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RISK-BASED INDEX STRATEGIES – A COMPARISON –

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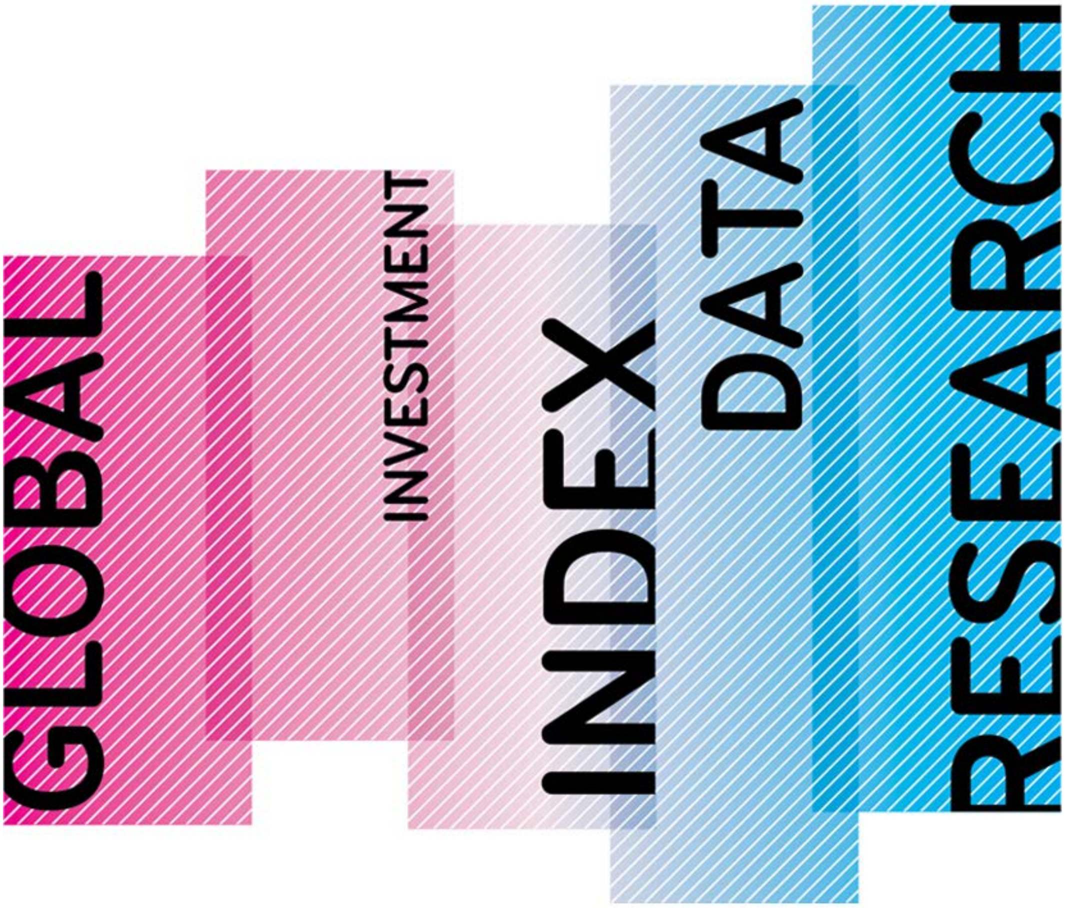

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RISK-BASED INDEX STRATEGIES
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Abstract

Risk-based index strategies have become increasingly popular over the last several years. Given the recent ups and downs in global equity markets, these strategies typically aim to decrease the standard deviation, or to put it differently, they aim to decrease the range within which portfolio returns can fluctuate. However, there is a wide range of different strategies available, and all use different models or assumptions. Whereas low-volatility concepts, to name an example, are based on a simplified, heuristic approach, minimum variance strategies take into account all parameters that contribute to the determination of portfolio risk. So-called equal risk contribution strategies offer a third attempt that primarily aims to diversify rather than minimize portfolio risk. This paper provides an overview of the most popular risk-based asset allocation strategies and empirically tests these strategies against their neutral market-cap weighted benchmark. Low-risk and minimum variance index strategies are found to significantly decrease overall portfolio risk while simultaneously increasing performance. Equal risk contribution strategies retain about the same risk levels but also noticeably increase index performance. Risk control strategies enable the investor to replicate any ex ante defined risk level as they are not subject to systematic risk existent within the equity asset class.

[1] The views and opinions expressed in this paper are solely those of the author and do not necessarily represent the views and opinions of STOXX Ltd.

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Introduction

During recent turbulent years, investors became increasingly aware of the risk implied in their equity portfolios. Looking at the European equity market, it can be observed that, especially since 2008, so-called smart-beta strategies that also comprise the concepts discussed in this paper, experienced a significant inflow of assets. In this context, index concepts that select and/or weight stocks according to different measures of risk in order to decrease overall portfolio risk and subsequently decrease the likelihood of severe losses became increasingly popular.

This paper compares four risk-based concepts: the heuristic low-volatility concept, equal risk contribution concepts, minimum variance concepts as well as risk control strategies.

It can be empirically shown that along the time dimension, risk is not, as it might have been expected, rewarded by additional (long-term) returns. We rather find that the contrary is true: times of high market volatility are primarily accompanied by negative returns. The empirical results further suggest that risk-based concepts are superior to market-cap weighted indices not only in highly volatile or bear markets but typically also provide superior risk-return profiles in less turbulent markets, when asset prices are rising.

The following chapter provides a brief introduction to all concepts discussed in this paper. The focus lies on a two-asset scenario to increase understandability. Chapter 3 then empirically tests the index concepts using historical data ranging from 2002 to 2013. Chapter 4 provides a conclusion.

1 The underlying strategies

1.1 Low-volatility indices

The low-volatility strategy is a simplified approach that targets portfolio risk reduction.

In this context, it merely takes into account each asset's volatility whereas dependencies among stocks are ignored. Such dependencies, typically measured via covariances, are assumed to be non-existent or zero.

The volatility figures are then applied in the process of selecting and weighting index components. After the least volatile companies of a given universe are identified, stocks are then weighted according to the inverse of their standard deviation $\left(\frac{1}{\sigma_i}\right)$. This means that more volatile stocks are less heavily weighted than stocks that are less volatile.

In a two-asset portfolio, the weights are given by:

$$x_1 = \frac{\sigma_2}{\sigma_1+\sigma_2} \quad (1)$$

$$x_2 = \frac{\sigma_1}{\sigma_1+\sigma_2} \quad (2)$$

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1.2 Minimum variance indices

Minimum variance indices can be regarded as having a more advanced approach in the attempt to reduce risk as they take into account the full spectrum of components that determine portfolio risk. Next to each stock's volatility, it also considers the correlations among stocks. Generally speaking, the covariance measures the co-movement of a given pair of assets.

Deutsche Boerse was the first to offer an index based on minimum variance strategies in 2007. These initial strategies followed the standard Markowitz approach by taking into account all covariances on constituent level.

In a two-asset scenario, the risk on portfolio level is given by:

$$\sigma_p^2 = {x_1}^2\sigma_1^2 + {x_2}^2\sigma_2^2 + 2x_1x_2cov_{1,2} \quad (3)$$

The weights, x_1 and x_2, are then determined so that the overall portfolio risk is minimized:

$$\min \sigma_p^2 = {x_1}^2\sigma_1^2 + {x_2}^2\sigma_2^2 + 2x_1x_2cov_{1,2} \quad (4)$$

In order to control for outliers and to restrain short selling, standard optimization strategies typically apply restrictions that reduce the solution space within which the optimum can be found.
The first constraint defines a minimum threshold for constituent weights:

Constraint 1: $x_i \geq y$ (5)

Minimum variance strategies are known for the occurrence of highly concentrated allocations. In order to prevent such concentration in single stocks, maximum thresholds are defined:

Constraint 2: $x_i \leq z$ (6)

A third constraint assures that the sum of the weights equals 100%.

Constraint 3: $x_1 + x_2 = 1$ (7)

This very basic methodology however causes difficulties whenever the number of portfolio constituents becomes quite large. As the number of parameters that needs to be estimated rises significantly with an increase in the portfolio constituents, the quality of the estimators decreases.

A solution to this problem is to offer factor-based models. They calculate the variance-covariance matrix based on factors that have been determined to underlie a portfolio's stocks rather than based on the stocks themselves. This reduction to the factor level significantly reduces the number of parameters that needs to be estimated and subsequently increases the reliability of the estimates. Only in a second step, the link between the factors and portfolio constituents is re-established. The stocks are then regressed against the given set of factors to estimate each factor's influence on the stocks included in the portfolio.

This factor-based method additionally enables the introduction of various constraints to the optimization process, e.g. it can now be directly controlled for industry or country exposures.

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The empirical analysis conducted hereunder is based on this second factor-based approach to compose minimum variance portfolios.

1.3 Equal risk contribution indices

Equal risk contribution strategies have just recently gained popularity. Unlike the two previously discussed concepts, equal risk contribution does not target risk reduction. Instead, the concept weights the stocks in a given portfolio so that each stock's contribution to overall portfolio risk is equal. Especially for cross-asset class portfolios it can be shown that asset allocation most often significantly deviates from risk allocation. In a portfolio that consists of 20% equity and 80% bonds, the risk contribution can easily be reversed (i.e. 80% of this portfolio's risk comes from equity whereas only 20% comes from the bond component).

To derive the weights of a portfolio (again consisting of just two components) in which each asset contributes in an identical way to the overall risk, the portfolio variance as defined in (3) is first transferred to the standard deviation by taking the square root.

$$\sigma_p = \sqrt{{x_1}^2\sigma_1^2 + {x_2}^2\sigma_2^2 + 2x_1x_2cov_{1,2}} \tag{8}$$

In a second step, the first derivative with respect to each constituent's weights is determined:

$$MRC_1 = \frac{\partial\sigma_p}{\partial x_1} = \frac{x_1\sigma_1^2 + x_2cov_{1,2}}{\sigma_p} \tag{9}$$

$$MRC_2 = \frac{\partial\sigma_p}{\partial x_2} = \frac{x_2\sigma_2^2 + x_1cov_{1,2}}{\sigma_p} \tag{10}$$

The risk contributions (RC) of the two assets are then defined by multiplying each marginal risk contribution (MRC) with the stocks' weights:

$$RC_1 = x_1MRC_1 \tag{11}$$

$$RC_2 = x_2MRC_2 \tag{12}$$

Setting $RC_1 = RC_2$ equal to each other and solving for x then yields the constituent weights:

$$x_1 = \frac{1/\sigma_2}{1/\sigma_1 + 1/\sigma_2} \tag{13}$$

$$x_2 = \frac{1/\sigma_1}{1/\sigma_1 + 1/\sigma_2} \tag{14}$$

1.4 Risk control indices

So-called risk control or target risk strategies follow a different approach.

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The underlying concept is quite intuitive: in the first step of the allocation process, a target risk level is defined prior to the investment period. The investor then sticks to this level during the entire investment period. To control for risk, the strategy typically consists of a risky equity and a risk-free money market asset. In case the volatility of the risky component increases to levels above the targeted risk, parts of the portfolio are reallocated into the risk-free money market to decrease the portfolio's overall volatility. On the other hand, in case a given equity market does not provide enough implied risk, the risk level is increased by allowing leveraged positions. In the first scenario, the investor receives two income streams: the interest from the money-market investment, e.g. approximated by EONIA, as well as the return from the equity market investment. In the latter case, the investor needs to borrow additional money to build up leveraged positions. In this scenario, the investor has to pay the respective interest rate which lowers the index performance.

The performance of an index depicting this strategy can be defined as:

$$\mathrm{RC_t} = \mathrm{RC_0}\left(1 + \mathrm{x}\left(\frac{\mathrm{SI_t}}{\mathrm{SI_{t-1}}} - 1\right) + (1-\mathrm{x})\mathrm{i}\frac{\Delta \mathrm{t}}{360}\right) \quad (15)$$

With SI being an equity index, the performance of the risk control index can therefore be decomposed into a risky component $\left(\frac{SI_t}{SI_{t-1}} - 1\right)$ and a risk-free component $i\frac{\Delta t}{360}$. The contribution of the two components to the performance of the index is further determined by the asset allocation among the two assets *x* and (*1-x*).

In a two-asset scenario, the share x of the investment allocated into the risky component SI can be derived based on the risk of the portfolio *p*:

$$\sigma_p^2 = x^2\sigma_{SI}^2 + (1-x)^2\sigma_r^2 + 2x(1-x)cov_{SI,r} \quad (16)$$

Setting σ_p^2 equal to the squared target risk *a* yields:

$$\sigma_p^2 = x^2\sigma_{SI}^2 + (1-x)^2\sigma_r^2 + 2x(1-x)cov_{SI,r} = a^2 \quad (17)$$

Solving the equation for *x* yields:

$$x = \left(\frac{\frac{2cov_{SI,r}-2\sigma_r^2}{\sigma_{SI}^2+\sigma_r^2-2cov_{SI,r}}}{2}\right) + \sqrt{\frac{\frac{2cov_{SI,r}-2\sigma_r^2}{\sigma_{SI}^2+\sigma_r^2-2cov_{SI,r}}}{2} - \frac{\sigma_r^2-a^2}{\sigma_{SI}^2+\sigma_r^2-2cov_{SI,r}}} \quad (18)$$

If we assume the second component *r* to be risk-free, the equation can be simplified to:

$$x = \sqrt{\frac{a^2}{\sigma_{SI}^2}} = \frac{a}{\sigma_{SI}} \quad (19)$$

According to (17), the equity investment is determined by the ratio of the target volatility *a* and the implied volatility of the equity market σ_{SI}. Example, a target risk of 10% compared to an implied risk of 20% would lead to an equal asset distribution into the money and the equity markets. If the equity market provided a risk of just 10% compared to a targeted risk of 20%, $\frac{a}{\sigma_1}$ then equals 2. In order to realise a return of $2 * \left(\frac{SI_t}{SI_{t-1}} - 1\right)$, the investor then needs to pay $i\,\frac{\Delta t}{360}$.

2 Empirical analysis

2.1 Low-volatility indices

As discussed above, low-volatility or low-risk weighted indices are based on a very simple or heuristic attempt to decrease portfolio risk.

The single aim of such strategies is to reduce portfolio volatility. Classical portfolio theory states that in market equilibrium, additional risk bearing should typically be rewarded by additional return; otherwise, no rational investor would hold relatively more risky assets without such additional reward. Given this theoretical reasoning, a portfolio that displays lower volatility levels compared to its neutral benchmark should consequently offer less return. Looking at Figure LV1 provides quite surprising results. The EURO STOXX 50 (Low Risk Weighted) provides even better returns compared to its market-cap weighted alternative.

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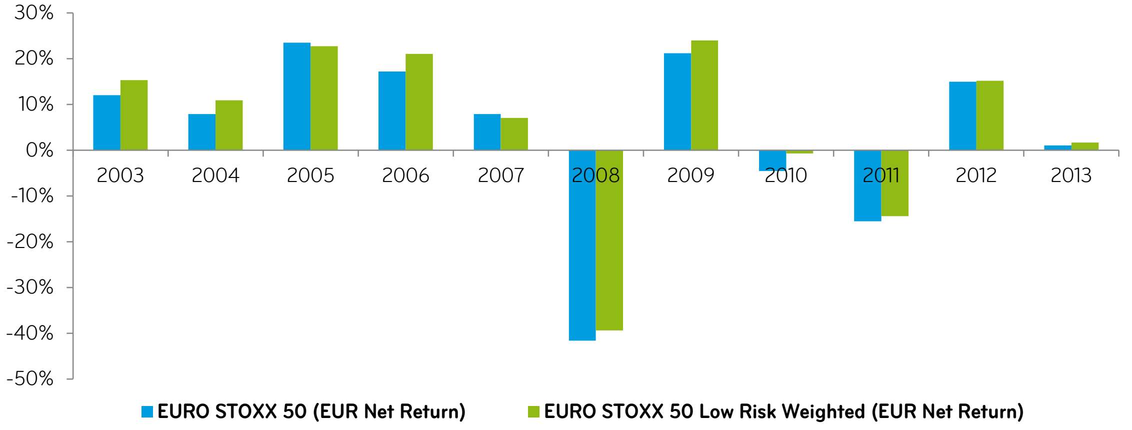
FIG. LV1: HISTORICAL PERFORMANCE OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 LOW RISK WEIGHTED (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013

To see how persistent this initial observation is, Figure LV2 provides an annualized breakdown of the performances of the two indices. It can be seen that the low-volatility strategy outperforms the neutral cap-weighted benchmark in nine out of 11 years. Thus, the outperformance observed over the entire investment horizon as depicted in Figure LV1 is not just achieved by the avoidance of losses in bear markets but also by higher positive returns in bull markets.

FIG. LV2: ANNUALIZED RETURNS OF EURO STOXX 50 (EUR NET RETURN) AND THE EURO STOXX 50 LOW RISK WEIGHTED (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



But since the strategy actually aims at reducing risk, its success should primarily be measured by an assessment of risk reduction rather than a performance increase. Figure LV3 displays the volatility levels of a low-volatility strategy and the neutral benchmark. As expected, the strategy's volatility is found to be consistently and significantly lower in every year included in the analysis.

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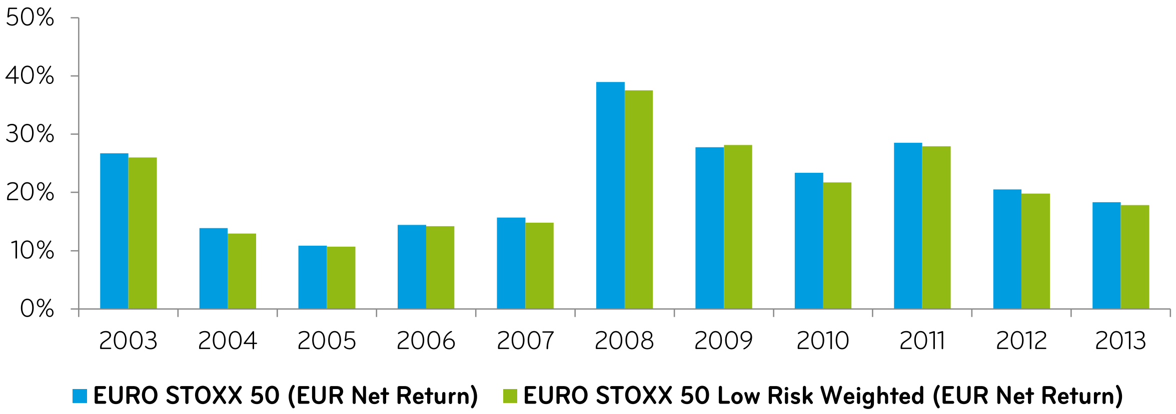
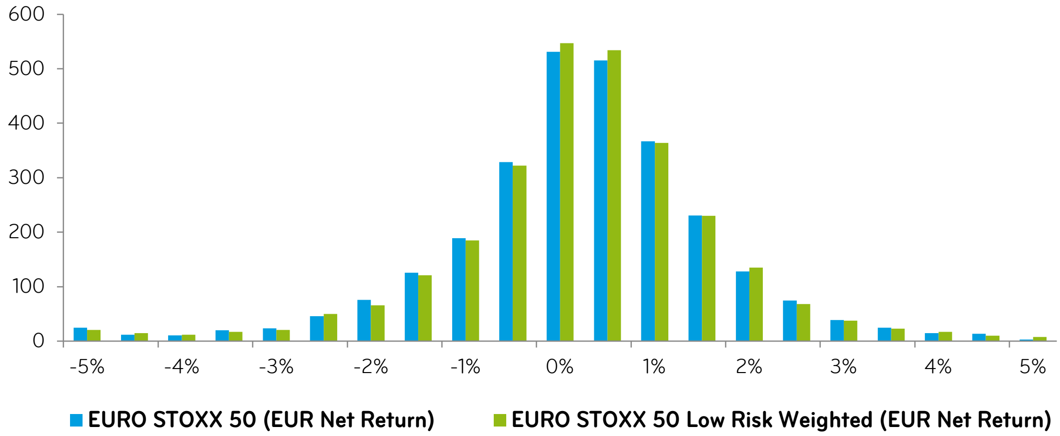
FIG. LV3: ANNUALIZED VOLATILITY OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 LOW RISK WEIGHTED (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



Further insight into the advantages of low volatility strategies can be gained from the distribution of historical returns. Figure LV4 shows that the methodology decreases the presence of highly negative and highly positive returns; thus, it implicitly reduces tail risk. The probability of small but positive returns is increased compared to its benchmark whereas the number of small but negative returns is reduced.

FIG. LV4: RETURN-DISTRIBUTION OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 LOW RISK WEIGHTED (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



Another way to assess the characteristics of investments is the so-called drawdown. The drawdown represents the maximum loss that an investor who follows a buy-and-hold strategy has to accept over the investment's lifecycle up to a given (and trailing) point in time.

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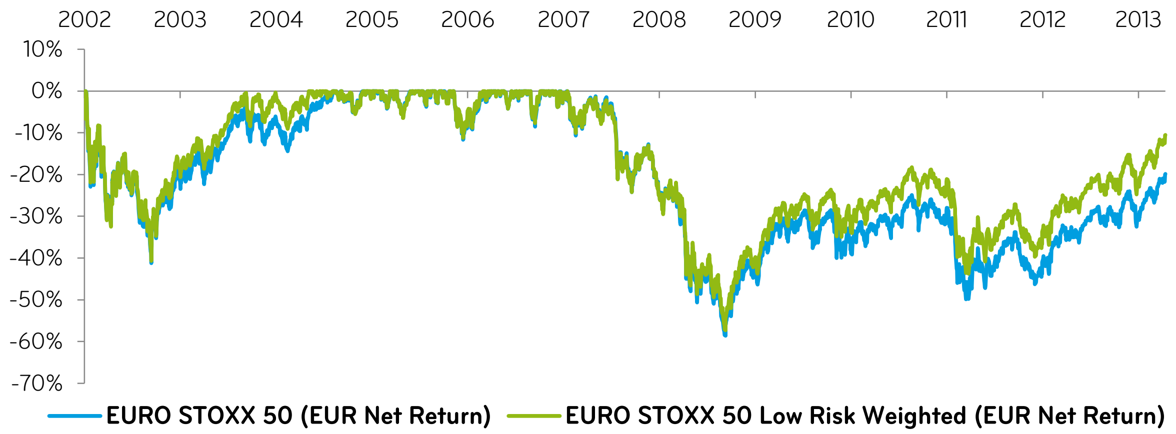
By looking at Figure LV5, it can be seen that the overall maximum drawdown of the low-risk strategy based on the entire period covered is not significantly lower compared to the maximum drawdown of the market-cap weighted benchmark. However, it is on average lower.

FIG. LV5: MAXIMUM DRAWDOWN OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 LOW RISK WEIGHTED (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



2.2 Minimum variance indices

The empirical analysis of the minimum variance strategy is based on two different concepts. In a so-called constrained version, the solution space within which the optimal (variance minimal) portfolio is to be found, is restricted along different dimensions. Such restrictions are typically defined relative to a given benchmark; for example, maximum deviations from the benchmark's sector or country allocation. This is done for investors who are benchmarked against a market-cap weighted index but still want to exploit the benefits of a minimum variance strategy. The existence of such restrictions assures that they do not deviate too much from their benchmark which can be quite helpful in case the minimum variance strategy should significantly underperform the market-cap weighted alternative.

On the other hand, the unconstrained version is mostly free of such restrictions[2]. Consequently, it can be expected that the unconstrained index provides lower risk compared to the constrained version as it has more space within which it can search for optimal solutions. However, due to the lack of such restrictions, sector or country allocations can become more concentrated in case the algorithm finds such extreme allocations to further reduce the overall portfolio risk.

Figure MV1 provides the historical backtesting for the two minimum variance strategies compared to the EURO STOXX 50 Index as a neutral benchmark.

[2] The unconstrained version is not constrained with regard to factor exposures, but it also includes basic constraints that primarily take into account regulatory requirements (example, maximum constituent weights).

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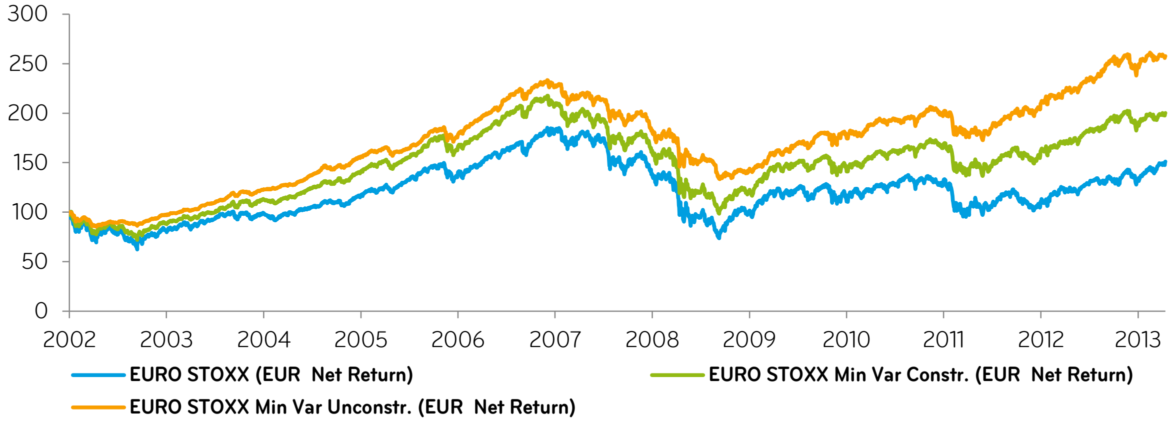
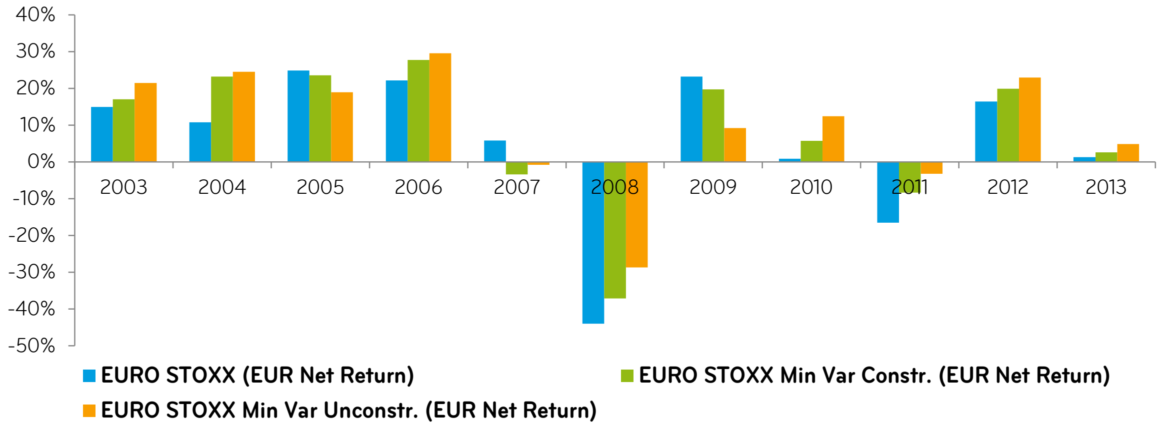
The increase in index performance, as it has already been observed in the context of low-volatility strategies, is also found here with the unconstrained version to display an even better performance over the last 10 years compared to the constrained index.

FIG. MV1: HISTORICAL PERFORMANCE OF EURO STOXX (EUR NET RETURN) AND EURO STOXX MINIMUM VARIANCE (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



This observation still holds when we disaggregate the returns to a yearly basis. In fact, with the exception of just three years, both minimum variance indices outperformed the market cap weighted EURO STOXX 50 Index.

FIG. MV2: ANNUALIZED RETURNS OF EURO STOXX (NR) EUR AND EURO STOXX MINIMUM VARIANCE (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



This outperformance is achieved with a significant reduction in portfolio risk (compare Figure MV3). For the unconstrained minimum variance strategy, volatility decreased by as much as 50%.

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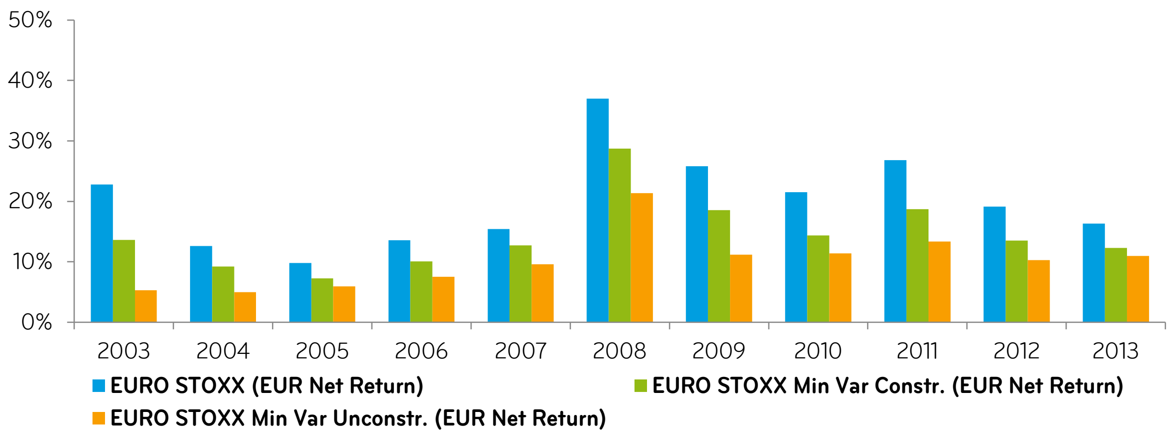
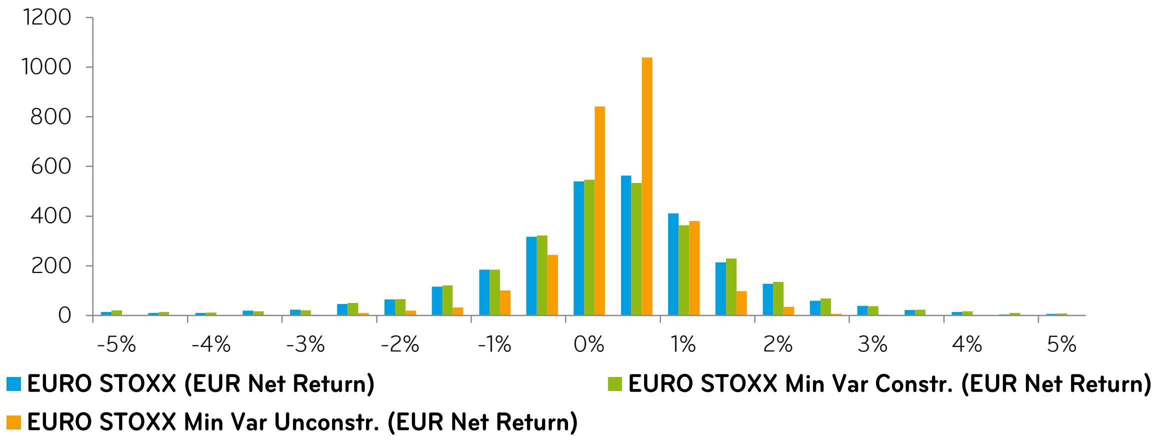
FIG. MV3: ANNUALIZED VOLATILITY OF EURO STOXX (EUR NET RETURN) AND EURO STOXX MINIMUM VARIANCE (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



The concept reduces the occurrence of both highly negative and highly positive yields, whereas the likelihood of small but positive returns is significantly increased (compare Figure MV4).

FIG. MV4: RETURN-DISTRIBUTION OF EURO STOXX (EUR NET RETURN) AND EURO STOXX MINIMUM VARIANCE (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



The superiority is further supported by the trailing drawdown calculated over the course of the investment horizon (2002-2013). Whereas the market-cap weighted benchmark provides the highest average drawdowns, the constrained and the unconstrained minimum variance indices have, on average, lower drawdown levels with the unconstrained version being superior to the constrained version.

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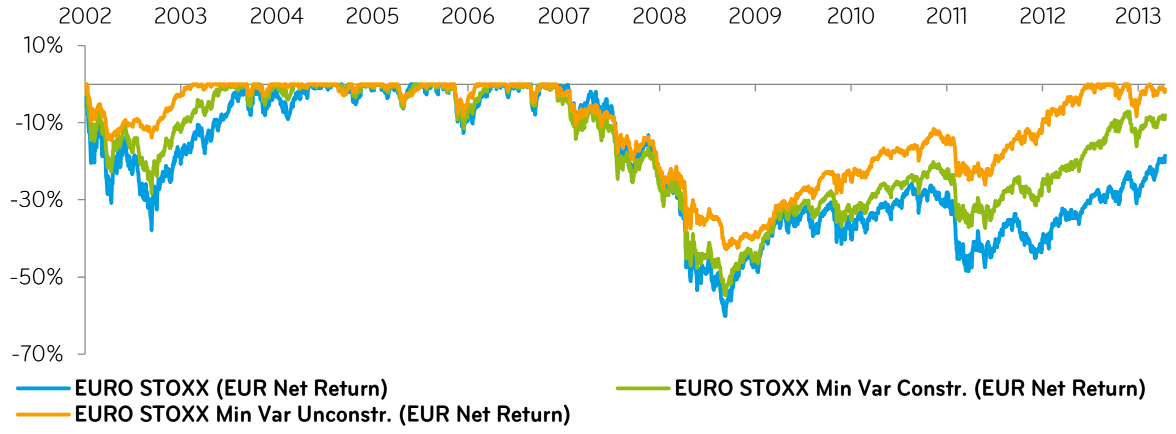
FIG. MV5: DRAWDOWN OF EURO STOXX (EUR NET RETURN) AND EURO STOXX MINIMUM VARIANCE (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



2.3 Equal risk contribution indices

As mentioned above, equal risk contribution indices do not primarily aim at reducing risk. They rather try to spread risk evenly across all assets in a given portfolio. As such, they are comparable to well-known diversification strategies with the difference that they directly diversify risk rather than hoping for a risk diversification as a by-product of a diversification that focuses on asset weights.

The historical performance of the equal risk contribution strategy compared to the EURO STOXX 50 looks quite appealing (compare Figure ER1).

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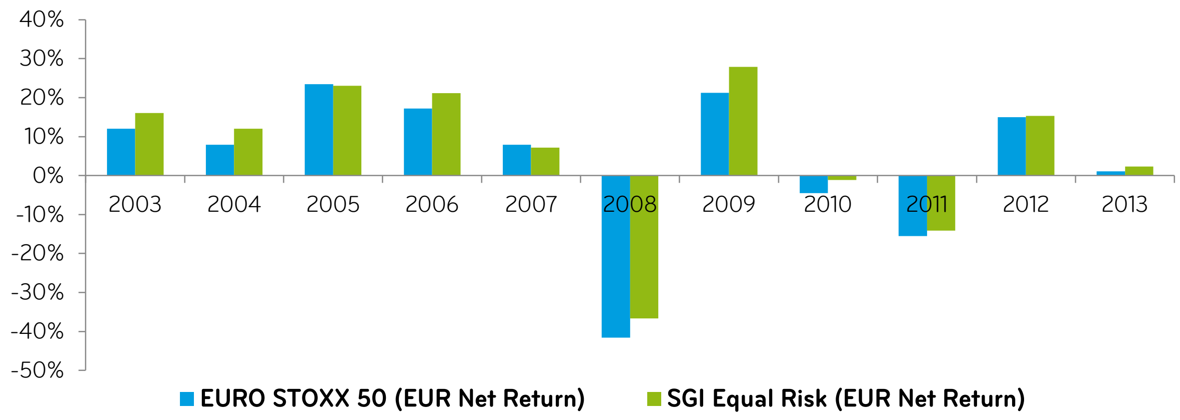
FIG. ER1: HISTORICAL PERFORMANCE OF EURO STOXX 50 (EUR NET RETURN) AND SGI EQUAL RISK (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013

Also, a more detailed look at yearly returns shows that the strategy has outperformed the EURO STOXX 50 in nine out of 11 years.

FIG. ER2: ANNUALIZED RETURNS OF EURO STOXX 50 (EUR NET RETURN) AND SGI EQUAL RISK (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



The volatility levels, however, look quite different compared to what we have observed for the previous concepts. The annualized volatility is not significantly different compared to the volatility of its benchmark. However, given the rationale behind this strategy, the results are not surprising as it has not been the aim of this strategy to decrease portfolio risk. The actual volatility level which is achieved by equal risk contribution strategies is rather a function of the risk implied in the respective asset class, which is in our case the equity asset class.

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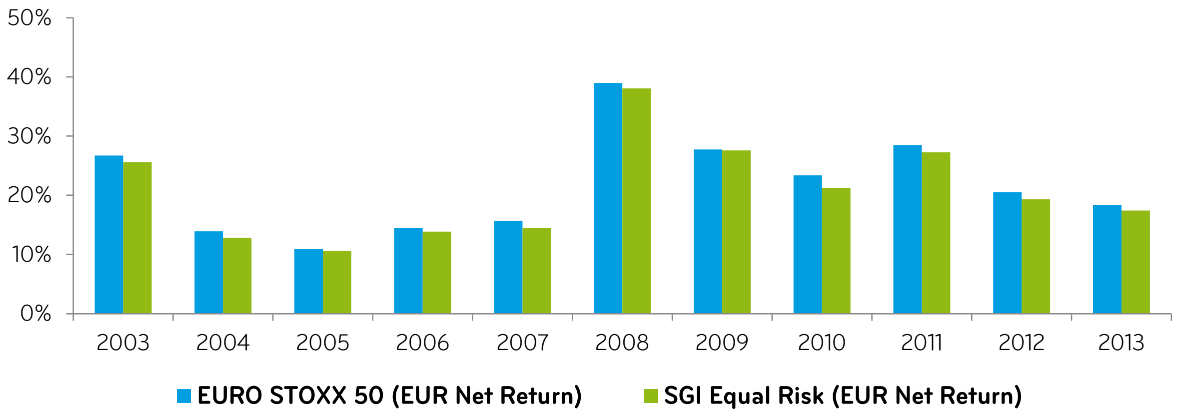
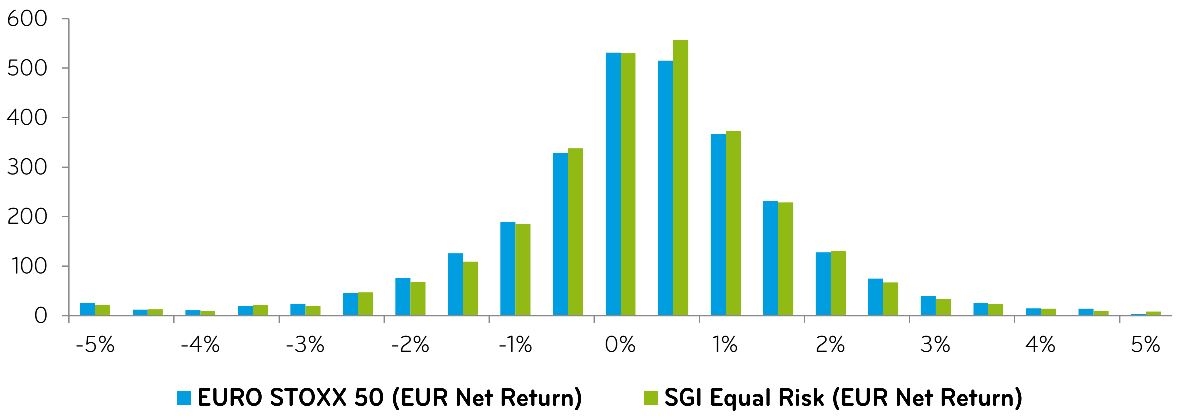
FIG. ER3: ANNUALIZED VOLATILITY OF EURO STOXX 50 (EUR NET RETURN) AND SGI EQUAL RISK (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



The proximity of the equal risk contribution strategy to its benchmark is further supported by a comparison of the distribution of daily returns. Both indices have similar distributions (compare Figure ER4).

FIG. ER4: RETURN-DISTRIBUTION OF EURO STOXX 50 (EUR NET RETURN) AND SGI EQUAL RISK (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



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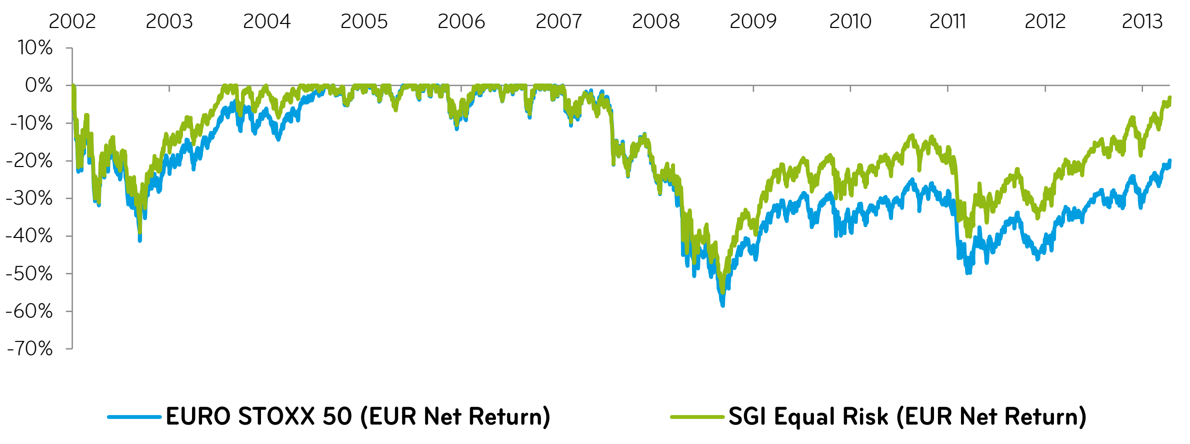
Lastly, the trailing drawdown reveals that the equal risk contribution strategy has far lower levels compared to its benchmark. However, the maximum drawdown is quite comparable.

FIG. ER5: DRAWDOWN OF EURO STOXX 50 (EUR NET RETURN) AND SGI EQUAL RISK (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



2.4 Risk control indices

As stated in the introduction, risk control indices do not try to minimize volatility but try to stick as close as possible to a predefined volatility level. Unlike all previously discussed concepts, they do so by allocating assets between a risky and a risk-free asset class. This is new as the investable universe of all other concepts has so far been restricted to equity.

Figure RC1 provides the historical backtesting for four different risk control levels ranging from 5% to 20%.

It can already be observed from the graphical representation that the index volatility decreases with a decrease in the targeted risk level.

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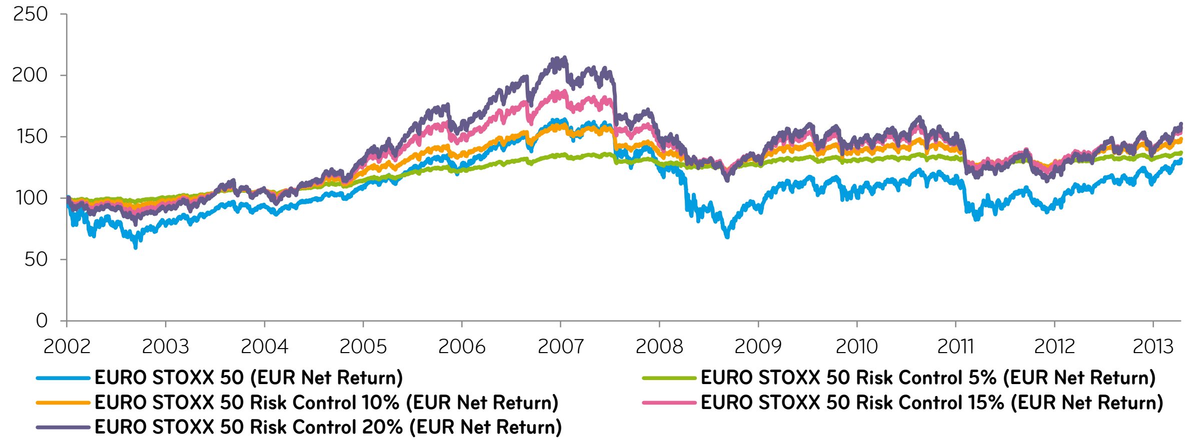
FIG. RC1: HISTORICAL PERFORMANCE OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



The Figures RC2 and RC3 further emphasize this initial observation. The amplitudes of positive and negative returns are the more pronounced, the higher the targeted (and consequently, the higher the realized) risk level.

When looking at 2008, it can be observed that the lower the targeted volatility level, the more reduced the losses were. This is the case as losses during this year were accompanied by very high volatility levels. On the other hand, however, during the recovery phase in 2009 higher returns came with higher levels of target volatility. This makes intuitive sense as much of the allocation was still shifted out of the equity market as prices started to recover.

FIG. RC2: ANNUALIZED RETURNS OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013

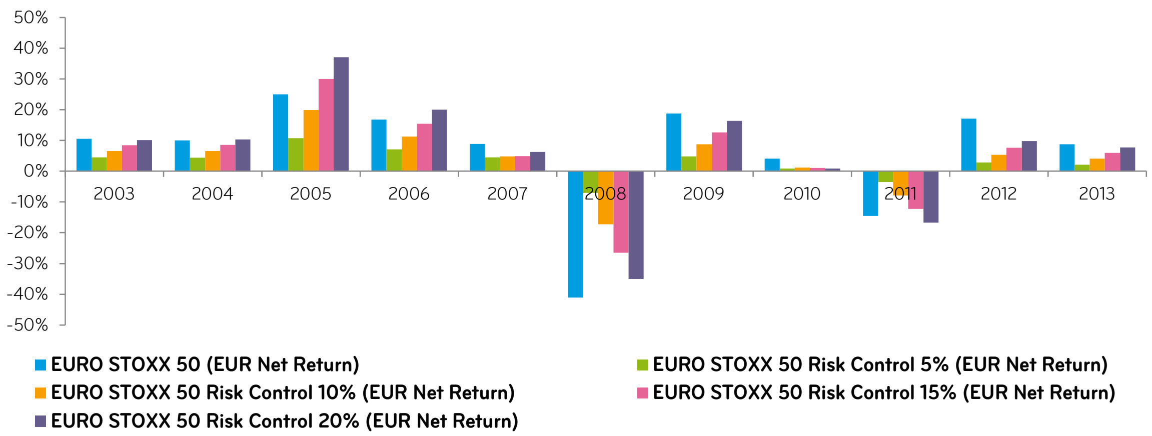


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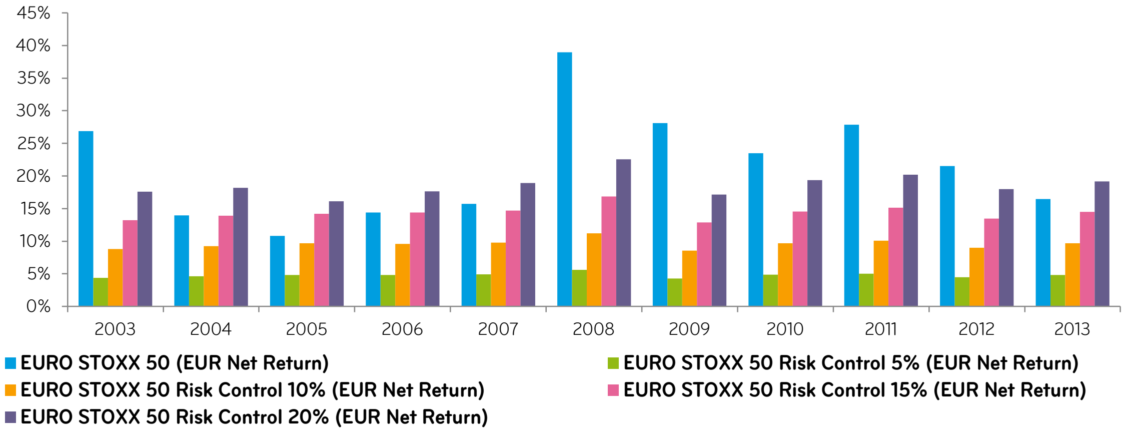
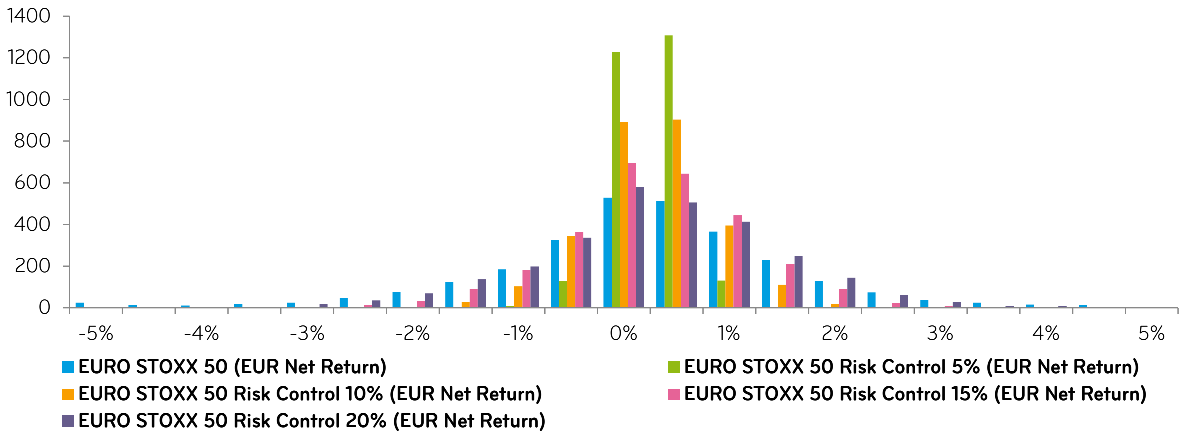
FIG. RC3: ANNUALIZED VOLATILITY OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2003 TO 2013



The return distribution (see Figure RC4) looks quite similar compared to the previously discussed concepts. The likelihood of small but positive returns is significantly increased for the low-risk versions (e.g. 5% and 10% target risk levels). On the other hand, the occurrence of large negative and positive returns is reduced compared to the market capitalization weighted alternative. The higher the targeted risk, the more similar the return distribution becomes compared to the EURO STOXX 50 index.

FIG. RC4: RETURN-DISTRIBUTION OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



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Thus, risk control strategies targeting low-volatility levels are an ideal investment for risk-averse investors. The attractiveness of this investment strategy lies in the fact that it allows investors to partially or totally leave the risky equity market and alternatively invest in the money market in case the risk implied in an equity investment becomes too large.

Whenever investors are restricted to a risky asset class, risk can only be decreased up to a certain point. This point is set by the non-diversifiable or systematic risk which sets the lower boundary of possible risk reduction. By allowing a second risk-free asset class to enter the investable universe, risk control strategies are able to reduce risk to levels even beyond the systematic risk inherent in a pure equity investment.

This also leads to a subsequent decrease in the drawdown observed for target risk strategies (see Figure RC5).

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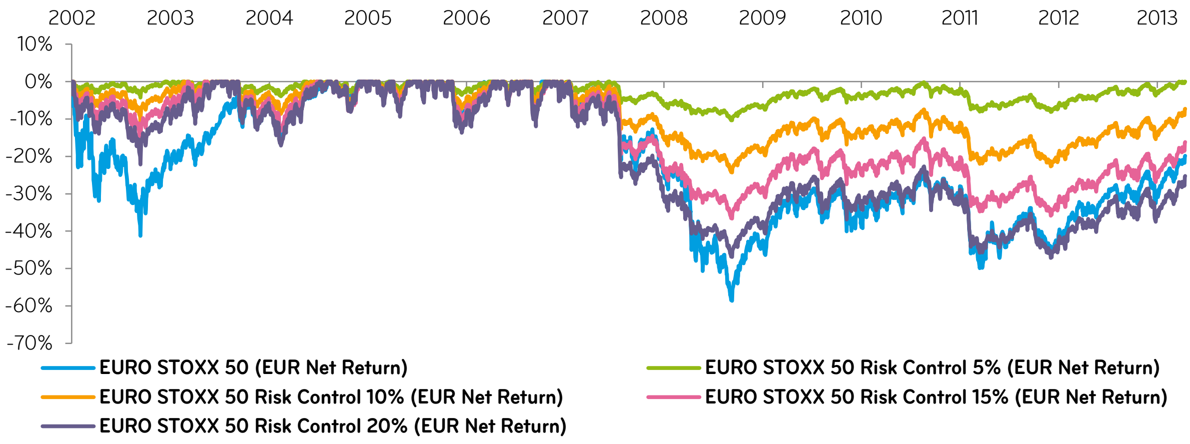
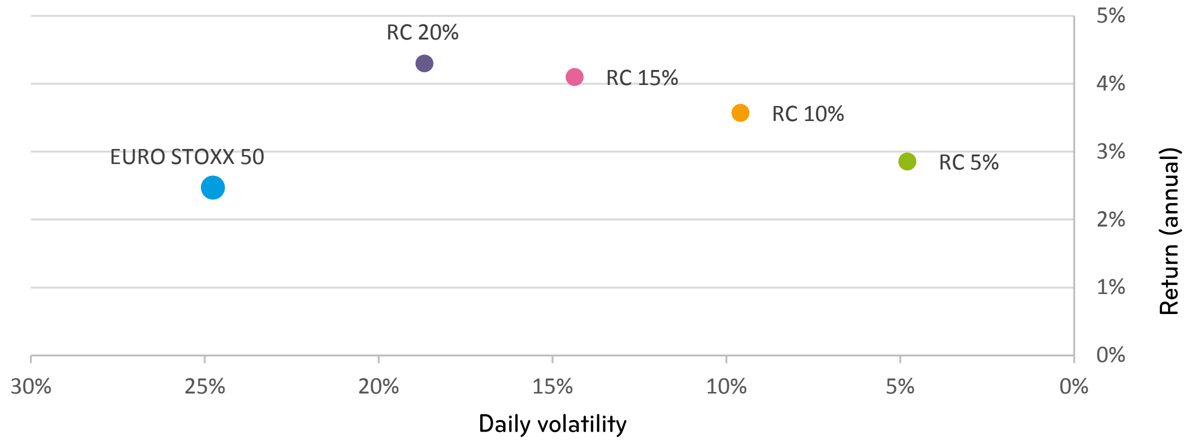
FIG. RC5: DRAWDOWN OF EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



If we compare the four target risk strategies to the underlying index, the EURO STOXX 50, in a risk-return context (see Figure RC6), it can be observed that all four risk control strategies are significantly more risk-return efficient than the underlying index. Looking at this picture, no rational investor would actually invest into the "inefficient" market-cap weighted EURO STOXX 50 Index.

FIG. RC6: RISK-RETURN CHARACTERISTICS EURO STOXX 50 (EUR NET RETURN) AND EURO STOXX 50 RISK CONTROL (EUR NET RETURN) INDICES. STOXX DATA FROM 2002 TO 2013



RISK-BASED INDEX STRATEGIES
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3 Conclusion

The empirical analysis showed that it is very important to understand the different risk-based investment strategies. Due to differing assumptions and models, they provide significantly different risk-return characteristics.

Whereas low-risk and minimum variance strategies aim to reduce the risk of an equity investment given the implicit lower bound as set by a portfolio's systematic risk, target risk strategies try to keep an ex ante defined risk level by allowing a second, presumably risk-free asset to enter the equation. This allows target risk strategies to reach any level of predefined risk as they are not subject to the systematic risk existent within equity assets.

Equal risk concepts as a fourth investment strategy simply try to evenly distribute risk across all portfolio constituents to avoid single stocks from overly contributing to portfolio risk.

Interestingly, the empirical analysis showed that the strategies discussed above typically lead to significantly better returns compared to the market-cap weighted benchmark, even though none of the strategies explicitly aims to increase performance. This primarily shows how inefficiently market-cap weighted indices exploit their risk budget.

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