European Market Portfolio Diversification Strategies across the GFC

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Keywords Portfolio Diversification, Markowitz Analysis, Downside Risk, CVaR, Draw-down

JL Classification G11, C61.

Working Paper nº 1427
October , 2014
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*Corresponding author. Acknowledgements: For financial support, the first author acknowledges the Australian Research Council, and the second author is most grateful to the Australian Research Council, National Science Council, Taiwan, and the Japan Society for the Promotion of Science. We are grateful to the anonymous reviewers for helpful comments.

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1. Introduction

It is now some sixty years since Markowitz (1952) developed portfolio theory. Although it became a central foundation of classical finance, leading directly to the development of the Capital Asset Pricing Model (CAPM) by Sharpe (1964), Lintner (1965), Mossin (1966) and Treynor (1962), its practical application has been surrounded with difficulties. Markowitz (1952, 1959) suggested choosing the portfolio with the lowest risk for a given level of portfolio return and defined such portfolios as being ‘efficient’. Merton (1972) demonstrated the parabola that constitutes the efficient frontier in mean variance space.

Markowitz (1959, p.206) states that: “Problems concerning the proper information to serve as the basic inputs concerning securities are outside the scope of this monograph. There are no magic formulas to supplant the sources of information and the rules of judgement of the security analyst”. The position of the efficient frontier has to be estimated and this leads to ‘estimation risk’. A common approach to portfolio selection is to use historical data to estimate the required means and covariances but this leads to estimation risk which, in turn, can lead to extreme and unstable portfolio weights over time. Michaud (1989, p. 31) suggests that: “The traditional MV procedure often leads to financially irrelevant or false ‘optimal’ portfolios and asset allocations. In fact, equal weighting can be shown to be superior to MV optimization in some cases”. Michaud (1989, p.33) also suggests that: ‘MV optimizers are, in a fundamental sense, “estimation-error maximizers”. They have a tendency to over-weight (under-weight) those securities which have large (small) estimated returns, negative (positive) correlations and small (large) variances’. In turn, these are the securities likely to have the largest estimation errors.

One approach to adjusting for estimation risk involves the application of Bayesian techniques, and some of the original suggested adjustments were either based on the use of diffuse priors; see for example, Barry (1974), and Bawa et al. (1979), or ‘shrinkage’ estimators. The latter were explored by Jobson et al. (1979), Jobson and Korkie (1980) and Jorion (1985, 1986). More recent approaches have used an asset-pricing model to establish a prior; see for example Pástor (2000) and Pástor and Stambaugh (2000).

Markowitz considered a number of downside risk measures as an alternative to mean-variance analysis (1959, 1991) and similarly, as early as (1952) Roy developed his ‘safety-first’ asset selection criteria. Rockafellar et al. (2006 a, 2006 b, 2007) developed the mean-deviation approach to portfolio as an extension to the classic mean-variance approach generalising the results to the one fund theorem, (2006 a), the CAPM (2006 b), plus the derivation of market equilibrium for investors using different deviation measures (2007). More recently, Zaharankin et al. (2014) have extended the CAPM with a draw-down measure to measure betas and alphas based on draw-downs.

We draw on several of this portfolio optimisation approaches in the empirical work in this paper, namely: naïve diversification, Markowitz mean variance analysis with positive constraints, Conditional Value at Risk (CVaR), Conditional Draw-Down (CDaR), Average Draw-Down (AveDD), Maximum-Drawing...
Down (MaxDD), plus draw-down metrics set at 95% confidence levels (CDaR95) and (CDaRmin95). We test their out-of-sample capabilities in times of market turbulence in a series of hold-out and backtests.

The paper is organised into five sections; this introduction is followed by a discussion of research methods in section 2, which discusses the various portfolio optimisation strategies adopted beginning with naive diversification, and then proceeding to Markowitz mean-variance analysis, CVaR, and a variety of optimal draw-down approaches. Section 3 introduces the data set and its characteristics, while section 4 presents the results, and a brief conclusion follows in section 5.

2. Research method

We proceed by adopting a variety of portfolio selection approaches and adopt a naive portfolio benchmark with $1/N$ weights as a comparator. This approach was also used by DeMiguel et al. (2007), in an out-of-sample analysis, of the mean-variance portfolio selection criteria, employing US data sets, plus a variety of adjustments for estimation risk. They concluded that there are still "many miles to go", before the gains promised by portfolio optimisation techniques can be realised out of sample.

Our focus, is broader than theirs, in that we employ a variety of portfolio optimisation techniques that go well beyond mean-variance optimisation. We contrast naive diversification, with mean-variance analysis, plus other portfolio optimisation techniques, such as the optimisation of Conditional Value at Risk (CVaR), and other techniques, such as stochastic portfolio analysis, and our analysis is conducted across the major European equity markets.

2.1. Naive $1/N$ diversification strategy

In this strategy we just consider holding a portfolio where the weights for the asset $\omega_j = 1/N$ which is applied for each of the $N$ risky assets. This strategy ignores the data and does not involve any estimation or optimisation. DeMiguel et al. (2009) suggest that this can be considered as equivalent to imposing the restriction that $\mu_t \propto \sum 1_N$ for all $t$, implying that expected returns are proportional to total risk rather than systematic risk.

2.2. Markowitz Mean-Variance Analysis

Markowitz (1952) founded modern mathematical finance and ushered in formal portfolio analysis in one giant step with his introduction of the mean-variance model of the risk-return relationship. Variance is an appropriate risk-measure if either the investor’s utility set is quadratic or the return series considered are multivariate normal.

The Markowitz (1952) approach can be presented as the following non-linear-programming problem.

\[
\min_{\omega} \frac{1}{n} \sum_{i=1}^{n} \left( \sum_{j=1}^{m} \omega_j (r_{i,j} - \mu_j) \right)^2
\]
2.3 Optimising Conditional Value at Risk (CVaR)

\[
\begin{align*}
\text{s.t.} \\
\sum_{j=1}^{m} \omega_j \mu_j &= C \\
\sum_{j=1}^{m} \omega_j &= 1
\end{align*}
\]

\[
\omega_j \geq 0, \forall j \in \{1, \ldots, m\}
\]

in the above formulation, \( \omega \) are the portfolio weights for the universe of the \( j = 1, \ldots, m \) assets available, \( i = 1, \ldots, n \) are the number of periods considered for the returns \( r \) and for \( \mu_j \), which is the forecast return. The optimisation involves minimizing the portfolio variance subject to the portfolio forecast return being set to a level \( C \). A full investment constraint and positive constraints on the weights are included, effectively ruling out short sales. In our subsequent analyses we apply mean-variance optimisation with both a positive weight constraint, and with an upper limit on the weight of any one security being less than 0.4 or 40% of the chosen portfolio.

Jagannathan and Ma (2003) demonstrate that the placement of a short-sale constraint on the minimum variance portfolio is equivalent to shrinking the elements of the covariance matrix. For this reason, we do not make any other adjustments for estimation risk. See for example, the discussions in Best and Grauer (1992), Chan, Karceski and Lakonishok (1999), and Ledoit and Wolf (2004).

2.3. Optimising Conditional Value at Risk (CVaR)

Uryasev and Rockafellar (1999) in a series of papers have advocated CVaR as a useful risk metric. Pfug (2000) proved that CVaR is a coherent risk measure with a number of attractive properties such as convexity and monotonicity, among other desirable characteristics. A number of papers apply CVaR to portfolio optimization problems; see, for example, Rockafellar and Uryasev (2002, 2000), Andersson et al. (2000), Alexander, Coleman and Li (2003), Alexander and Baptista (2003) and Rockafellar et al. (2006).

The conditional value at risk of \( X \) at level \( \alpha \in (0, 1) \) is defined by:

\[
CVaR_\alpha(X) = \text{expectation of } X \text{ in its } \alpha - \text{tail}
\]

which can also be expressed as:

\[
CVaR_\alpha(X) = \frac{1}{1-\alpha} \int_{\alpha}^{1} VaR_\tau(X) d\tau
\]

In terms of portfolio selection, CVaR can be represented as a non-linear programming minimisation problem with an objective function given as:
2.4 Optimal draw-down portfolios

\[
\min_{\omega, v} \frac{1}{na} \sum_{i=1}^{n} \left[ \max(0, v - \sum_{j=1}^{m} \omega_j r_{i,j}) \right] - v
\]  \hspace{1cm} (4)

where \(v\) is the \(\alpha\)-quantile of the distribution. In the discrete case, this was shown by Rockafellar and Uryasev (2000) to be capable of being represented by using auxiliary variables in the linear programming formulation below:

\[
\min_{\omega, d, v} \frac{1}{na} \sum_{i=1}^{n} d_i + v
\]

\[s.t.\]

\[
\sum_{j=1}^{m} \omega_j r_{i,j} + v \geq -d_i, \forall \in \{1, \ldots, n\}
\]

\[
\sum_{j=1}^{m} \omega_j \mu_j = c
\]  \hspace{1cm} (5)

\[
\sum_{j=1}^{m} \omega_j = 1
\]

\[
\omega_j \geq 0, \forall j \in \{1, \ldots, n\}
\]

\[
d_i \geq 0, \forall i \in \{1, \ldots, n\}
\]

where \(v\) represents the VaR at the \(\alpha\) coverage rate and \(d_i\) the deviations below the VaR.

2.4. Optimal draw-down portfolios

Chekhlov et al. (2000, 2004, 2005) considered the optimization of portfolios with respect to the portfolio’s drawdown. The Conditional Drawdown (CDD) measure includes the Maximum Drawdown (MaxDD) and Average Drawdown (AvDD) as its limiting cases. The CDD family of risk functional measures is similar to Conditional Value-at-Risk (CVaR). Chekhlov et al. (2005) suggest that portfolio managers would like to avoid large drawdowns and/or extended drawdowns as it may lead to a loss of mandate or withdrawal of business.

The analysis can be developed as follows; let a portfolio be optimised over some time interval \([0, T]\), and let \(W(t)\) be the portfolio value at some moment in time \(t \in [0, T]\). The portfolio drawdown is defined as:

\[
\max_{\tau \in [0, t]} W(\tau) - W(t)/W(t)
\]  \hspace{1cm} (6)

If we think in terms of the portfolio’s constituent assets and write \(W(\omega, t) = y^\prime \omega\) as the uncompounded portfolio value at time \(t\), with \(\omega\) the portfolio weights
2.4 Optimal draw-down portfolios

for the $N$ constituent assets and write $y_t$ for the cumulated returns, the Drawdown can be written as:

$$D(\omega,t) = \max_{0 \leq \tau \leq t} \{W(\omega,\tau)\} - W(\omega,t)$$  \hspace{1cm} (7)

This definition can be converted into the three previously mentioned functional risk measures; MaxDD, AvDD and Conditional Draw-down at Risk (CDaR). CDaR is dependent on the chosen confidence level $\alpha$ in the same way that CVaR is. CDaR can be defined as:

$$CDaR(\omega)_{\alpha} = \min_{\varsigma} \{\varsigma + \frac{1}{(1-\alpha)T} \int_0^T [D(\omega,t) - \varsigma]^+ dt\}$$  \hspace{1cm} (8)

where $\varsigma$ is the threshold value for drawdowns so that only $(1 - \alpha)T$ observations exceed this value. The limiting cases of this family of risk functions are MaxDD and the AvDD. In the case that $\alpha \rightarrow 1$, CDaR approaches the maximum draw-down, $CDaR(\omega)_{\alpha \rightarrow 1} = MaxDD(\omega) = \max_{0 \leq t \leq T} \{D(\omega,t)\} dt$. The AvDD results from the case in which $\alpha = 0$. That is $CDaR(\omega)_{\alpha \rightarrow 0} = AvDD(\omega) = (1/T)\int_0^T D(\omega,t) dt$.

These risk functionals can be used in terms of the optimization of a portfolio’s drawdown and implemented as inequality constraints for a fixed share of the wealth at risk.

The goal of maximizing the average annualised portfolio return with respect to limiting the maximum draw-down can be written:

$$\begin{align*}
P_{\text{MaxDD}} &= \arg\max_{\omega,u} R(\omega) = \frac{1}{dC} y_T \omega, \\
u_k - y'_k \omega &\leq v_1 C, \\
u_k &\geq y'_k \omega, \\
u_k &\geq u_{k-1}, \\
u_0 &= 0,
\end{align*}$$  \hspace{1cm} (9)

where $\omega$ denotes a $(T + 1 \times 1)$ vector of slack variables in the program formulation, in effect, the maximum portfolio values up to time period $k$ with $1 \leq k \leq T$.

We include these three approaches to portfolio optimisation; CDaR, MaxDD and AvDD, in our portfolio analyses. We use programs from the R library to conduct our analyses, in particular the packages fPortfolio, FRAPO and PerformanceAnalytics. We also modify R code from Pfaff (2013) to undertake the various draw-down optimisations.
### Table 1: Descriptive Statistics of Indices daily continuously compounded returns

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>Std. Dev</th>
<th>Skewness</th>
<th>Ex. Kurtosis</th>
<th>Hurst ExpONENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEX</td>
<td>0.000209306</td>
<td>0.000604318</td>
<td>-0.111806</td>
<td>0.131065</td>
<td>0.0168772</td>
<td>0.151445</td>
<td>8.60375</td>
<td>0.552931</td>
</tr>
<tr>
<td>BFX</td>
<td>0.000135558</td>
<td>0.000391543</td>
<td>-0.0906908</td>
<td>0.110042</td>
<td>0.0161834</td>
<td>0.0177818</td>
<td>5.29293</td>
<td>0.570771</td>
</tr>
<tr>
<td>BVL</td>
<td>0.0000685788</td>
<td>0.000296413</td>
<td>-0.121168</td>
<td>0.111047</td>
<td>0.0152447</td>
<td>0.0657292</td>
<td>7.74367</td>
<td>0.586224</td>
</tr>
<tr>
<td>DAX</td>
<td>0.000497582</td>
<td>0.000730373</td>
<td>-0.0915454</td>
<td>0.131672</td>
<td>0.0171735</td>
<td>0.177855</td>
<td>6.46489</td>
<td>0.535675</td>
</tr>
<tr>
<td>FCH</td>
<td>0.000215969</td>
<td>0.000403166</td>
<td>-0.110744</td>
<td>0.129115</td>
<td>0.0179219</td>
<td>0.271767</td>
<td>6.96039</td>
<td>0.521829</td>
</tr>
<tr>
<td>FTSE</td>
<td>0.0002</td>
<td>0.0006</td>
<td>-0.10002</td>
<td>0.129967</td>
<td>0.0153948</td>
<td>0.150327</td>
<td>9.69932</td>
<td>0.533963</td>
</tr>
<tr>
<td>IBEX</td>
<td>0.000218544</td>
<td>0.000198572</td>
<td>-0.101087</td>
<td>0.161465</td>
<td>0.0187447</td>
<td>0.302523</td>
<td>6.79814</td>
<td>0.558791</td>
</tr>
<tr>
<td>OMXC</td>
<td>0.000463244</td>
<td>0.000820621</td>
<td>-0.130423</td>
<td>0.118779</td>
<td>0.0163018</td>
<td>-0.0765109</td>
<td>6.65507</td>
<td>0.576929</td>
</tr>
<tr>
<td>OMXSP</td>
<td>0.000228989</td>
<td>0.000135171</td>
<td>-0.0968762</td>
<td>0.104224</td>
<td>0.0175208</td>
<td>0.126917</td>
<td>4.20111</td>
<td>0.576929</td>
</tr>
</tbody>
</table>

3. **Data set**

We utilise a sample of the daily values of ten European Stock Indices taken from Datastream for a period from the beginning of 2005 to the end of 2013. The nine year sample period, which incorporates the period of both the Global Financial Crisis (GFC) and subsequent European Debt Crisis (EDC) is challenging one for the application of portfolio investment strategies. The ten markets and indices involved are: the FTSE100 index, the DAX index, the CAC 40 index, the AEX Amsterdam Index, the IBEX 35 Index, the OMX Copenhagen 20 Index, the OMX Stockholm all share Index, the OMX Helsinki all share Index, the BVLG PSI Portuguese general index and the BFX Belgian 20 Index. The end of day values of these indices are differenced in to form arithmetically compounded return series. Graphs of the returns on these indices, for the whole sample period, are shown in Figure 1, and QQPlots in Figure 2.

It is clear from the QQ plots, in Figure 2, that all the index return distributions are non-normal and fat-tailed. This has implications for the use of Markowitz’s method to select efficient portfolios, given that it is based on the assumption of multivariate normal distributions. Descriptive statistics for the series are given in Table 1.

The descriptive statistics in Table (1) suggest that the series have the typical characteristics of financial return series in that they are skewed, mainly positively, but the OMXC series demonstrates negative skewness. They all demonstrate excess kurtosis and some evidence of long memory, in that the Hurst coefficient for all of them is above 0.5. This suggests that portfolio analysis based on mean variance analysis is not likely to match the characteristics of the data.

4. **Results**

4.1. *Naive diversification versus Markowitz portfolios*

The analysis commenced with a naive set of portfolios calculated for an annual holding period for each year with portfolio weights of 1/N. The results
4.1 Naive diversification versus Markowitz portfolios

Figure 1: Plots of Indices continuously compounded daily returns

(a) AEX and BFX

(b) BVL and DAX

(c) FCH and FTSE

(d) IBEX and OMEXC

(e) OMXH and OMXS

(f) STOXX
4.1 Naive diversification versus Markowitz portfolios

Figure 2: QQ Plots of Indices

(a) QQPlot AEX and BFC

(b) BVL and FCH

(c) DAX and FTSE

(d) IBEX and OMXC

(e) OMXH and OMXSP

(f) STOXX
4.1 Naive diversification versus Markowitz portfolios

Table 2: Portfolio Optimisation Results Yearly Hold-Out Samples

<table>
<thead>
<tr>
<th>Year</th>
<th>Indices included</th>
<th>Equal Weights (st dev.)</th>
<th>Markowitz P., Constraints (Max weight 0.4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>0.00058263 0.010669 0.0546</td>
<td>Dummy (dummy dummy dummy) 0.010669 0.0546</td>
</tr>
<tr>
<td>2008</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>-0.0027037 0.026519 -0.1019</td>
<td>Dummy (dummy dummy dummy) -0.00248078 0.0269006 -0.0922</td>
</tr>
<tr>
<td>2009</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>0.0011225 0.019535 0.05746</td>
<td>Dummy (dummy dummy dummy) 0.0011954 0.020944 0.04927</td>
</tr>
<tr>
<td>2010</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>0.000076592 0.016380 0.00467</td>
<td>Dummy (dummy dummy dummy) 0.00070664 0.00054330 1.3006</td>
</tr>
<tr>
<td>2011</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>-0.00072393 0.019653 -0.0368</td>
<td>Dummy (dummy dummy dummy) -0.00061439 0.020027 -0.03067</td>
</tr>
<tr>
<td>2012</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>0.0051752 0.013875 0.3729</td>
<td>Dummy (dummy dummy dummy) 0.00092886 0.013461 0.0690</td>
</tr>
<tr>
<td>2013</td>
<td>All DAX(0.4) OMXC(0.4) OMXSP(0.2)</td>
<td>0.00083955 0.0096324 0.0871</td>
<td>Dummy (dummy dummy dummy) 0.00097143 0.0098360 0.0987</td>
</tr>
</tbody>
</table>

Table 3: Markowitz with positive constraints, 1 year hold-out results

<table>
<thead>
<tr>
<th>Year</th>
<th>Indices included (weights)</th>
<th>Return (%)</th>
<th>St.Dev</th>
<th>Sharpe Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>FTSE(0.32)+OMXC(0.014)+BVLG(0.66)</td>
<td>0.00058082</td>
<td>0.0091520</td>
<td>0.063</td>
</tr>
<tr>
<td>2008</td>
<td>AEX(0.17)+IBEX(0.05)+BVLG(0.78)</td>
<td>-0.00256311</td>
<td>0.0251282</td>
<td>-0.102</td>
</tr>
<tr>
<td>2009</td>
<td>GDAX(0.12)+BVLG(0.69)+BFEX(0.19)</td>
<td>0.00127888</td>
<td>0.016421</td>
<td>0.077</td>
</tr>
<tr>
<td>2010</td>
<td>BVLGRET(0.86)+BFXRET(0.14)</td>
<td>-0.000520745</td>
<td>0.0175202</td>
<td>-0.0369</td>
</tr>
<tr>
<td>2011</td>
<td>FTSE(0.36)+OMXC(0.15)+BVLG(0.49)</td>
<td>-0.00050713</td>
<td>0.0149820</td>
<td>-0.0369</td>
</tr>
<tr>
<td>2012</td>
<td>FTSE(0.77)+OMXC(0.22)+BVLG(0.01)</td>
<td>0.000565371</td>
<td>0.0109104</td>
<td>0.0518</td>
</tr>
<tr>
<td>2013</td>
<td>FTSE(0.66)+OMXC(0.26)+BVLG(0.08)</td>
<td>0.000648125</td>
<td>0.00798428</td>
<td>0.0812</td>
</tr>
</tbody>
</table>

are shown in the second to fifth columns of Table 2. Portfolios were also calculated using Markowitz mean/variance analysis with all the portfolio weights constrained to be positive and an upper limit of 0.4 was set on the holding of any individual security. The analysis was conducted over a two-year sample period, the optimal portfolio weights were calculated and then these were applied to a portfolio held for a subsequent period of one year. The analysis suggested that the optimal portfolio throughout the sample period consisted of 0.4 invested in the DAX, 0.4 invested in the OMXC and 0.2 invested in the OMXSP. The focus on these three individual markets is not surprising given that Table 1 reveals that these markets have the highest returns over the sample period.

The outcomes for the one-year holding periods are shown in columns six to nine in Table 2. The naive diversification strategy gives a higher return in one year; 2012. However, when risk is also taken into account the naive portfolio has higher Sharpe ratios in 2009 and in 2012, and so, on balance, the results favour the Markowitz with constraints in 5 of the 7 years considered.

The results in Table 3 suggest that the Markowitz optimisation with positive weights produces a higher Sharpe ratio in the one-year holdout sample in 2007, 2009, and 2010 only, and in the other four periods has an inferior outcome. This is consistent with the previous findings of DeMiguel et al. (2009) who suggested, that in their sample and simulation analysis, it took around 3000 months with a portfolio of 25 assets to outperform the naive diversification strategy.
4.2 Markowitz versus CVaR portfolios

In the next part of the analysis we compared a standard Markowitz optimisation with an optimisation procedure based on the risk measure CVaR. We use a one year period to estimate the weights for both the Markowitz and CVaR portfolios and then roll the window forwards through the data sets to conduct our back tests. We use two different quantiles to set the CVaR parameters at 10% and 20% respectively. We employ the R packages FRAPO and fPortfolio and modify some of the R code provided in Pfaff (2013). Plots of the results are shown in Figure 3.

It is clear in Figure 3, that if the quantile for the CVaR is set to 0.1, for the purposes of the backtest, that there are very few occasions when CVaR outperforms minimum variance with positive constraints, when applied to this European set of markets, over the recent nine year sample period. The plot for CVaR (blue line) in the first diagram in Figure 3, is predominantly below the plot of the Markowitz outcome (black line). This is clear in the second diagram in which the plot for the difference between the CVaR and minimum variance outcomes in blue, very rarely pierces the horizontal line at 0, at the top of the diagram, and ventures into positive territory.

The outcomes change to a considerable degree when we alter the quantile for the CVaR optimisation to 0.2. The results of this second analysis are shown in Figure 4. There is no longer uniform dominance by the minimum variance portfolio and for for a prolonged period in 2010-2011, the CVaR portfolio has superior outcomes, but over the entire backtest it is still inferior. This is indicated by the summary statistics for the two separate backtests of the CVaR versus minimum variance strategy in Table 4.

It can be seen in Table 4 that CVAR used as an optimiser at both the 0.1 and
### 4.3 Draw-down portfolio analyses

Table 4: Backtests Minimum CVaR versus Minimum Variance

<table>
<thead>
<tr>
<th></th>
<th>CVaR(0.1) - Min Var</th>
<th>CVaR(0.2) - Min Var</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>-9.294</td>
<td>-2.7527</td>
</tr>
<tr>
<td>1st Qu.</td>
<td>-7.678</td>
<td>-1.1399</td>
</tr>
<tr>
<td>Median</td>
<td>-5.544</td>
<td>-0.5865</td>
</tr>
<tr>
<td>Mean</td>
<td>-5.112</td>
<td>-0.3207</td>
</tr>
<tr>
<td>3rd Qu.</td>
<td>-2.324</td>
<td>0.3218</td>
</tr>
<tr>
<td>Max</td>
<td>0.604</td>
<td>3.6258</td>
</tr>
</tbody>
</table>

Table 5: Average Portfolio weights GMV and Min CVaR through rolling windows

<table>
<thead>
<tr>
<th></th>
<th>FTSE</th>
<th>DAX</th>
<th>ECH</th>
<th>AEX</th>
<th>OMXC</th>
<th>OMXS</th>
<th>OMXH</th>
<th>BVL</th>
<th>BMX</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMV Weights</td>
<td>0.380222</td>
<td>0.044829</td>
<td>0</td>
<td>0.006797</td>
<td>0.00049</td>
<td>0</td>
<td>0.111106</td>
<td>0</td>
<td>0.003272</td>
</tr>
<tr>
<td>CVaR (0.1) Weights</td>
<td>0.344506</td>
<td>0.047293</td>
<td>0</td>
<td>0.000478</td>
<td>0.002555</td>
<td>0</td>
<td>0.132861</td>
<td>0</td>
<td>0.003192</td>
</tr>
<tr>
<td>CVaR (0.2) Weights</td>
<td>0.33971665</td>
<td>0.064228</td>
<td>0</td>
<td>0</td>
<td>0.002498</td>
<td>0.00689</td>
<td>0.142548</td>
<td>1.09E-10</td>
<td>0.007579</td>
</tr>
</tbody>
</table>

0.2 quantiles is still inferior, in that the mean and median differences are still negative. The CVaR(0.2) works better but the mean and median differences are still negative. There is the further problem that ex-ante it is difficult to know what is the appropriate quantile to pick for the CVaR optimisation.

Table 5 shows the average weights applied in the rolling windows in the optimisation techniques. On average the Markowitz minimum variance portfolios place greater weight on the FTSE, average weight 0.38, OMXS with an average of 0.11, and BVL with an average weight of 0.424. The CVaR techniques still emphasize the FTSE but with an average weight of 0.04 less than GMV, put slightly more emphasis on the DAX, much greater emphasis on OMXC at around 0.13-0.14, given that it was not included in the GMV. They drop investment in OMXS and increase the weight in BVL.

However, they both perform worse than Markowitz optimisation, which in the previous analysis was shown to be inferior to naive diversification for this sample set of European markets for this particular nine-year period, which includes the GFC and the European debt crisis.

#### 4.3.1 Draw-down portfolio analyses

Figure 5 shows the draw-downs of the global minimum variance portfolio.

The trajectory of draw-downs of the global minimum variance portfolio, as shown in Figure 5, reflects the initial shock of the GFC, on European markets, followed by the continuing impact of the European Sovereign debt crisis. The period from 2007 onwards has been a tough time for investors in European markets.

A comparison of the draw-downs for the various strategies is shown in Figure 6. The imposition of an average draw-down constraint to optimise the portfolio can still result in large draw-downs as shown in the first graph labelled “(a) AveDD” in the top left-hand panel of Figure 6. The draw-down of -150% is
Figure 5: Draw-Downs of the Global Minimum Variance Portfolios

Figure 6: Comparison of draw-downs

much greater than the other draw-down optimiser outcomes, with the minimum CDaR, in panel (d) of Figure 6, producing the smallest draw-down.

In Table 6 we further analyse these portfolios fitted to historic data in terms of their weights, risk contributions and diversification ratios.
### 4.3 Draw-down portfolio analyses

**Table 6: Comparison of portfolio allocations and characteristics**

<table>
<thead>
<tr>
<th></th>
<th>GMV</th>
<th>MaxDD</th>
<th>AveDD</th>
<th>CDaR95</th>
<th>CDaRMin95</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTSE</td>
<td>0.393953078</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Weight</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MES</td>
<td>0.00</td>
<td>0.00</td>
<td>0.034926</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MPR</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>GDAXI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FCHI</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>AEX</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>IBEX</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>OMXC20</td>
<td>14.37856</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>OMXSPI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>OMXHPI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BVLG</td>
<td>46.22613</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BFX</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Overall</td>
<td>2.9383168</td>
<td>1.9985201</td>
<td>3.4926388</td>
<td>2.2582148</td>
<td>0.1812922</td>
</tr>
<tr>
<td>Div Ratio</td>
<td>1.078599</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
In Table 6 we show how the portfolio weights vary if we apply the various strategies across the entire 9 year sample period. The GMV strategy with positive weights, places 39% of the portfolio in the FTSE, nearly 15% in OMXC20, and remainder of around 46% in BVLG. The other strategies, which concentrate on minimising the maximum draw-down, average draw-down, or conditional average draw-downs, or minimum draw-downs at a 95% confidence level produce much less diversified portfolios, with MaxDD placing 100% in the FTSE, AveDD placing 100% in the DAX, and CDaR95 and CDaRMIN95, both placing 100% in the FTSE.

The impact on reducing diversification is shown in the bottom line of Table (6) which reports the Diversification Ratio which is lower for all the CDaR based strategies than the minimum variance one, which is the entry at the bottom of the first column. The Diversification Ratio was developed by Choueifaty and Cognard (2008) and Choueifaty et al. (2011) and provides a measure of the degree of diversification of long only portfolios. It has a lower bound of one, which is achieved in single asset portfolios.

Paradoxically, optimising by reducing the average draw-down produces a higher expected shortfall at the 95% level than the mean variance optimiser, as shown in the penultimate entry in the fourth column of Table (6), and this is consistent with the graphical analysis presented in Figure 6.

These results are obtained by fitting the optimisations to the entire data set and are of limited use. The crucial tests are the out of sample ones, and these are considered next, using rolling one year windows for estimation purposes. In the next section of the analysis we compute the draw-down portfolio solutions, and use the maximum draw-down of the minimum variance portfolio as a benchmark value. The CDaR portfolios are calculated for a confidence level of 95%.

4.4. Portfolio comparisons using back-tests

We conducted further analyses to compare the results of the minimum variance strategy with the various conditional draw-down at risk strategies. The back-tests are carried out using a recursive window of 250 days, or one year of daily data. The CDaR portfolio is optimised for a conditional draw-down of 10% at a 95% confidence level. The GMV portfolio is again constrained to be long only.

Figure 7 provides a graph of the wealth trajectories of the CDaR strategy contrasted with the GMV one. An initial wealth of 100 units is assumed. There are two periods in 2013 when the wealth trajectory of the GMV portfolio falls well below that of the CDaR strategy, which is much less volatile, but by the end of the period the GMV trajectory is well above that of the CDaR portfolio.

Table 7 provides an analysis of the five greatest draw-downs, that resulted from the implementation of each strategy. The draw-downs for the CDaR strategy are much shallower, and the period of the drawdowns is slightly less, than for the GMV strategy.

Figure 8 provides a comparison of the draw-down trajectories. It is readily apparent that the CDaR strategy successfully minimises draw-downs but it does not necessarily provide compensating returns.
4.4 Portfolio comparisons using back-tests

Figure 7: Comparison of wealth trajectories

Table 7: Drawdowns Comparison

<table>
<thead>
<tr>
<th>Drawdowns(MVRet)</th>
<th>From</th>
<th>Trough</th>
<th>To</th>
<th>Depth</th>
<th>Length</th>
<th>To Trough</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4/02/2013</td>
<td>24/06/2013</td>
<td>19/09/2013</td>
<td>-0.1216</td>
<td>164</td>
<td>101</td>
<td>63</td>
</tr>
<tr>
<td>2</td>
<td>23/10/2013</td>
<td>1/11/2013</td>
<td>28/11/2013</td>
<td>-0.0299</td>
<td>27</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>2/12/2013</td>
<td>13/12/2013</td>
<td>23/12/2013</td>
<td>-0.0289</td>
<td>16</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>20/09/2013</td>
<td>9/10/2013</td>
<td>14/10/2013</td>
<td>-0.0279</td>
<td>17</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>16/01/2013</td>
<td>16/01/2013</td>
<td>17/01/2013</td>
<td>-0.0081</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drawdowns(CDRet)</th>
<th>From</th>
<th>Trough</th>
<th>To</th>
<th>Depth</th>
<th>Length</th>
<th>To Trough</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4/02/2013</td>
<td>24/06/2013</td>
<td>16/09/2013</td>
<td>-0.013</td>
<td>161</td>
<td>101</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>25/10/2013</td>
<td>8/11/2013</td>
<td>27/11/2013</td>
<td>-0.0066</td>
<td>24</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>2/12/2013</td>
<td>13/12/2013</td>
<td>23/12/2013</td>
<td>-0.0062</td>
<td>16</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>20/09/2013</td>
<td>9/10/2013</td>
<td>14/10/2013</td>
<td>-0.0066</td>
<td>17</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>31/01/2013</td>
<td>31/01/2013</td>
<td>1/02/2013</td>
<td>-0.0008</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
4.4 Portfolio comparisons using back-tests

It can be seen in Table 8 that the CDaR optimiser works in terms of the reducing the size of draw-downs, there are slightly more of them, 13 compared to 11 for GMV, in the analysis period, but their average size is much smaller, with a mean value of 0.19910 for CDaR, and a maximum of 1.303 compared with a mean of 2.131 and a maximum of 12.16 for the GMV strategy.

Table 8: Relative performance statistics GMV versus CDaR

<table>
<thead>
<tr>
<th>Statistics</th>
<th>GMV</th>
<th>CDaR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk/return</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VaR 95%</td>
<td>0.03097294</td>
<td>0.03879076</td>
</tr>
<tr>
<td>ES 95%</td>
<td>0.01963578</td>
<td>0.01727134</td>
</tr>
<tr>
<td>Sharpe ratio</td>
<td>0.4341370</td>
<td>0.05088481</td>
</tr>
<tr>
<td>Return annualised %</td>
<td>0.02303186</td>
<td>0.000515948</td>
</tr>
<tr>
<td>Draw-down</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.1208</td>
<td>0.00063</td>
</tr>
<tr>
<td>1st Quartile</td>
<td>0.2369</td>
<td>0.02455</td>
</tr>
<tr>
<td>Median</td>
<td>0.7765</td>
<td>0.05347</td>
</tr>
<tr>
<td>Mean</td>
<td>2.1310</td>
<td>0.19910</td>
</tr>
<tr>
<td>3rd Quartile</td>
<td>2.8430</td>
<td>0.2570</td>
</tr>
<tr>
<td>Maximum</td>
<td>12.16</td>
<td>1.306</td>
</tr>
</tbody>
</table>

However, the more standard risk/return analyses, such as those provided by Sharpe ratios, are less compelling. The Sharpe ratio is higher for GMV at 0.434, than for CDaR at 0.0508. This is a result of the relative differences in returns and standard deviations. The annualised return for the GMV strategy was 0.0230, whereas that for the CDaR was only 0.0035. Although, the volatility of the CDaR strategy was relatively low, when combined with this low return,
it produced a lower Sharpe ratio.

Thus, in summary, this portion of the analysis demonstrated that portfolio strategies, based on optimisers based on reducing draw-downs, do reduce risk but at the cost of greatly lowering returns, at least in this sample of European stock indices over this recent nine year sample period. It is not clear that using a CDaR based strategy dominates portfolio optimisation strategies based on mean variance optimisers.

5. Conclusion

In this paper we have examined the effectiveness of a variety of portfolio optimisation strategies, for a sample of ten major European market indices over a recent nine year period terminating at the end of 2013. The optimisation strategies examined included naive $1/N$ diversification, Markowitz mean variance analysis with positive weights and a maximum individual weight $\leq 0.4$, plus Markowitz with only positive weights, but no upper bound constraint. A set of analyses using CVaR optimisers, plus a further set using four different applications of draw-down optimisers: MaxDD, AveDD, CDaR95, CDaRMin95. These were evaluated using a series of one year hold out samples, or rolling one-year window back tests.

The results suggest that none of these strategies dominates naive diversification. The most successful of the optimisation strategies was the Markowitz one with positive constraints and upper bound on individual exposures $\leq 0.4$. Markowitz with positive constraints was less successful than naive diversification. The CVaR strategy did not seem to dominate Markowitz and depends on the quantile level chosen. The draw-down optimisation techniques did successfully diminish extreme adverse outcomes, but at the expense of returns, and did not have higher Sharpe ratios.

Thus, the results of our analyses concur with those of DeMiguel et al. (2009), and suggest that none of the more sophisticated analyses appears to dominate naive diversification.

References


