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The Midas Margin Methodology: Description and Quality Control

Note

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Authors Kjersti Aas
Anders Løland

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Norwegian Computing Center

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Authors	**Kjersti Aas** <Kjersti.Aas@nr.no> **Anders Løland** <Anders.Loland@nr.no>

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Abstract

Oslo Clearing is the central counterpart appointed by Oslo Børs to clear market equity instruments and equity derivatives. Through the project *MagiCa* Oslo Clearing has established a common margining model, the *Midas margin model*, for the two clearing segments. This margin model calculates a close to real-time margin for multi-currency and multi-asset portfolios, decomposed into subportfolios. The subportfolios are either defined to be *correlated* or *anti-correlated*. The first kind of portfolios allows interdependencies between underlying assets, while the other type contains instruments of the same underlying asset only. Margins are computed individually for each subportfolio using a Monte Carlo simulation approach.

Norsk Regnesentral (NR) has evaluated the methodology for computing the margins, and this report summarises the results. The focus of the evaluation has been on the statistical aspects of the margin methodology.

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1 Introduction

Oslo Clearing is the central counterpart appointed by Oslo Børs to clear market equity instruments and equity derivatives. Through the project *MagiCa* Oslo Clearing has established a common margining model, the *Midas margin model*, for the two clearing segments. This margin model calculates a close to real-time margin for multi-currency and multi-asset portfolios, decomposed into subportfolios. The subportfolios are either defined to be *correlated* or *anti-correlated*. The first kind of portfolios allows interdependencies between underlying assets, while the other type contains instruments of the same underlying asset only. Margins are computed individually for each subportfolio, using a Monte Carlo simulation approach.

Norsk Regnesentral (NR) has evaluated the methodology for computing the margins for **equities** and **derivatives on equities and equity indices**. This report summarises the results. The focus of the evaluation has been on the statistical aspects of the margin methodology.

The rest of this report is organised as follows. NR's final evaluation is given in Chapter 2. Chapter 3 describes the margin methodology used by Oslo Clearing. In Chapter 4, various statistical aspects related to this methodology are discussed and evaluated, while Chapter 5 summarises the results of a backtesting study.

2 Executive summary

Oslo Clearing's margin methodology: Oslo Clearing's margin methodology is based on the 1%-percentile of the probability distribution of the value of an instrument or a portfolio the next day. This percentile is also denoted 99% Value-at-Risk (VaR). The probability distribution is obtained through Monte Carlo simulation. Oslo Clearing assumes that the logarithmic returns for single stocks are multivariate t-distributed with 6 degrees of freedom. The portfolios may consist of both equities and options. The standard Black & Scholes formula is used for determining option prices.

The volatilities of the most imortant instruments are re-estimated every month, while the remaining volatilities are quarterly updated. The correlation matrix is re-estimated every day. The volatility for an equity instrument is defined as the *Scanning Range* of this instrument divided by 2.33, the 99%-percentile of the standard normal distribution. The scanning range specification is unaltered from the previous version of the margin methodology. The Exponentially Moving Average (EWMA) model is used to determine option volatilities as well as the correlations between pairs of equities.

NR's quality control: To NR's knowledge, VaR is an industry standard used by several clearing houses for computing margins. Recommendations provided by European Regulators require that margins shall cover at least 99% of expected price movements. VaR is a manageable risk measure both computationally and methodologically. However, VaR has one major weakness. It provides no information on the potential size of a loss, given that it exceeds the 99%-percentile. To cover losses that are greater than 99% VaR, additional financial resources, such as a clearing fund and Oslo Clearings own capital, are easily accessible. To identify the size of potential extreme losses, Oslo Clearing performs a daily stress test.

Since equity returns measured over short time intervals are characterized by heavy tails, the use of the t-distribution seems to be appropriate. However, as indicated by the backtesting study, the combination of a t-distribution with 6 degrees of freedom and the current approach for setting margin rate volatilities might give too conservative margin requirements.

Oslo Clearing uses the EWMA-method to obtain the time varying correlation matrix for pairs of equities. In a recent study (Harris and Nguyen, 2011) the parsimonious long memory EWMA model outperforms several versions of more complex multivariate GARCH models at all forecast horizons. Hence, the EWMA model seems to be a good choice.

With the chosen model for equities, the portfolio margin cannot be analytically computed without resorting to approximations. Hence, to obtain a more precise estimate, it is wise to use Monte Carlo simulations to obtain the desired percentile.

Estimating the future implied volatility of an option is a very demanding problem. Even for this task, EWMA is currently Oslo Clearing's preferred approach, since the trading volume of options at Oslo Børs is not necessarily sufficiently high. According to Donaldson and Kamstra (2005), ARCH-based methods (like the EWMA-method) give better volatility predictions than market-based ones if the trading volume is low. Hence, it is NRs opinion that it is wise to use the EWMA method in the current version of Midas.

Backtesting study: To verify that Oslo Clearing's margin methodology is adequate, a backtesting study was performed for 31 stocks listed at Oslo Børs and 15 portfolios consisting of these stocks as well as of options on some of the stocks. The results from the backtesting study indicate that the margin requirements might be too conservative. This is probably due to the choice of the t-distribution with 6 degrees of freedom. Combining this distribution with conservative parameter values (e.g. for equity volatilities) seems to overestimate the portfolio risk.

Conclusion: In NR's opinion the margin methodology used by Oslo Clearing agrees with the industry standard and is appropriate in general. The backtesting study shows however that the margin requirements are on the conservative side. Since too high margin requirements could discourage trading, Oslo Clearing should consider increasing the number of degrees of freedom in the t-distribution and/or using slightly less conservative margin rate volatilities.

3 Description of margin methodology

The Midas margin model calculates a close to real-time margin for multi-currency and multi-asset portfolios, decomposed into subportfolios. The subportfolios are either defined to be *correlated* or *anti-correlated*. The first kind of portfolios allow interdependencies between underlying assets, while the other type contains one specific instrument and/or derivatives on this instrument. A subportfolio is defined to be *anti-correlated* if the corresponding underlying security has been traded less than 5 days during the last 60-days period. Such subportfolios are given the correlations ± 1 with the rest of the portfolio.

Margins are first determined individually for each subportfolio using a Monte Carlo simulation approach. Then the margin for the whole portfolio is computed as the sum of the margins for all subportfolios. The margin corresponding to a subportfolio at a specific day is computed as the 1% percentile of the probability distribution for the portfolio value the next day (i.e. the 99% Value-at-Risk)[1]. The rest of this chapter is organised as follows: Section 3.1 describes the model used for equity prices, while the option methodology in Midas is treated in Section 3.2. Finally, the actual simulation procedure is given in Section 3.3.

3.1 Model

Oslo Clearing assumes that the price of equity i is modelled by

$$S_{i,t} = S_{i,t-1} \exp\left(-\frac{1}{2}\sigma_{i,t}^2 + w_{i,t}\right). \tag{1}$$

In order to account for heavy-tailed behaviour, the noise terms $w_{i,t}$ are assumed to follow a multivariate Student's t-distribution with ν degrees of freedom, mean vector equal to $\mathbf{0}$ and covariance matrix $\boldsymbol{\Sigma}_t$. Hence, the logaritmic returns are assumed to be multivariate t-distributed with covariance matrix $\boldsymbol{\Sigma}_t$. In the current version of Midas Oslo Clearing have set the degrees of freedom parameter ν to be 6.

The covariance matrix can be decomposed into

$$\boldsymbol{\Sigma}_t = \boldsymbol{D}_t \, \boldsymbol{R}_t \, \boldsymbol{D}_t,$$

where $\boldsymbol{D}_t$ is a diagonal matrix with the equity standard deviations $\sigma_{1,t}$, $\sigma_{2,t}, \ldots$. at the diagonal, and $\boldsymbol{R}_t$ is the equity correlation matrix. The standard deviation, $\sigma_{i,t}$, of equity i at day t is denoted the *margin rate volatility*. In what follows we describe how the margin rate volatilities $\sigma_{i,t}$ and the correlation matrix $\boldsymbol{R}_t$ are determined in Midas.

3.1.1 Margin rate volatility

The margin rate volatility $\sigma_{i,t}$ for equity i at day t is a central ingredient in the margin rate calculations. It is defined as the *Scanning Range* of this instrument divided by the

1. We are actually interested in the portfolio value at the end of the closing period, where the length of the closing period might different from 1 day. However, this is accounted for when computing the margin rate volatilities, see e.g. Aas and Løland (2010).

99%-percentile of the standard normal distribution. The scanning ranges for the different instruments are set by the risk management department in Oslo Clearing, based on quantitative information (such as price volatility, turnover and frequency of trades), as well as qualitative issuer information. The specific methodology for setting scanning ranges is outside the scope of the evaluation described in this report. For more about scanning ranges, see Aas and Løland (2010).

3.1.2 Correlation matrix

Oslo Clearing uses the Exponentially Moving Average (EWMA) model (JPMorgan, 1996) to determine the correlation matrix $\boldsymbol{R}_t$. More specifically, for each pair of equities, EWMA is first used to compute the covariance matrix $\boldsymbol{\Gamma}_t$, and then the correlation matrix $\boldsymbol{\Omega}_t$ for the current pair is found as

$$\boldsymbol{\Omega}_t = \boldsymbol{\Delta}_t^{-1}\boldsymbol{\Gamma}_t\boldsymbol{\Delta}_t^{-1}.$$

Element (j,k) in the covariance matrix $\boldsymbol{\Gamma}$ is obtained as follows:

$$\gamma_{t,j,k} = \lambda\, \gamma_{t-1,j,k} + (1-\lambda)\, r_{j,t-1}\, r_{k,t-1}, \tag{2}$$

where λ is a decay factor that determines the weighting of recent observations compared to older ones, and $r_{j,t}$ is the logarithmic return of equity j at day t. In the current version of Midas the value of λ is set to be 0.99. $\boldsymbol{\Delta}_t$ is a diagonal matrix with the square roots of the $\gamma_{t,j,j}$s at the diagonal.

The full correlation matrix $\boldsymbol{R}_t$ is obtained by putting together the $\boldsymbol{\Gamma}_t$ matrices for all pairs. Obtaining $\boldsymbol{R}_t$ in this way, one is not guaranteed a positive definite correlation matrix. Hence, Oslo Clearing uses a method proposed by Higham (2002) to find the closest positive definite correlation matrix $\boldsymbol{R}_t^*$ to $\boldsymbol{R}_t$. Specifically, this algorithm minimises $||\boldsymbol{R}_t^* - \boldsymbol{R}_t||_F$, where $||\boldsymbol{X}||_F = \sum_{i,j} X_{i,j}$ denotes the Frobenius norm of $\boldsymbol{X}$.

3.2 Option methodology

The Midas margin model uses the standard Black & Scholes formula for pricing the options[2]. The prices of a call and a put option having i as underlying asset, K as strike and T as time to maturity are

$$P_{i,t,T,K}^{call} = S_{i,t}\Phi(d_1) - e^{r\,T}\, K\, \Phi(d_2),$$

and

$$P_{i,t,T,K}^{put} = K\, e^{r\,T}\, \Phi(-d_2) - S_{i,t}\Phi(-d_1),$$

respectively, where $S_{i,t}$ is the value of the underlying equity at day t, r is the risk free rate,

$$d_1 = \frac{\log(S_{i,t}/K) + (r - \kappa_{i,t,T,K}^2/2)\, T}{\kappa_{i,t,T,K}\sqrt{T}}$$

2. Black & Scholes formula is assumed to be valid even for American options. As an American option would be expected to have a slightly higher value than the corresponding European option this is not a strictly correct assumption. However, Oslo Clearing considers the difference to be insignificant for margining purposes.

and

$$d_2 = d_1 - \kappa_{i,t,T,K}\sqrt{T}.$$

Further, $\kappa_{i,t,T,K}$ is the option volatility at day t for options with instrument i as underlying, K as strike, and T as time to expiration. In what follows we describe how the option volatilities are determined in Midas.

3.2.1 Option volatilities

Oslo Clearing uses the principle of *uncertain volatility* (Avellaneda et al., 1995) when determining the option volatilities $\kappa_{i,t,T,K}$. Instead of obtaining one specific estimate of the volatility, one determines a volatility range, defined by a low and a high volatility, respectively. Based on these volatility limits one finds the best and worst case prices of each derivative. The low and high volatility estimates are used for a long and a short derivative position, respectively. In the current version of Midas, the high and low volatilities are determined in two different ways:

1. Using the EWMA method
2. Using prespecified default values

The first approach is used if certain conditions that are described below are met, otherwise the second approach is used. Oslo Clearing is also developing a third approach for determining the option volatilities based on market information. Hence, this approach is also included in the evaluation described in this report. In what follows, the three approaches for obtaining the high and low volatility estimates are more thoroughly described.

Using the EWMA method: Oslo Clearings's preferred approach is to use the EWMA method described in Section 3.1.2 to compute the option volatilities. Given that the underlying stock has been traded for at least 55 of the last 60 trading days, Equation 2 is first used to compute volatility estimates for these days, setting λ equal to 0.94. Then, the high and low volatilities are obtained as the maximum and minimum of these estimates, respectively, multiplied by the factors 1.25 and 0.75.

Default values: If the underlying stock has been traded less than 55 of the last 60 trading days, Oslo Clearing uses prespecified default values for the option volatilities. In this approach, the **high volatility** is defined as

$$\min\left\{1.25 \times \exp\left(3 \times \sigma_{i,t}\right) - 0.4; 3\right\},$$

and the **low volatility** as

$$\min\left[\max\left\{0.05; 1 - \exp\left(-2 \times \sigma_{i,t}\right)\right\}; 0.5\right],$$

where $\sigma_{i,t}$ is the margin rate volatility for equity i at day t. Since most of the options at Oslo Børs are based on liquid underlying instruments, these default values probably will be rarely used.

IV surface: Oslo Clearing is also considering a third approach for determining the option volatilities based on market information. This approach is not fully developed, but the main ideas are as follows:

- Start with market data in terms of ask and bid option prices for a specific underlying instrument at a specific day.
- Remove the options for which the bid and ask prices are more than $p\%$ apart.
- Obtain implied volatilities for each bid/ask and put/call price.
- Assume that the implied volatility is a function of the strike K and maturity T and that it can be represented by a third degree polynomial[3]:

$$IV = a_{00} + a_{10}\,T + a_{01}\,K + a_{11}T\,K + a_{21}T^2\,K + \cdots$$

- Fit preferably one such polynomial to each of the ask-put, ask-call, bid-put and bid-call volatilities using a least squares technique.
- Multiply all polynomials by confidence factors, to obtain high and low volatility surfaces.

Note that this approach is only intended to be used for options for which there are sufficient market data.

3.3 Monte Carlo simulation method

The margin for a subportfolio at day $t-1$ is computed as follows:

For each simulation:

- Generate noise terms $\boldsymbol{w}_t$ from a multivariate t-distribution with 6 degrees of freedom, mean vector equal to $\mathbf{0}$ and scale matrix S equal to $(4/6) \times \boldsymbol{\Sigma}$ (with this choice of scale matrix, the covariance matrix for the noise terms will be $\boldsymbol{\Sigma}$).
- For all instruments i:
  - Compute the price $S_{i,t}$ using Equation 1.
  - For all strikes K and time to maturities T:
    - Compute the prices $P^{call}_{i,t,T,K}$ of all call options having i as underlying asset, K as strike and T as time to maturity. If the corresponding position is short, use the high volatility estimate, otherwise use the low volatility estimate.
    - Compute the prices $P^{put}_{i,t,T,K}$ of all put options having i as underlying asset, K as strike and T as time to maturity. If the corresponding position is short, use the high volatility estimate, otherwise use the low volatility estimate.

3. The exact shape of the polynomial is currently not determined.

- Compute the value of this subportfolio at day t as

$$V_t = \sum_{i=1}^{N} \left[M_{i,t}^{equity} \, S_{i,t} + \sum_K \sum_T M_{i,t,T,K}^{call} \, P_{i,t,T,K}^{call} + \sum_K \sum_T M_{i,t,T,K}^{put} \, P_{i,t,T,K}^{put} \right],$$

  where N is the number of underlying equities, $M_{i,t}^{equity}$ is the number of stocks corresponding to equity i at day t, $M_{i,t,T,K}^{call}$ is the number of call options at day t having i as underlying asset, K as strike and T as time to maturity, and similarly for the put options.

This procedure is repeated S times, resulting in the probability distribution for V_t. The margin, MA_{t-1}, is given as the 1% percentile in this distribution. In the current version of Midas Oslo Clearing uses S=100 000 scenarios to compute the margins (for intra-day margin computations a lower number of scenarios might be used). The margin for the whole portfolio is computed as the sum of the margins for all subportfolios.

4 Quality control

In this chapter we summarize the evaluation of the different statistical aspects of Oslo Clearing's methodology for computing the margins.

4.1 Using Value-at-Risk as a risk measure

As described in Chapter 3, the method used by Oslo Clearing is based on the 1%-percentile (i.e. 99% Value-at-Risk) of the probability distribution for the portfolio value the next day. To NR's knowledge, VaR is the industry standard used by clearing houses for computing margins, mainly because it is both computationally and methodologically a manageable risk measure. It is, however, important to be aware of the weaknesses of VaR, of which the most significant is that it does not measure the tail length of the corresponding probability distribution. According to Artzner et al. (1999), Expected Shortfall (ES) should be used as risk measure instead of VaR. ES is the expected size of a loss that exceeds VaR.

4.2 Probability distribution, volatility and correlations

As stated in Section 3.1, the Midas margin model assumes that logarithmic returns are multivariate t-distributed. It is well known that equity returns measured over short time intervals are characterized by heavy tails, see e.g. McNeil et al. (2006). Hence, the use of the t-distribution seems to be appropriate. However, as indicated by the backtesting study described in Section 5, the combination of a t-distribution with 6 degrees of freedom and the current approach for setting margin rate volatilities might give too conservative margin requirements. Hence, Oslo Clearing should consider increasing the number of degrees of freedom in the t-distribution and/or using slightly less conservative margin rate volatilities.

When computing the portfolio margin one is not interested in a single financial time series, but in the simultaneous behaviour of multiple time series. Hence, the correlations between the series are very important. It is widely believed that correlations change, but there are varying ways of interpreting this stylized fact in terms of underlying models. Oslo Clearing uses the EWMA-method to obtain the time varying correlation matrix. In a recent study (Harris and Nguyen, 2011) the parsimonious long memory EWMA model outperforms several versions of more complex multivariate GARCH models at all forecast horizons. Hence, the EWMA model seems to be an appropriate choice. Since the correlations are computed pairwise in Midas, one is not guaranteed that the final multivariate correlation matrix is positive definite. Hence, it is reassuring that Midas contains a post-processing step, in which one finds the nearest positive definite correlation matrix to the one obtained by the EWMA method.

4.3 Monte Carlo Simulation method

Assuming the model in Equation 1 for equities, the portfolio margin cannot be analytically computed without resorting to approximations. Hence, to obtain an as exact estimate as possible, one should use Monte Carlo simulations to obtain the desired percentile. Monte Carlo analysis is by far the most powerful method to compute Value-at-Risk. The only drawback with this approach is its computational cost. To obtain a sufficiently accurate p% percentile, one needs a certain number of scenarios S. The simulation accuracy may be assessed by computing the standard error $\hat{se}(\hat{q}_p)$ of the p% percentile q_p. An approximate formula for this standard error is (Jorion, 1997):

$$\hat{se}(\hat{q}_p) = \frac{1}{f(q_p)}\sqrt{\frac{p(1-p)}{S}}, \tag{3}$$

where $f(\cdot)$ is the probability density function of the portfolio value. This function is unknown, but can be estimated from the simulations using a density estimation method (Silverman, 1986). Oslo Clearing should use this or another approach to verify that the chosen number of scenarios gives a sufficiently accurate estimate of the 1% percentile.

4.4 Option methodology

As stated in Section 3.2, the Midas margin model uses the standard Black & Scholes formula for obtaining option prices. Hence, having simulated equity prices, using this formula, the only uncertain quantity is the future implied option volatility. Estimating this volatility is an even more demanding task than predicting the future volatility of the underlying stock, since one wants to determine the traders view on the future volatility one day from now. A further complicating factor is that the market actors believe in different future volatilities when they price options with different strikes and/or different maturities on the same underlying equity. This is seen when the implied volatility is plotted against strike price.

The methods for estimating the future volatility of the underlying stock may be categorized into two main groups; those based on historical information and those based on market information. It is not clear from the literature whether one of the two types of approaches are significantly better than the other. The survey article by Poon and Granger (2003) concludes that option implied volatility appears to have superior forecasting capability, outperforming many historical volatility models. On the other hand, Musiela and Rutkowski (2005) cite a considerable body of research that found that implicit volatility has not markedly outperformed historical data in predicting future option prices.

The EWMA method, that is Oslo Clearing's preferred approach, belongs to the first group of approaches, and the IV surface-method to the other. Oslo Clearing's main reason for not using the IV surface-method in the current version of Midas is that the trading volume of options at Oslo Børs is not necessarily sufficiently high. According to Donaldson and Kamstra (2005), ARCH-based methods (like the EWMA-method) give better volatility predictions than market-based ones if the trading volume is low. Hence, it is NRs opinion that it is wise to use the EWMA method in the current version of Midas.

As far as the volatility surface approach described in Section 3.2.1 is concerned, it has one major weakness. It does not take into account that volatility surfaces change dynamically over time ("the sticky strike rule"), at least not explicitly[4]. Cont and da Fonseca (2002)

4. As stated in Section 3.2.1 the obtained volatility surfaces are multiplied by so-called confidence factors.

show that the volatility surface corresponding to a simple underlying is not static, but fluctuates around its average profile. According to their studies of put and call options on the SP500 index, the daily standard deviation of the implied volatility can be as large as a third of its typical value for out of the money options, resulting in an important impact on option prices. Hence, they propose to model the implied volatility surface as a stationary random field, to which they apply a Karhunen-Loéve decomposition. A simpler way of incorporating uncertainty into the volatility surface is to add a random shock to the strike-maturity polynomial, like in Bernales and Guidolin (2010).

We also have another comment to the volatility surface approach. We would consider using the sticky moneyness rule instead of the sticky strike rule. The moneyness is defined as the strike divided by the current value of the underlying equity. Hence, the implied volatility surface is represented in relative coordinates (see Carr and Wu (2010) for an example).

The default volatility approach is intended for options on illiquid stocks. Hence, it gives very conservative estimates. If e.g. the margin rate volatility of the underlying equity is 12.9%, the low and high volatilities are 23 and 144%, respectively. If the margin rate volatility is larger than 34%, meaning that the underlying equity either is very illiquid or very volatile or both, the low and high volatilities are set to their maximum values 50 and 300%. As the default volatility approach is quite ad hoc, we find it a bit difficult to evaluate it. Oslo Clearing has however found the default values to be reasonable based on comparison with bid/ask volatilities observed in the market. Moreover, as stated in Section 3.2.1, the default values probably will be rarely used, since most of the options at Oslo Børs are on very liquid equities.

This may be viewed as an implicit way of taking the uncertainty of the volatility surface into account.

5 Backtesting study

In Chapter 4 we have given a theoretical evaluation of the margin methodology. A full quality assessment should also include a backtesting study to verify that the resulting margins fulfil their purpose. A trustworthy clearing operation requires reasonably conservative margins. On the other hand, too high margin requirements could discourage trading.

In agreement with NR, Oslo Clearing conducted a backtesting study for the time period from March 27th 2002 to December 30th 2011. A set of 31 stocks listed at Oslo Børs, including very liquid and very illiquid ones, was selected. Subsequently, 15 portfolios were constructed, all consisting of the same 31 stocks, but with different positions, both long and short. In addition, the portfolios consisted of positions on 10 different call and put options. See Appendix A for an overview of the stocks and portfolios. For each portfolio the positions were assumed to be the same every day in the backtesting period.

For each day (2454 days in total) in the backtesting period, Oslo Clearing computed the margin for all stocks and portfolios using the methodology described in Section 3[5]. Then, we used the likelihood ratio test statistic by Kupiec (1995) to verify the adequacy of the margins. This method consists in calculating the number of times the observed price difference is larger (in absolute value) than the margin (a so-called violation of the margin), and comparing it to the expected number of violations. It is assumed that it takes two days on average to close a counterparty's positions and portfolios. For this reason, we compared the computed margins to changes in the market value during the two days following the margin date.

5.1 Results for single stocks

Using a 5% significance level in the Kupiec test, and assuming a long position in each stock, the results for the 31 single stocks were as follows:

- No stocks produced significantly more violations than expected.
- For 24 stocks there were significantly less violations than expected.
- For the remaining 7 stocks, the number of violations was as expected.

Similarly for short positions:

- 1 stock produced significantly more violations than expected.
- For 30 stocks there were significantly less violations than expected.
- For none of the 31 stocks, the number of violations was as expected.

5. For single stocks one does not have to turn to simulations to compute the margin. Instead the margin may be computed using the exact formulas given in Appendix B. These formulas have been used in the backtest, but they have not yet been implemented in Midas.

Comparing the number of violations to the ones reported by Aas and Løland (2010), we conclude that the new approach is more conservative than the current one. This might be due to the choice of the t-distribution with 6 degrees of freedom, or to conservative scanning ranges, or both. Moreover, the backtest might not provide a completely accurate picture of the performance of all the single stocks, since we have used a closing period of two days for all stocks, while for at least 9 of the stocks it presumably takes 5 days or more to close a corresponding position.

5.2 Results for portolios

Backtesting a portfolio consisting of options is very challenging due to the following reasons:

- The option market at Oslo Børs is not very liquid.
- Observed bid/ask prices available in the market does not necessarily give a true reflection of available prices. Moreover, obtained prices will be heavily dependent on the size of the position in question, as well as current market conditions.
- We make the simplifying assumption that the 10 options included in the backtest study were available each day in the backtesting period, even though they actually weren't.

Hence, although it is a suboptimal solution, it was found necessary to *construct* the true option prices used in the backtest study. First, the "true" implied volatility for a certain option at a specific day $t + 2$ was computed as the EWMA-estimate (with λ equal to 0.94) of the volatility of the underlying equity this day. Then, the "true" price of the corresponding option at day $t + 2$ was computed using the Black & Scholes formula with this implied volatility as input (the annual risk free interest rate in the Black & Scholes formula was set to 3% during the whole backtesting period).

To check whether the EWMA method gives an accurate estimate of the true option volatility, Oslo Clearing has compared the EWMA estimates with the implicit volatility for the OBX front options[6]. The result is shown in Figure 1, where the implied volatilities for the OBX front options and the EWMA-estimated volatilities are shown as red and grey curves, respectively. The two curves follow each other quite closely, but there are some discrepancies, especially in high-volatility regimes. In such regimes the EWMA estimate tend to be higher than the implicit volatility. Hence, from this example, the EWMA method seems to be a conservative choice. Due to low liquidity, it is not possible to repeat the above comparison for other options. We therefore have to assume that there is a similar picture for all options sold at Oslo Børs.

To test the impact of the number of simulations S, the portfolio margins were computed for three different values of S: 10 000, 20 000 and 100 000. There were some deviations between the three sets of margins. Hence, Oslo Clearing is recommended to study the simulation accuracy more closely before deciding on the number of simulations to use in

6. OBX front options are the options on OBX with the shortest time to expiration.

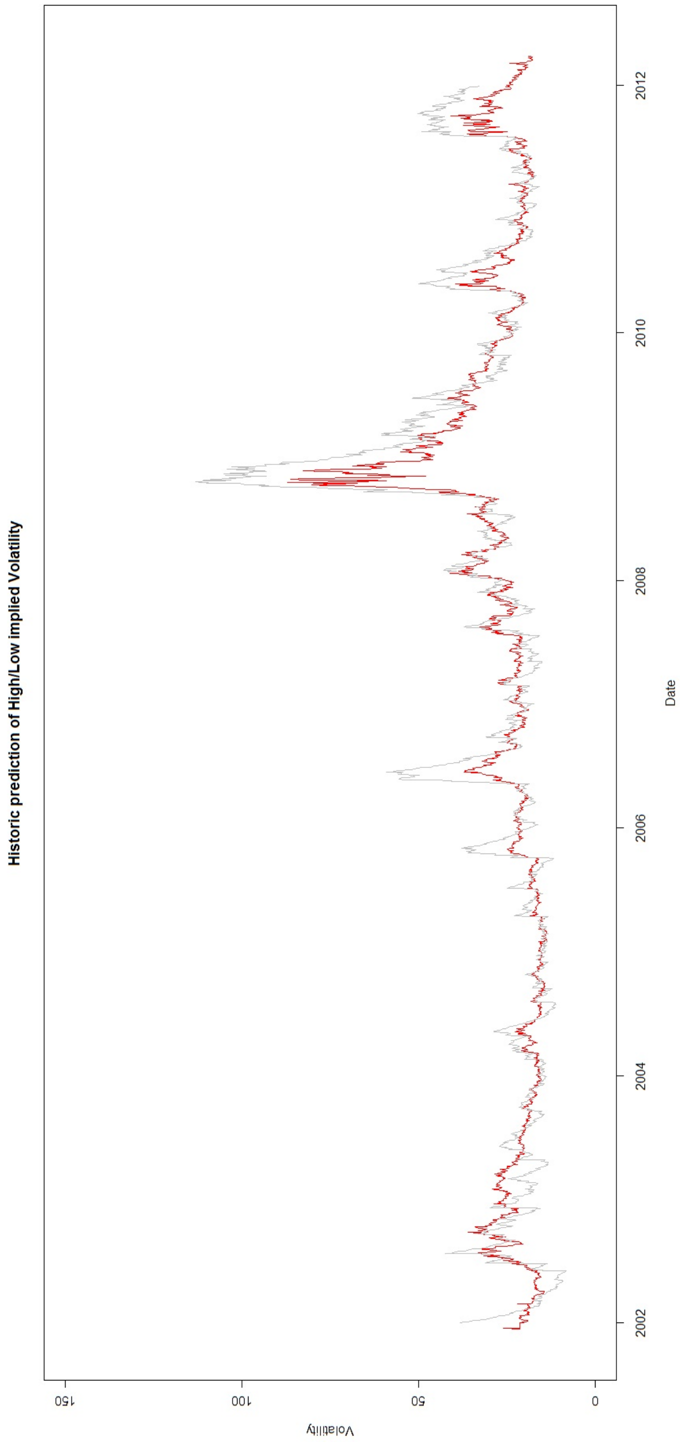

Figure 1. Comparison of volatilities. The red curve shows the implied annualised volatilities for the OBX front options, while the EWMA-estimated volatilities for OBX are represented by the grey curve.

the final version of Midas.

The results for the 15 portfolios were as follows:

- No portfolios produced significantly more violations than expected.
- For none of the portfolios, the number of violations was as expected.
- For all 15 portfolios there were significantly less violations than expected.
- The portfolios without derivatives seem to behave similarly to the other ones.

5.3 Summary of backtesting study

From a risk management perspective it is crucial to verify that the margin requirements are not too low. The results from the backtesting study indicate that this is certainly not the case for the current version of Midas. On the contrary, Oslo Clearing might be too conservative. Assuming that the scanning ranges are set exactly as before, the main difference between Midas and the current margin model for stocks described in Aas and Løland (2010) is that the t-distribution is used instead of the Gaussian to model financial returns. The backtesting results for single stocks indicate that the current choice of the degrees of freedom parameter in this distribution (i.e. 6), might be too conservative.

The very limited number of violations for portfolios is most likely due to the conservative models for single stocks. However, we cannot exclude the possibility of the correlation estimates being in the upper range also.

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A Description of portfolios

Table A.1 shows the positions for each portfolio that are used every day in the backtesting period. A negative sign identifies a short position. Since the positions are kept constant, the weight of each asset will potentially vary quite much with time. The last 10 rows of the table contains the following options:

- **STLCA+0211:** Call option on Statoil (STL) with strike 2% higher than the current spot price and 11 days left to maturity.
- **STLPU-0330:** Put option on Statoil (STL) with strike 3% lower than the current spot price and 30 days left to maturity.
- **TELPU+0130:** Put option on Telenor (TEL) with strike 1% higher than the current spot price and 30 days left to maturity.
- **TELCA-0610:** Call option on Telenor (TEL) with strike 6% lower than the current spot price and 10 days left to maturity.
- **DNBCA-0260:** Call option on DNB (DNB) with strike 2% lower than the current spot price and 60 days left to maturity.
- **DNBPU+0520:** Put option on DNB (DNB) with strike 5% higher than the current spot price and 20 days left to maturity.
- **OBXCA+0520:** Call option on Oslo Børs Benchmark index (OBX) with strike 5% higher than the current spot price and 20 days left to maturity.
- **OBXPU+0360:** Put option on Oslo Børs Benchmark index (OBX) with strike 3% higher than the current spot price and 60 days left to maturity.
- **PGSCA+1240:** Call option on Petroleum Geo-Services (PGS) with strike 12% higher than the current spot price and 40 days left to maturity.
- **PGSPU-1060:** Put option on Petroleum Geo-Services (PGS) with strike 10% lower than the current spot price and 60 days left to maturity.

POS	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
ATEA	100000	1000000	2000000	100000	0	-100000	500000	0	4000000	0	1500000	400000	10000	350000	450000
BIONOR	3000	1000000	-1000000	-1000000	-1000000	-1000000	1000000	-250000	250000	1200000	0	10000000	-1000000	0	-30000
BON	5000	1000000	96000	340150	0	0	0	0	-38930	50000	1000000	-500000	750000	0	150000
DNB	750000	91000000	-2384000	5718004	15048744.4	248744.4	-8000000	-1008931	500000	-50000	-300000	0	100000	0	-30000
DNO	65000	3000000	-1149000	308517	-11558360	-7000000	-10000000	-700000	3760340	800000	500000	750000	-10000	0	250000
EKO	1000	1000000	-1000000	100000	0	0	1000000	0	5000000	100000	500000	250000	-50000	-150000	-200000
FAR	1000	1000000	1000000	57000	0	0	-143550	0	0	25000	0	0	750000	0	250000
FOE	76000	6000000	-500000	3895504	0	0	-7351315	787197	-1075747	0	300000	0	500000	0	0
FRO	100000	5600000	-465000	-4173878	250000	60000	-8000000	0	10000000	300000	-100000	100000	150000	550000	200000
GOL	82000	500000	155000	134075	0	0	-496800	0	0	0	0	0	500000	0	0
GRO	1000	-100000	57000	77360	0	0	0	0	0	100000	-400000	0	750000	0	250000
HNA	1000	113450	18000	-93950	0	0	0	0	0	0	650000	100000	0	0	-250000
KOG	6000	-67610	292000	462707	0	0	0	0	0	0	-200000	-1500000	-150000	-500000	550000
MHG	12000	3000000	0	500000	25869800	2869800	6000000	-2500000	-5158167	500000	400000	-600000	10000	0	-200000
NEC	4000	1000000	1500000	2000000	0	0	1500000	100000	100000	-1000000	0	-25000000	0	0	250000
NHY	750000	-25000000	3040000	-7485500	-20000000	-1000000	-2801662	-500000	-1500000	-100000	150000	0	65000	0	35000
OBX	250000	10000000	600000	300000	0	100000	-10000000	-500000	2000000	0	0	-350000	0	11000000	-70000
ORK	235000	315938	-5000000	-1180888	-267300	-267300	2800000	-500000	-681980	0	150000	0	-50000	0	0
PGS	400000	12000000	811000	5672986	4441980	100000	-8427735	-583851	7000000	0	-100000	120000	-120000	-6000000	0
RCL	150000	8210920	538000	-27227477	714800	114800	-4323470	0	-12331440	10000	-150000	0	400000	0	0
SCH	100000	3989789	-685000	92610	2334510	10000	2174050	-463373	-419057	25000	350000	1000000	-200000	0	0
SNI	5000	10000	200000	250000	0	0	500000	-50000	100000	0	-800000	-750000	20000	-350000	-200000
SPOG	1000	570849	205000	494000	0	0	89900	0	0	0	-500000	250000	50000	250000	0
STB	206000	9175037	-2193000	-388948	0	0	-5000000	-655702	-1296421	-400000	250000	-1000000	-250000	0	550000
STL	1000000	-130000000	-1000000	-24296128	-1000000	-100000	-5000000	-800000	900000	0	200000	0	-50000	-7000000	50000
SUBC	300000	20000000	-2000000	1000000	0	0	-1000000	-3000000	-6000000	0	150000	150000	20000	2500000	0
TEL	600000	21928656	-1200000	5000000	-3000000	-700000	120280	-100000	-1500000	10000	-50000	0	-75000	7000000	0
TGS	180000	6720320	-1341000	1805372	2934430	100000	8000000	-400000	-25000000	-350000	0	0	350000	0	0
TOM	16000	2000000	1500000	-500000	0	0	-1000000	0	3000000	250000	1200000	-2000000	-70000	0	200000
TTS	1000	115155	-29000	-13804	0	0	0	0	0	-700000	700000	-250000	550000	-400000	150000
VEI	6000	151408	20000	-14500	0	-100000	0	0	0	10000	150000	0	-30000	0	-500000
STLCA+0211	200000	0	0	0	0	0	0	-2000000	-3000000	0	-200000	0	0	15000000	0
STLPU-0330	400000	-150000000	3000000	0	0	0	15000000	0	0	0	-200000	0	0	0	0
TELPU+0130	50000	20000000	3000000	0	15000000	150000	0	0	3000000	0	400000	0	0	0	0
TELCA-0610	0	0	0	15000000	0	0	15000000	-2000000	0	0	400000	0	0	-10000000	0
DNBCA-0260	0	-90000000	0	-10000000	0	0	-3000000	-2000000	0	0	0	0	0	0	0
DNBPU+0520	0	0	0	0	0	0	0	0	5000000	0	0	0	0	0	0
OBXCA+0520	0	0	0	0	0	0	0	-2000000	-6000000	0	-600000	0	0	0	0
OBXPU+0360	0	0	0	10000000	-1500000	-150000	20000000	0	0	0	-600000	0	0	16000000	0
PGSCA+1240	0	0	0	0	1000000	300000	0	-750000	1000000	0	500000	-150000	0	1000000	0
PGSPU-1060	0	0	-400000	0	0	0	0	0	-3000000	0	500000	0	0	-10000000	0

Table A.1. Positions for all portfolios.

B Univariate parametric evaluation

If a portfolio consists of only one equity, the margin may be computed exactly. Let $V_{i,t-1}$ be the amount invested in this equity at day $t-1$. Then, the margin for day $t-1$ is computed as follows

- Compute the α-quantile of the logaritmic returns as

$$q_t = -\frac{1}{2}\sigma_{i,t}^2 + z_{\alpha,\nu}\sqrt{(\nu-2)/\nu}\,\sigma_{i,t}.$$

- Compute the margin MA_{t-1} at day $t-1$ as the p-quantile of the portfolio value as

$$MA_{t-1} = V_{i,t-1}\,\exp(q_t).$$

Here, $z_{\alpha,\nu}$ is the α-quantile of the standard t-distribution with ν degrees of freedom.