Cboe Clear Europe N.V.

Cash Equities and Exchange-Traded Products Margin Model Description

(ClearisQ)

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1. Introduction

This document contains a description of Cboe Clear Europe's margin model (referred in this document as the "**ClearisQ**" model) and associated margin add-ons relevant to the clearing of cash equities and exchange-traded products[1] ("**ETP**s")[2].

The margin methodologies described in this document are designed to meet the requirements set out under European Market Infrastructure Regulation ("**EMIR**"), and EMIR Regulatory Technical Standards ("**EMIR RTS**").

ClearisQ calculates core initial margin requirements using a Filtered Historical Simulation ("**FHS**") methodology, based on an Expected Shortfall ("**ES**") tail measure at a confidence level of 99% and a lookback period of 700 business days. The FHS model is supplemented by a Stressed Historical Simulation ("**StressHS**") model in accordance with anti-procyclicality ("**APC**") requirements stipulated under EMIR. An APC-compliant margin is then computed as the weighted sum of the FHS and the StressHS components in line with regulatory requirements.

Where applicable, initial margin add-ons are calculated in addition to core IM to cover exposures related to wrong-way risk, liquidity risk, and large stress loss exposures.

Cboe Clear Europe calculates margin requirements on an overnight and intraday basis for every Clearing Participant portfolio containing cash equities and ETPs using the methodologies described in this document.

This document is intended for existing and prospective Clearing Participants, regulators, and internal users.

[1] Exchange-traded products include exchange-traded funds ("ETFs") exchange-traded notes ("ETNs") and exchange-traded commodities/currencies ("ETCs")

[2] A margin model description document relevant to equity derivatives products is available separately.

2. Overview

2.1 Margin requirements

EuroCCO calculates two types of margin requirements:

- Variation Margin ("**VM**") – covers current exposure
- Initial Margin ("**IM**") – cover potential future exposure

VM is defined as the current (unrealised) profit or loss in the portfolio and is calculated as the difference between the current mark-to-market value and the transaction value for all positions in a given portfolio. Cboe Clear Europe collects VM from Clearing Participants to avoid the accumulation of unrealised profit or loss over time and to ensure that Clearing Participants remain current on their outstanding obligations.

IM is defined as the potential future exposure of the portfolio, ie. the potential maximum loss in the portfolio over the assumed liquidation period under normal market conditions. Cboe Clear Europe collects initial margin from Clearing Participants to cover potential losses that may be incurred in the event of a Clearing Participant default.

Cboe Clear Europe calculates a total margin liability for each Clearing Participant portfolio as: min(0 , IM + VM).

In this document, VM losses (profits) are expressed as negative (positive) values, and IM liabilities are expressed as negative values.

This remainder of this document provides a detailed description of the Cboe Clear Europe IM methodology, comprising a core margin model and additional margin add-ons.

2.2 Initial Margin methodology overview

2.2.1 Filtered historical simulation

The core margin model described in this document is based on a Filtered Historical Simulation (**FHS**), Expected Shortfall[3] (**ES**) methodology. This model estimates potential loss based on historical price changes (returns). The margins calculated using this model represent the potential expected loss for a given portfolio based on Cboe Clear Europe's assumed lookback period, liquidation period, and confidence level (see Section 2.3).

The key features of the FHS model are its ability to capture dynamic volatility regime changes and reproduce the joint distribution of returns, without the need to compute the covariance matrix.

The FHS methodology quantifies risk exposure at the portfolio level, ie. allowing for risk offsets between individual instruments where appropriate. The calculation of margin at the portfolio level is subject to a portfolio margin limit rule in accordance with Article 27(4) of the EMIR RTS.

2.2.2 Anti-procyclicality measure

By construction, the margins computed using the FHS model adapt to changing market conditions. While this is desirable from the point of view of efficient capital allocation, it can lead to procyclical behaviour where margin requirements increase significantly during stress periods.

Article 28 of the EMIR RTS sets out requirements for CCPs to limit procyclicality of margin requirements to the extent that the soundness and financial security of the CCP is not negatively affected.

[3] Expected Shortfall is also commonly referred to as Expected Tail Loss (ETL) or Conditional Value-at-Risk (CVaR).

To comply with regulatory requirements, Cboe Clear Europe applies an anti-procyclicality (APC) measure in the form of a stressed historical simulation (**StressHS**) margin (ie. by applying the option set out under Article 28(1)(b) of the EMIR RTS).

The StressHS margin component is based on a historical simulation, expected shortfall methodology, Simulation scenarios are obtained by combining the most recent past returns with a set of defined stressed returns. The margins calculated using this model represent the potential expected loss for a given portfolio based on stressed data observations.

The calculation of StressFHS margin at the portfolio level is also subject to a portfolio margin limit rule in accordance with Article 27(4) of the EMIR RTS.

2.2.3 APC-compliant margin

An APC-compliant margin is then computed as the weighted sum of the FHS and the StressHS components (with the stress-based component having a weight of 25% in line with regulatory requirements).

2.2.4 Margin add-ons

In addition to underlying price volatility risk, Cboe Clear Europe is also exposed to other specific risks which require separate treatment in the form of margin add-ons:

- **Wrong-Way Risk ("WWR") add-on** – reflects the risk due to a Clearing Participant holding long positions on their own stock. This risk originates from the correlation between the default risk and the credit exposure of the member.
- **Liquidity Risk ("LR") add-on** – reflects the risk due to concentrated and/or illiquid positions in a Clearing Participant portfolio. This add-on captures the potential price impact of liquidating such positions in the event of a default.
- **Large Position ("LP") add-on** – reflects the potential excess stress loss in a Clearing Participant portfolio over and above available financial resources. This add-on captures the excess loss exposure taking into account available mutualised Clearing Fund resources under a Cover-2 standard and the Clearing Participant's individual margin collateral posted.
- **Exchange-Traded Note, Commodity or Currency ("ETN/ETC") add-on** – reflects the risk due to a change in the credit-worthiness of the issuer of an ETN or ETC contract that has not been reflected in historical observed price moves.

2.2.5 Total IM requirement

The total IM requirement is the aggregate of the APC-compliant margin plus all the margin add-ons.

2.3 Key model assumptions

2.3.1 Confidence level

Article 24 of the EMIR RTS requires that IM shall be calculated for financial instruments that are not OTC derivatives using a minimum confidence level of 99%.

To ensure compliance with the EMIR requirement, Cboe Clear Europe calculates margin requirements using an ES risk measure at a confidence level of 99%. For a given confidence level, the ES measure is a more conservative approach compared to Value-at-Risk ("**VaR**")[4] – therefore, the ES margin result is never less than VaR for a given confidence level.

[4] Reference to a VaR-based confidence level is implicit in EMIR.

2.3.2 Lookback window

Article 25 of the EMIR RTS requires that IM shall be calculated based on data covering at least the latest 12 months, and that data used shall capture a full range of market conditions including periods of stress.

Cboe Clear Europe satisfies these two requirements by:

- using a lookback window of 700 business days; and
- including 50 stress scenarios for computing the StressHS margin component.

2.3.3 Liquidation period (Margin period of risk)

Article 26 of the EMIR RTS requires that the defined time horizon for the liquidation of open positions shall be at least two business days for financial instruments that are not OTC derivatives.

To allow for additional conservativeness, Cboe Clear Europe assumes a liquidation period (also referred to as margin period of risk or "**MPOR**") of three business days when calculating margin requirements. The computation of the risk over the liquidation period is performed by taking into account possible trending or mean-reverting behaviour of consecutive returns observed over the lookback window.

2.3.4 Portfolio margin limit rule

Article 27(4) of the EMIR RTS requires that, where portfolio margining covers multiple instruments, the amount of margin shall be no greater than 80% of the difference between the sum of the margins for each product calculated on an individual basis (ie. Gross portfolio margin) and the margin calculated based on a combined estimation of the exposure for the combined portfolio (ie. Net portfolio margin).

To ensure compliance with the EMIR requirement, Cboe Clear Europe applies a portfolio margin limit rule at all times for the calculation of portfolio margin which is thus computed as the weighted sum of the gross and net portfolio margin (with the net portfolio margin having a weight of 80% in line with regulatory requirements).

2.4 Key model limitations

2.4.1 Procyclicality

Notwithstanding the mitigating impact of the APC adjustment, it is important to recognise that the Initial Margin methodology, as with any risk-based margin calculation, is sensitive and responsive to the prevailing market environment. As such, the methodology will generate higher margin requirements in times of market stress, at precisely the time that market participants may be subjected to increased market risk losses, increased credit risk or even, in some cases, operational risk arising from new, and unanticipated market conditions. While this, in itself, is a limitation, it must be weighed carefully against the benefits of a risk-sensitive measure, namely:

- coverage: the methodology ensures that margin levels cover the expected loss in observed market stress conditions;
- responsiveness: margin levels adapt automatically in an appropriate way to changing market conditions;
- efficiency: margin levels reduce automatically in times of lower volatility, subject to the dampening effect of the APC measure; and
- transparency: margin levels are determined by the data directly, and independently of any meaningful intervention on a day-to-day basis. Losses for individual scenarios may be investigated and explained.

2.4.2 Reliance on historical market data

As with any historical Value-at-Risk based methodology, the initial margin model uses, as its inputs, an extensive set of historical data points for a substantial range of risk factors. As such, it is limited by both the quality and quantity of this data and is sensitive to both errors and omissions. Cboe Clear Europe addresses this shortcoming by subjecting historical input data to a rigorous quality assessment, and by performing validation of new market data prior to being used in the margin calculation, with a view to capturing and excluding any erroneous data points. Furthermore, the methodology includes a robust proxying logic for addressing cases where data is unavailable, along with an accompanying proxy suppression methodology aimed at safeguarding the robustness of the calculation in the event that a subset of the required inputs are missing for a given day.

2.4.3 Sensitivity to model parameters

The methodology relies on the setting of parameters (see Appendix 1) which affect multiple aspects of the calculation. Although these levels have been determined based on extensive analysis and in line with all applicable regulations and best practice they are also, in a certain sense, arbitrary and could easily be set to different levels, which would produce different initial margin numbers.

2.4.4 Sensitivity to distributional assumptions

Although the Initial Margin methodology generates scenarios using actual observed risk factor returns, and hence avoids making explicit parametric distributional assumptions, it does rely on the assumption that equity prices can be modelled using log-returns, with adjustments for prevailing volatility.

Assumptions of this kind are unavoidable for any methodology in which future returns are modelled based on observed historical returns; however, they do represent a limitation to the model. If the distribution of future returns for a given risk factor were to deviate dramatically from its historical distribution over a short period of time, portfolios could experience losses in excess of those predicted. This is mitigated by the responsive nature of the model, which will pick up, and incorporate, the most severe of such scenarios and retain them indefinitely through the historical stress scenarios, such that future margin calculations will provide protection against a re-occurrence. Furthermore, the hypothetical stress-testing which drives the sizing of the default fund and, by extension, the large position add-on, does incorporate stresses in excess of those observed historically so that these stresses may also be covered.

3. Filtered Historical Simulation

The filtered historical Simulation (FHS) methodology is based on the simulation of the distribution of future returns (scenarios) by sampling the realised past returns, scaled by the ratio of past and most recent volatility estimate. Compared to a standard historical simulation (HS) approach, which directly identifies the scenarios with the past returns and thus assumes that returns are independent and identically distributed (i.i.d.), the FHS directly models the volatility dynamics, without making any distributional parametric assumption. This point is a strong 11dventage as it allows to capture non-trivial statistical properties of return distributions, such as asymmetry (skewness), fat-tails (kurtosis), volatility clustering, and tail dependence.

In this chapter, we describe in detail the computation of IM within the FHS model.

3.1 Data inputs and returns computation

The FHS model relies on the following historical data inputs:

- historical daily closing equity/index prices[5]; and
- historical daily closing FX rates.

Assuming a lookback window of *N* = 700 scenarios and an MPOR of *m* = 3, we require *N* + *m* = 703 historical equity/index prices per instrument time series.

The daily price and FX rate returns are calculated from the historical data inputs over the lookback window. For a given equity/index i, the daily logarithmic returns[6] are calculated as:

$$p_t^i = ln\left(\frac{S_t^i}{S_{t-1}^i}\right) \tag{3.1}$$

where S_t^i is the equity/index price on day t.

Denote the most recent end-of-day (EOD) date as *T*. We construct a matrix of daily log returns where each row *k* contains the returns on day *T*-*k*+1 (in reverse chronological order, starting with the most recent day in row 1 and ending on day *T*-*N**+1) and each column corresponds to instrument *i=1,…,I*.

$$p = \begin{pmatrix} p_T^1 & p_T^i & \cdots & p_T^I \\ p_{T-1}^1 & p_{T-1}^i & \cdots & p_{T-1}^I \\ \vdots & \vdots & \ddots & \vdots \\ p_{T-N^*+1}^1 & p_{T-N^*+1}^i & \cdots & p_{T-N^*+1}^I \end{pmatrix} \tag{3.2}$$

where $N^* = N + m - 1$ denotes the total number of daily returns needed to compute *N* scenarios with MPOR of m.

3.2 Volatility and residuals estimation

The main goal of FHS is to capture the changes in volatility to produce future return scenarios that are consistent with the present level of the volatility. In order to do so, a dynamic volatility model is required. The model described in this section is motivated by the observation that volatility regime changes typically happen on a short time scale compared with the regime duration. Within each regime the shape of the returns distribution is thus rather stable.

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[5] Adjusted to account for corporate actions and dividends.

[6] Logarithmic returns have the advantage of being additive and this property is used later for MPOR scaling and FX adjustment.

The starting assumption of the FHS model is that the returns are well modelled as:

$$p_t^i = \sigma_t^i \varepsilon_t^i \tag{3.3}$$

where ε_t^i are normalised residuals (unit variance) and σ_t^i is the forecast instrument volatility on day t.

The volatilities σ_t^i are estimated from the historical returns (3.2) using an Exponentially Weighted Moving Average (EWMA) model[7] with a decay factor λ = 0.99, namely:

$$\left(\hat{\sigma}_t^i\right)^2 = \lambda\left(\hat{\sigma}_{t-1}^i\right)^2 + (1-\lambda)\left(p_{t-1}^i\right)^2 \quad , \quad t \geq 2 \tag{3.4}$$

The normalised residuals are then estimated as:

$$\hat{\varepsilon}_t^i = \begin{cases} sign\left(\frac{p_t^i}{\hat{\sigma}_t^i}\right).min\left(\left|\frac{p_t^i}{\hat{\sigma}_t^i}\right|, C\right) & \text{if } \hat{\sigma}_t^i \neq 0 \text{ (general case)} \\ \frac{p_t^i}{\hat{\sigma}_{t+1}^i} & \text{if } \hat{\sigma}_t^i = 0 \text{ and } \hat{\sigma}_{t+1}^i \neq 0 \text{ (first } p_t^i \neq 0 \text{ after stale price)} \\ 0 & \text{if } \hat{\sigma}_{t+1}^i = 0 \text{ (stale prices)} \end{cases} \tag{3.5}$$

where C=30 is a constant factor used as a cap to handle extreme return outliers (such as the CHF depegging event[8]. The two latter formulae handle the edge case of singular residuals: this can only happen when returns are exactly equal to zero over the whole period before t (e.g. stale prices). In the general case, a single non-zero return anywhere in the past guarantees non-zero volatility estimates by property of the EWMA.

Repeating the calculations (3.4) and (3.5) for all rows of the matrix (3.2) gives the following matrix of normalised residuals:

$$\hat{\varepsilon} = \begin{pmatrix} \hat{\varepsilon}_T^1 & \hat{\varepsilon}_T^i & \cdots & \hat{\varepsilon}_T^I \\ \hat{\varepsilon}_{T-1}^1 & \hat{\varepsilon}_{T-1}^i & \cdots & \hat{\varepsilon}_{T-1}^I \\ \vdots & \vdots & \ddots & \vdots \\ \hat{\varepsilon}_{T-N^*+1}^1 & \hat{\varepsilon}_{T-N^*+1}^i & \cdots & \hat{\varepsilon}_{T-N^*+1}^I \end{pmatrix} \tag{3.6}$$

The estimation of the volatilities according to Eq. (3.4) requires the specification of initial volatility seeds σ_1^i. In order to assess the relative importance of choosing a given seed value it is useful to inspect the solution of Eq. (3.4), which can be written as:

$$\left(\sigma_t^i\right)^2 = (1-\lambda)\sum_{n=1}^{t-1} e^{-n/\psi}\left(\hat{p}_{t-n}^i\right)^2 + e^{-(t-1)/\psi}\left(\sigma_1^i\right)^2 \quad , \quad t \geq 2 \tag{3.7}$$

In Eq. (3.7), the parameter λ defines a time scale ψ = −1/ ln(λ), characterising the exponential decay of the weights given to past observations. For example, for λ = 0.99, ψ ~ 100 days, while for λ = 0.97, ψ ~ 33 days. The contribution of the seed value in the volatility estimate as $t \gg \psi$ becomes negligible.

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[7] In the literature, the EWMA model is sometimes defined as $\left(\hat{\sigma}_t^i\right)^2 = \lambda\left(\hat{\sigma}_{t-1}^i\right)^2 + (1-\lambda)\left(p_t^i\right)^2$. This convention differs from the one used here in the interpretation of the volatility estimate: with this alternative convention $\hat{\sigma}_t^i$ is the estimate made on day t for day $t+1$. In contrast with the convention used in this document, $\hat{\sigma}_t^i$ denotes the estimate made on day $t-1$ for day t.

[8] In January 2015, the Swiss National Bank unexpectedly removed the peg on the EUR/CHF exchange rate resulting in an extremely large one-day rate move. As a consequence, the uncapped residual estimate on that date deviates significantly from unit variance.

We compute σ_1^2 as the average of the squared returns over the first 200 days at the start of the historical data period commencing 1st January 2003 (sufficiently far back to allow for convergence over time) and propagate the recursion from there on. The seed period of 200 days corresponds approximately to twice the characteristic period of the EWMA for λ = 0.99 and therefore appropriately reflects the time scale of the volatility process.

3.3 Scenario generation

Once determined, the normalised residuals can be used to generate a set of hypothetical *m*-day return scenarios for a defined number of scenarios N (where *m* = 3 and N = 700).

To obtain *m*-day return scenarios, we sum 1-day residuals over *m* consecutive days in order to capture possible auto-correlations, ie. Trending or mean-reverting behaviours. The sums of residuals are then multiplied by the last available volatility, which under the EWMA volatility process assumption, is the one-day ahead forecast volatility. Note that the summation across residuals requires the use of logarithmic returns.

The MPOR-scaled hypothetical return scenario for instrument *I* and scenario *k* is calculated as:

$$\hat{r}_k^i = \hat{\sigma}_{T+1}^i \sum_{j=0}^{m-1} \hat{\varepsilon}_{T-k+1-j}^i \tag{3.8}$$

In matrix notation, the MPOR-scaled hypothetical returns are represented as:

$$\hat{r} = \begin{pmatrix} \hat{r}_1^1 & \hat{r}_1^i & \dots & \hat{r}_1^I \\ \hat{r}_k^1 & \hat{r}_k^i & \dots & \hat{r}_k^I \\ \vdots & \vdots & \ddots & \vdots \\ \hat{r}_N^1 & \hat{r}_N^i & \cdots & \hat{r}_N^I \end{pmatrix} \tag{3.9}$$

Each column of (3.9) represents a set 700 scenarios of hypothetical 3-day returns for instrument *i* .

Scenarios for *m* consecutive days are calculated from sets of consecutive residuals hence capturing possible auto-correlations, ie. trending or mean-reverting behaviours.

3.4 FX treatment

For products denominated in a currency different from the portfolio base currency (ie. EUR), simulations of the relevant currency pairs are also required. The latter can be obtained by modelling the foreign exchange (FX) spot rate return p_t^{fx} for currency pair *fx* as:

$$p_t^{fx} = \sigma_t^{fx} \varepsilon_t^{fx} \tag{3.10}$$

The MPOR-scaled hypothetical return scenario for currency pair *fx* and scenario *k* is then calculated in the same manner as described in Sections 3.2 and 3.3, with instrument *i* being replaced with currency pair *fx*.

The FX scenarios are used to convert the corresponding return scenarios of equity *i* to the portfolio base currency as:

$$\hat{r}_k^{i,base} = \hat{r}_k^{i,term} - \hat{r}_k^{fx} \tag{3.11}$$

where *base* denotes the portfolio base currency (ie. EUR), and *term* denotes the currency of the product *i*, and the FX rate is quoted in the form base/term (where 1 unit of base currency buys the quoted amount of term currency). Note that for logarithmic returns Eq. (3.11) is exact, while it holds only up to first order for arithmetic returns.

In matrix notation, the MPOR-scaled, FX-adjusted, hypothetical returns are represented as:

$$\hat{r}^{base} = \begin{pmatrix} \hat{r}_1^{1,base} & \hat{r}_1^{i,base} & \dots & \hat{r}_1^{I,base} \\ \hat{r}_k^{1,base} & \hat{r}_k^{i,base} & \dots & \hat{r}_k^{I,base} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{r}_N^{1,base} & \hat{r}_N^{i,base} & \dots & \hat{r}_N^{I,base} \end{pmatrix} \tag{3.12}$$

Each column of (3.12) represents a set 700 scenarios of hypothetical FX-adjusted 3-day returns for instrument *i* .

3.5 P&L scenarios

Given the array of portfolio positions:

$$v = \begin{pmatrix} v^{1,base} \\ v^{i,base} \\ \vdots \\ v^{I,base} \end{pmatrix} \tag{3.13}$$

where v_i is the market value (ie. number of shares times EOD price in base currency on day *T*) of the portfolio position on instrument *i*, we define the weighted portfolio P&L scenarios matrix as:

$$w^{FHS} = \begin{pmatrix} v^{1,base}(\exp(\hat{r}_1^{1,base}) - 1) & v^{i,base}(\exp(\hat{r}_1^{i,base}) - 1) & \dots & v^{I,base}(\exp(\hat{r}_1^{I,base}) - 1) \\ v^{1,base}(\exp(\hat{r}_k^{1,base}) - 1) & v^{i,base}(\exp(\hat{r}_k^{i,base}) - 1) & \dots & v^{I,base}(\exp(\hat{r}_k^{I,base}) - 1) \\ \vdots & \vdots & \ddots & \vdots \\ v^{1,base}(\exp(\hat{r}_N^{1,base}) - 1) & v^{i,base}(\exp(\hat{r}_N^{i,base}) - 1) & \cdots & v^{I,base}(\exp(\hat{r}_N^{I,base}) - 1) \end{pmatrix} \tag{3.14}$$

The columns of w are the simulated P&L scenarios for the instruments in the portfolio.

3.6 Margin calculation

3.6.1 Expected Shortfall risk measure

Margin requirements are obtained by calculating an ES risk measure for the portfolio based on the simulated P&L scenarios in matrix w.

Given a random vector of portfolio P&L or return scenarios $\vec{x} = (x_1, \dots, x_N)$, the ES risk measure with confidence level α is estimated as follows[9]:

1. Sort $\vec{x}$ in ascending order, where $x_{\pi,i} \leq x_{\pi,i+1}$:

$$\vec{x}_\pi = \begin{pmatrix} x_{\pi,1} \\ x_{\pi,2} \\ \vdots \\ x_{\pi,N} \end{pmatrix} \tag{3.15}$$

2. Compute $N_\alpha = \lfloor N(1-\alpha) \rfloor$ where $\lfloor y \rfloor$ is the closest integer smaller or equal to y. For example, if $\alpha = 99\%$ then $N_\alpha = 7$ (for $N = 700$).

The ES (or conditional value-at-risk) is then estimated as:

[9] Note that flooring to the closest integer is more conservative than applying interpolation to estimate the empirical quantile.

3.

$$ES_\alpha = \frac{1}{N_\alpha}\sum_{n=1}^{N_\alpha} x_{\pi,n} \tag{3.16}$$

3.6.2 Portfolio margin limit rule

The initial margin for a given portfolio is subject to a portfolio margin limit rule in accordance with Article 27(4) of the EMIR RTS.

Accordingly, the portfolio IM is calculated as a weighted sum of the gross and net portfolio margins:

$$IM^{FHS} = (1-c)IM_{gross}^{FHS} + c.IM_{net}^{FHS} \tag{3.17}$$

where $c = 0.8$, and IM is expressed as a negative value. Note that the sub-additivity property of the ES tail measure guarantees that $IM_{net}^{FHS} > IM_{gross}^{FHS}$.

The gross portfolio margin IM_{gross}^{FHS} is the sum of the individual instrument margins:

$$IM_{gross}^{FHS} = \sum_{i=1}^{I} f\,(w_i) \tag{3.18}$$

and the net portfolio margin IM_{net}^{FHS} is the margin of the netter portfolio including the effect of diversification:

$$IM_{gross}^{FHS} = f\left(\sum_{i=1}^{I} w_i\right) \tag{3.19}$$

where f denotes the ES function described in Section 3.6.1.

4. Anti-Procyclicality Measure

Article 28 of the EMIR RTS sets out requirements for CCPs to limit procyclicality of margin requirements to the extent that the soundness and financial security of the CCP is not negatively affected.

To comply with regulatory requirements, Cboe Clear Europe applies an anti-procyclicality (APC) measure in the form of a stressed historical simulation (StressHS) margin which aims at reducing the procyclicality of the stand-alone FHS IM (ie. by applying the option set out under Article 28(1)(b) of the EMIR RTS).

An APC-compliant margin is then computed as a weighted sum of the FHS and the StressHS margins.

In this chapter, we describe in detail the computation of the StressHS margin component and resultant APC-compliant margin.

4.1 StressHS margin

The StressHS margin component is based on a historical simulation, expected shortfall methodology, Simulation scenarios are obtained by combining the most recent past returns with a set of defined stressed returns. The margins calculated using this model represent the potential expected loss for a given portfolio based on stressed data observations.

The incorporation of a stable margin component derived from historical periods of stress provides for a conservative margin estimate that is less sensitive to the current dynamics of market volatility. As a result, margin requirements are more conservative during low volatility periods and more stable during high volatility periods.

4.1.1 Data inputs, returns, and scenario generation

The StressHS computations are based on a combination of historical stress returns and recent historical price returns, which together form the set of simulated return scenarios.

The relevant historical stress returns correspond to the Cboe Clear Europe stress testing scenario dates which are defined by Cboe Clear Europe as part of its overall stress testing framework; the selection and review of these stress scenarios is performed on a periodic basis and is subject to internal risk management and regulatory governance. Currently, Cboe Clear Europe's stress testing scenario suite contains 50 historical stress scenarios covering all relevant markets that Cboe Clear Europe clears.

The 50 historical stress returns are complemented by the $(N-50)$ most recent 3-day unscaled returns in the lookback period to form a total of N unscaled return scenarios. The total length of the simulation window is $N=700$ scenarios[10], and therefore the most recent 650 unscaled scenarios are included[11].

In accordance with ESMA regulatory guidelines, the StressHS margin component is based on unscaled (unfiltered) historical returns, and therefore the EWMA normalisation process described in Section 3.2 is not used for the generation of StressHS return scenarios.

The historical daily log returns described in Section 3.1 can be used to directly generate a set of unscaled *m*-day return scenarios for the required number of recent lookback scenarios $N-50$ (ie. 700–- 50 = 650). Similar to the process described in Section 3.3, we obtain unscaled 3-day return scenarios by summing 1-day log price returns over 3 consecutive days for instrument *i* and scenario *k* as follows (where *m* = 3):

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[10] The inclusion of 50 stress scenarios in the total simulation window of 700 scenarios is therefore sufficient to cover the tail of the distribution at the chosen confidence level (99%).

[11] Without duplication of scenarios, ie. where a scenario in the $(N-50)$ lookback period corresponds with a stress scenario, it is treated as an invalid scenario for the purposes of scenario generation.

$$\hat{r}_k^{SHS,i} = \sum_{j=0}^{m-1} p_{T-k+1-j}^{i} \tag{4.1}$$

Similarly for each stress period, 3-day returns are computed by summing the three overlapping logarithmic one-day returns over that period.

FX risk is handled as in Section 3.4, where the FX scenarios are used to convert the corresponding unscaled return scenarios of equity *i* to the portfolio base currency as:

$$\hat{r}_k^{SHS,i,base} = \hat{r}_k^{SHS,i,term} - \hat{r}_k^{SHS,fx} \tag{4.2}$$

where *base* denotes the portfolio base currency (ie. EUR), and *term* denotes the currency of the product *i*, and the FX rate is quoted in the form base/term (where 1 unit of base currency buys the quoted amount of term currency).

In matrix notation, the final scenarios are simply the MPOR-scaled and FX-rebased historical returns, represented as:

$$\hat{r}^{SHS,base} = \begin{pmatrix} \hat{r}_1^{SHS,1,base} & \hat{r}_1^{SHS,i,base} & \dots & \hat{r}_1^{SHS,I,base} \\ \hat{r}_k^{SHS,1,base} & \hat{r}_k^{SHS,i,base} & \dots & \hat{r}_k^{SHS,I,base} \\ \vdots & \vdots & \ddots & \vdots \\ \hat{r}_N^{SHS,1,base} & \hat{r}_N^{SHS,i,base} & \cdots & \hat{r}_N^{SHS,I,base} \end{pmatrix} \tag{4.3}$$

Each column of matrix (4.3) represents a set of *N*=700 unscaled 3-day return scenarios for instrument *i* , made up of the most recent 650 return scenarios (*k* = 1,…,650) and 50 stress scenarios (*k* = 651,…,700).

4.1.2 P&L scenarios

Given the current instrument market values $v^{1,base}$, the portfolio P&L matrix is calculated as in Section 3.5, represented as:

$$w^{SHS} = \begin{pmatrix} v^{1,base}(\exp(\hat{r}_1^{SHS,1,base}) - 1) & v^{i,base}(\exp(\hat{r}_1^{SHS,i,base}) - 1) & \dots & v^{I,base}(\exp(\hat{r}_1^{SHS,I,base}) - 1) \\ v^{1,base}(\exp(\hat{r}_k^{SHS,1,base}) - 1) & v^{i,base}(\exp(\hat{r}_k^{SHS,i,base}) - 1) & \dots & v^{I,base}(\exp(\hat{r}_k^{SHS,I,base}) - 1) \\ \vdots & \vdots & \ddots & \vdots \\ v^{1,base}(\exp(\hat{r}_N^{SHS,1,base}) - 1) & v^{i,base}(\exp(\hat{r}_N^{SHS,i,base}) - 1) & \cdots & v^{I,base}(\exp(\hat{r}_N^{SHS,I,base}) - 1) \end{pmatrix} \tag{4.4}$$

The columns of w^{SHS} are the simulated P&L scenarios for the instruments in the portfolio that will be used for the StressHS margin computation.

4.1.3 Margin calculation

Finally, the StressHS margin, IM^{SHS}, is computed similarly to Section 3.6, where the gross and net portfolio margin estimates are obtained by calculating ES risk measures for the portfolio based on the simulated P&L scenarios in matrix w^{SHS}, and the portfolio IM is calculated as a weighted sum of the gross and net portfolio margins in accordance with the portfolio margin limit rule.

Accordingly, the portfolio IM is calculated as a weighted sum of the gross and net portfolio margins:

$$IM^{SHS} = (1-c)IM_{gross}^{SHS} + c.IM_{net}^{SHS} \tag{4.5}$$

where,

$$IM_{gross}^{SHS} = \sum_{i=1}^{I} f\left(w_i^{SHS}\right) \tag{4.6}$$

$$IM_{gross}^{SHS} = f\left(\sum_{i=1}^{I} w_i^{SHS}\right) \tag{4.7}$$

and where again c = 0.8, f denotes the ES function described in Section 3.6.1, and IM is expressed as a negative value.

4.2 APC-compliant margin

Once the StressHS margin component has been calculated as per Eq. (4.5), it is combined with the FHS margin calculated as per Eq. (3.17) to produce the final APC-compliant margin in accordance with Article 28(1) of the EMIR RTS:

$$IM_{unfloored}^{APC} = (1-\eta)IM^{FHS} + \eta.IM^{SHS} \tag{4.8}$$

where η = 0.25.

This unfloored APC margin is then subject to a floor at the IM^{FHS}. This step is undertaken to ensure that, during times of heightened market volatility, the combined margin will never drop below the level of the unadjusted IM^{FHS}.

$$IM_{floored}^{APC} = \max\left(IM^{FHS}, IM_{unfloored}^{APC}\right) \tag{4.9}$$

5. Margin add-ons

In addition to underlying price volatility risk, Cboe Clear Europe is also exposed to other specific risks which require separate treatment in the form of margin add-ons. The following margin add-ons are applied by Cboe Clear Europe and included in the total initial margin requirement:

- Wrong-Way Risk (WWR) add-on
- Liquidity Risk (LR) add-on
- Large Position (LP) add-on

In this chapter, we describe the methodology for calculating the above margin add-ons.

5.1 Wrong-way risk (WWR) add-on

The WWR add-on addresses the specific wrong-way risk arising when a Clearing Participant holds one or more unsettled long positions in either:

i) its own stocks or those of an institution belonging to the same financial group or,

ii) ETNs/ETCs that it has issued, or that have been issued by an institution belonging to the same financial group or,

iii) ETNs that reference the Clearing Participant, or an institution belonging to the same financial group[12].

In any such case, the position is excluded from the standard margin computation and a 100% fixed margin is applied on the position reflecting the fact that, in case of Clearing Participant default, the position value will fall to zero. Thus in absolute terms, the WWR add-on for instrument *i* is computed as:

$$WWR_i \ = -v_i \tag{5.1}$$

where v_i denotes the last mark-to-market value of the position on instrument *i*.

For a given Clearing Participant, the portfolio WWR add-on is the sum of all instrument WWR add-ons:

$$WWR_{portfolio} = \sum_{i=1}^{I} WWR_i \tag{5.2}$$

5.2 Liquidity Risk (LR) add-on

The LR add-on addresses the specific risk due to concentrated and/or illiquid positions in a Clearing Participant portfolio. This add-on captures the potential price impact of liquidating such positions in the event of a Clearing Participant default.

In the core IM calculation, it is assumed that all positions can be liquidated within three trading days and that the liquidation of any position does not result in any additional price impact. It is possible that there will be occasions where this assumption will not hold, especially in cases where a position is large compared to the traded volume in the market. In such cases, liquidation of large and/or illiquid positions may incur additional

[12] The Wrong-Way Risk add-on only addresses cases where an ETN references the relevant institution in isolation. A small amount of wrong-way risk will also arise in cases where a Clearing Participant holds an unsettled long position in an ETN that references an index containing the Clearing Participant, or an institution within the same financial group. Given the low levels of WWR introduced by such products, this risk is deemed to be acceptable in the context of the conservatism of the methodology as a whole.

costs[13] beyond those captured in the standard margin computations, which address underlying price volatility risk only.

The LR add-on calculation requires the following additional time-series for each instrument *i*:

- the percentage bid-ask spread defined as:

$$Sp_{i,t} = \frac{Ask_{i,t} - Bid_{i,t}}{0.5\left(Ask_{i,t} + Bid_{i,t}\right)} \tag{5.3}$$

- the daily traded volume[14] denoted as $V_{i,t}$.

For a given calculation date, the LR add-on for instrument *i*, is computed as:

$$LR_i \;\; = -|v_i| \times \left(0.5\overline{Sp_i} + \gamma_i \sigma_i \sqrt{\frac{|Q|_i}{\overline{V_i}}} \right) \tag{5.4}$$

where,

- v_i is the last mark-to-market value of the position on instrument *i*,
- $\overline{Sp_i}$ is the arithmetic average bid-ask spread computed over the last 250 observations of SP_i,
- Q_i is the position size to be liquidated on instrument *i*,,
- $\overline{V_i}$ is the average daily traded volume computed over the last 250 observations of V_i,
- σ_i is the most recent EWMA volatility computed on instrument *i*, and
- γ_i is a coefficient measuring market impact, with default value equal to 1.

For each member and for each instrument, position size Q_i is determined aggregating positions across all accounts so that long and short positions are allowed to offset each other. Note that aggregation is not performed across custodian domiciles nor currencies to account for custodian charge risk and FX risk. In the case of a long and a short position held through different custodians, this means that the LR add-ons are calculated for each position separately.

The first part of the LR add-on accounts for the exogenous liquidity component, which does not depend on the position size and covers half of the typical bid-ask spread to reflect the use of mid-prices in the margin computations.

The second part of the LR add-on accounts for the endogenous liquidity component, which considers the market impact of liquidating the position given the position size[15]. As the position to be liquidated gets larger, it will incur additional costs.

In cases where data inputs are missing:

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[13] Potential fees associated with transferring fungible equities between different custodians for netting purposes (rather than trading out directly) are implicitly covered by the LR add-on since the custodian fee is never greater than the cost of directly trading out of a position.

[14] Where required, the primary listing of the instrument is used to avoid underestimating the instrument liquidity.

[15] The shape of the market impact function has been widely investigated in the literature and the square-root form with γ_i = 1 adopted in Eq. (5.4) has been shown to perform well with respect to observable trading data. Commercial applications using the square-root form of the market impact include for instance Barra and Bloomberg.

- If an observation $SP_{i,t}$ (or $V_{i,t}$) is not available, the missing value is set equal to the last available rolling average $SP_{i,t-1}$ (or $V_{i,t-1}$).
- Where observations of $SP_{i,t}$ are not available at the start of the observation window, the spread time series is pre-filled with conservative default values, Sp_i^*, set to 5% in order to start the rolling average calculation (typical bid-ask quotes for large caps are in the range of few percentage basis points).
- Similarly, where observations of $V_{i,t}$ are not available at the start of the observation window, the volume time series is pre-filled with conservative default values Q_i/π, where π = 0.2. This implies that on the first trading day, $Q_i/V_i = \pi$. In other words, it is assumed that any position in an IPO stock constitutes a fraction π of the unknown tradeable volume[16]. This assumption fades out progressively as actual volume data are observed. For new IPOs, the volumes over the first week of trading are discarded as these are not representative of the standard market trading activity.

For a given Clearing Participant, the portfolio LR add-on is the sum of all instrument LR add-ons:

$$LR_{portfolio} = \sum_{i=1}^{I} LR_i \tag{5.5}$$

5.3 Large Position (LP) add-on

The LP add-on reflects the potential excess stress loss in a Clearing Participant portfolio over and above available financial resources. This add-on captures the excess loss exposure taking into account available resources in the cash equities/ETP segment of the mutualised Clearing Fund (under a Cover-2 standard) and the Clearing Participant's individual margin collateral posted.

For a given Clearing Participant, the portfolio LP add-on is calculated as follows:

$$LP_{portfolio} = min[0, MaxSTL - TM + \varsigma_i . DF] \tag{5.6}$$

where,

- $MaxSTL$ is the maximum cash equities/ETP-related stress loss observed for the Clearing Participant (expressed as a negative value).
- TM is the total cash equities/ETP-related margin requirement including WWR for the Clearing Participant (expressed as a negative value).
- DF is total size of the cash equities/ETP segment of the Cboe Clear Europe Clearing Fund.
- ς_i is defined by Clearing Participant, with a maximum (default) value of 0.45.

The LR add-on has been removed from the total margin requirement to ensure that this figure is comparable with the stress scenarios, which deal exclusively with market risk.

5.4 Exchange-Traded Note, Commodity or Currency (ETN/ETC) add-on

An Exchange-Traded Note ("ETN") or Exchange-Traded Commodity/Currency ("ETC") is a type of unsecured debt security that is designed to track one or more underlying indices, assets, commodities or currencies (hereafter referred to as the "underlier"). The IM methodology will capture any risk associated with these products that arises due to the price of the underlier, because these will be reflected in the historical price moves of the ETN/ETC contract. The ETN/ETC add-on addresses the additional loss that could arise due to a sudden decline in, or increase in, the credit-worthiness of the ETN/ETC issuer. In the case of such a move, it is

[16] In practice, trades larger than 10% of the daily volume are rarely observed for large- and mid-caps.

possible that the price of an ETN/ETC will fluctuate more than the levels that can be predicted by looking at the historical time-series of that ETN/ETC in isolation. The potential magnitude of a move such as this can be estimated by assessing the move in price of a zero-coupon bond with a maturity date of 1 week. This maturity is used because it corresponds to the typical redemption period of an ETN/ETC contract. The add-on is calculated as follows:

$$ETN/ETC_{portfolio} = \sum_{v_{ETN/ETC,i}>0} v_{ETN/ETC,i} \cdot \vartheta_{long} - \sum_{v_{ETN/ETC,i}<0} v_{ETN/ETC,i} \cdot \vartheta_{short} \tag{5.7}$$

where,

- $v_{ETN/ETC,i}$ is the last mark-to-market value of the position on ETN/ETC instrument *i*
- ϑ_{long} is the long ETN/ETC issuer risk factor add-on
- ϑ_{short} is the short ETN/ETC issuer risk factor add-on

The long ETN/ETC issuer risk factor is calibrated to reflect the expected drop in the price resulting from a sudden decline in the credit-worthiness of the ETN/ETC issuer from highly credit-worthy to a distressed level. The short ETN/ETC risk factor add-on is calibrated to reflect the expected increase in price resulting from a recovery in credit-worthiness from a distressed level to highly credit-worthy. The short ETN/ETC issuer add-on is typically smaller than the long ETN/ETC issuer add-on to reflect the fact that recoveries in credit-worthiness are generally smaller and less frequent than declines in credit-worthiness.

6. Treatment of missing data

The FHS methodology requires a complete series of returns for each instrument. It may happen, however, that valid prices are unavailable on otherwise valid trading days. The following section describes the methodology adopted to address this situation. The approach addresses two aspects:

1. Missing or stale prices within a time series,
2. Missing prices at the beginning of a time series.

6.1 Forward filling prices and EWMA volatilities

Missing prices are filled forward from the last valid price. Note that as the number of consecutive missing returns increases, this approach will result in a series of zeros returns followed, most likely, by a set of (mpor-1) large returns, corresponding to a longer time horizon. For this reason, if an instrument has several periods of missing prices, this instrument will have several periods of zero returns, each with a small number of large returns. For the purposes of the initial margin calculation, these zero returns will be ignored, and the large returns will drive the P&L simulation in the margin calculation. This approach is therefore conservative and reflects an observed property of the instrument timeseries.

The forward-filling approach requires an ad-hoc adjustment to the EWMA computation. A recent prolonged series of filled zero returns will result in a lower EWMA estimate and, consequentially, lower FHS-CVaR margins. To address this issue, the EWMA process is modified in the case of zero returns as follows:

$$\sigma_t^i = \begin{cases} \sigma_{t-1}^i, \text{ if } p_{t_1}^i = 0 \\ \sqrt{\lambda\left(\sigma_{t-1}^i\right)^2 + (1-\lambda)\left(p_{t-1}^i\right)^2}, \text{ else.} \end{cases} \tag{6.1}$$

In practice, when prices are missing, the last available EWMA estimate of the instrument is re-used.

6.2 Proxy methodology for missing initial returns

If an instrument does not have valid prices at the beginning of the extended lookback window (i.e., over the last $N + N_0$ days) and/or for stress dates (e.g., in the case of an IPO) we cannot directly compute the returns necessary for the FHS-CVaR and StressHS-CVaR margin calculations.

Because no previous information for the instrument is available, the methodology must rely on proxying. The proxy instrument is chosen as an equity index determined by the domicile and sector of the proxied equity. The choice of using domicile and sector indexes balances out the needs of having a tractable set of proxies, an extended coverage and a clear mapping between instruments and proxies. Indexes are, by construction, less volatile than individual securities. For this reason, a scaling coefficient (ϕ) is applied to returns that are proxied in this manner. For an instrument X with associated proxy index Q, a missing return at time t is proxied according to:

$$p_t^X = \beta\phi p_t^Q \tag{6.2}$$

Here $\beta \in \{-1,1\}$ is the sign of the correlation between X and I[17], i.e. β = 1 if Corr$\left(p_t^X, p_t^Q\right)$> 0 and β = -1 if Corr$\left(p_t^X, p_t^Q\right)$< 0, where Corr denotes the Pearson correlation. In order to limit the estimation errors, a minimum of n_β = 20 valid returns are required to compute β. If these returns are unavailable, a configurable value is used instead. The proxy scaling factor ϕ in Eq. (6.2), which can be interpreted as the ratio of the instrument and index volatilities, determines the initial margin level and is calibrated via backtesting. As soon as instrument returns become available, they are used in the normal way to estimate future volatilities. For this reason, the scaling factor ϕ has only a transient effect on the EWMA and the margin. the calculation of which converges on the normal estimate on a time scale of $\propto -1/\ln(\lambda)$ as measured in terms of observation days, as seen in Fig. 6.1.

6.2.1 Margin offsets

When several instruments within a portfolio fall back to the same proxy and have missing data on a common set of dates, particular care must be taken to avoid excessive margin offset benefits generated due to perfectly correlated proxied returns. Overstated correlations such as these can lead to the underestimation of risk and margin when performing aggregation for long-short portfolios. To address this problem, a coefficient $\gamma \in [0,1]$, is used to limit the margin offset benefits. This coefficient is applied prior to aggregation of all P&L scenarios $v^{i,base}\left(exp\left(\hat{r}_k^{FHS,i,base}\right) - 1\right)$ or $v^{i,base}\left(exp\left(\hat{r}_k^{SHS,i,base}\right) - 1\right)$ (see Eqs. (3.14) and (4.4)) that satisfy the following two conditions:

1. The P&L scenario is proxied.
2. The P&L scenario is positive, i.e. $v^{i,base}\left(exp\left(\hat{r}_k^{FHS,i,base}\right) - 1\right) > 0$ in the case of FHS scenarios or, in the case of stress scenario $v^{i,base}\left(exp\left(\hat{r}_k^{SHS,i,base}\right) - 1\right) > 0$.

If conditions 1 and 2 are met, then the substitution $v^{i,base}exp\left(\hat{r}_k^{FHS,i,base}\right) \rightarrow \gamma v^{i,base}exp\left(\hat{r}_k^{FHS,i,base}\right) > 0$ or $v^{i,base}exp\left(\hat{r}_k^{SHS,i,base}\right) \rightarrow \gamma v^{i,base}exp\left(\hat{r}_k^{SHS,i,base}\right)$ is made. Consequently, the number of gains allowed from proxied instruments is determined by γ. For example, setting $\gamma = 0$ would result in no margin offset being generated by proxied returns. Alternatively, setting $\gamma = 1$ would result in the full margin offset being generated by proxied returns. The value of γ is currently set to 0.8, which has been calibrated using sensitivity analysis. Note that the standard netting rule presented in Section 4.1.3 still applies on top of this adjustment, which provides further conservatism.

[17] Negative correlations can occur for example for inverse ETFs with short positions.

Appendix A – Margin model parameters

Table A.1 –Margin model parameters

Parameter	Symbol	Value
Lookback window	N	700 days
EWMA decay factor	λ	0.99
EWMA seed period	-	200 days
Portfolio margin limit coefficient	c	0.8
StressHS margin coefficient	η	0.25
Proxy initial buffer	ϕ	3
Proxy suppression factor	γ	0.8
Residual cap	C	30
Proxy correlation period	n_β	20 days
Long ETN/ETC issuer risk factor	ϑ_{long}	0.01
Short ETN/ETC issuer risk factor	ϑ_{short}	0.005