eqw_daily(USA)	eqw(USA)	eqw_jan(USA)
			PtoB 1			
-10%	127	20.28%	25.98%	16.31%	17.70%	17.70%
-20%	221	16.95%	25.70%	23.11%	25.76%	25.62%
-30%	351	12.36%	15.69%	19.75%	22.62%	21.55%
-40%	553	6.54%	10.13%	15.68%	18.44%	16.93%
-49.94%	618	6.13%	10.92%	14.27%	16.82%	15.42%
			PtoB 2			
-10%	61	0.42%	-5.05%	-0.95%	-1.24%	-0.79%
-20%	229	5.98%	13.19%	4.57%	6.07%	4.75%
-30%	243	7.72%	29.23%	5.35%	7.13%	5.58%
-40%	256	8.56%	44.01%	5.69%	7.61%	5.95%
-53.60%	348	4.82%	23.41%	5.89%	7.93%	6.11%

Panel B:

			EMU			
% drop	n	lsw (EMU)	lsh(EMU)	eqw_daily(EMU)	eqw(EMU)	eqw_jan(EMU)
			PtoB 1			
-10%	33	15.03%	27.91%	29.98%	25.87%	25.87%
-20%	238	0.12%	-3.57%	14.39%	14.74%	14.27%
-30%	356	1.09%	1.04%	12.70%	13.43%	12.85%
-40%	539	-1.17%	-2.99%	11.54%	12.70%	11.73%
-63.10%	711	2.63%	11.28%	13.04%	15.20%	13.54%
			PtoB 2			
-10%	50	-6.60%	-3.71%	-2.32%	-3.18%	-2.30%
-20%	157	-7.31%	2.64%	-4.96%	-6.73%	-4.82%
-30%	300	-3.98%	1.23%	-1.46%	-1.99%	-1.38%
-40%	315	-3.79%	1.17%	-0.31%	-0.42%	-0.21%
-60.55%	415	1.53%	20.01%	3.66%	5.12%	3.85%
			PtoB 3			
-10%	54	1.73%	26.18%	2.39%	3.39%	2.38%
-20%	110	1.86%	16.85%	7.63%	10.92%	7.72%
-20.08%	111	1.84%	16.70%	7.77%	11.13%	7.87%

Source: MSCI, UBS Asset Management