Looking Beyond SA-CCR

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Federal Reserve Board

Financial Engineering Workshop

Bayes Business School

February 8, 2023

The opinions expressed here are my own, and do not necessarily reflect the views of the *Federal Reserve Board*

Discussion Plan

- SA-CCR and its shortcomings
- Modeling fundamentals of the proposed framework
- Expected exposure and exposure at default
- Examples
  - Interest rate swap
  - Cross-currency swap and foreign exchange forward
  - Foreign exchange options

Papers:

Michael Pykhtin, *Analytical Framework for Counterparty Credit Exposure*,
SSRN working paper: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4121677

Michael Pykhtin, *Looking beyond SA-CCR*, Risk, January 2023

SA-CCR and its shortcomings

Counterparty Credit Exposure in Basel III

- Basel III treats ***counterparty credit risk*** (CCR) under the rules for ***wholesale exposures*** with CCR-specific rules for calculating ***exposure at default*** (EAD)
- A bank can use the ***internal model method*** (IMM) to calculate EAD, subject to supervisory approval
- All banks ***without*** supervisory approval of IMM must use the ***standardized approach for counterparty credit risk*** (SA-CCR) for EAD calculation
- Other applications of SA-CCR would include centrally cleared transactions, leverage ratio, large exposure framework

Exposure at Default (EAD)

- The target **EAD** measure for SA-CCR is the corresponding IMM's measure of ***alpha*** (equal to **1.4**) times ***Effective EPE***
- SA-CCR specifies EAD at a ***netting set*** (NS) level:

$$\mathrm{EAD} = \alpha \cdot \left(\mathrm{RC} + \mathrm{PFE}\right)$$

  - **RC** is ***replacement cost***; **PFE** is ***potential future exposure***
- The RC is defined differently for ***non-margined*** vs. ***margined*** NS

$$\mathrm{RC}_{\text{No Margin}} = \max\left\{V(0),\, 0\right\}$$

$$\mathrm{RC}_{\text{Margin}} = \max\left\{V(0) - \mathrm{VM}(0) - \mathrm{IM}(0),\, H_C, 0\right\}$$

  - H_C is the counterparty VM ***threshold***
- The RC of a ***margined*** NS can be unreasonably high for large H_C
  - This problem is remediated by capping ***margined*** **EAD** by the otherwise equivalent ***non-margined*** **EAD**

Potential Future Exposure (PFE)

- SA-CCR specifies **PFE** as

$$\text{PFE} = A_{\text{NS}} \cdot \text{Multiplier}\left(\frac{V(0) - \text{VM}(0) - \text{IM}(0)}{A_{\text{NS}}}\right)$$

  - A_{NS} is the ***aggregated*** add-on of the NS
  - The ***multiplier*** reduces the value of PFE when $V(0) - \text{VM}(0) - \text{VM}(0) < 0$

$$\text{Multiplier}(x) = \min\left\{0.05 + 0.95 \cdot \exp\left(\frac{x}{1.9}\right); 1\right\}$$

- A_{NS} is obtained via aggregating ***trade-level*** add-ons in the NS

$$A_{\text{NS}} = \left[\sum_{j,k \in \text{NS}} \rho_{jk} \cdot A_j \cdot A_k\right]^{\frac{1}{2}}$$

  - In reality, there is a ***three-step*** aggregation based on this formula: within primary risk factor $\rightarrow$ within hedging set $\rightarrow$ within NS

Trade-Level Add-On

- ***Trade-level*** add-on A_i for contract ***i*** can be represented as

$$A_i = \text{RegSens}_i \cdot \text{RW}_i$$

  - **RegSens$_i$** is the ***sensitivity*** of the market value of contract *i* to the primary risk factor that drives contract *i*, specified by regulators
  - **RW$_i$** is the ***risk weight*** of the primary risk factor of contract *i* that accounts for the risk factor's variability over the appropriate risk horizon
    - The risk horizon is **min{*M$_i$*,1Y}** for ***non-margined*** trades and **MPoR** for ***margined*** trades
- This representation is ***similar*** to the one used in FRTB in the ***sensitivity-based method*** (SbM) for market risk ***except***
  - The representation applies to a ***contract*** rather than a ***risk factor***
  - The sensitivities are supplied by ***regulators*** rather than calculated ***internally***
  - The risk weights connect to ***expected exposure*** measure rather than ***expected shortfall***

Regulatory Sensitivities

- Each regulatory sensitivity is expressed as

$$\text{RegSens}_i = \delta_i \cdot d_i$$

- ***Adjusted notional*** d_i is the regulatory sensitivity of contract i to the primary risk factor that ***ignores***: (i) the contract's ***direction*** (long/short); (ii) possible ***non-linearity***
  - The adjusted notional is specified for each asset class using simplified valuation of most common linear instruments of that asset class

- ***Supervisory delta adjustment*** δ_i specifies the ***direction*** of the contract with respect to the primary risk factor and provides a ***scaling adjustment*** for options and CDO tranches
  - **Options:** the Black-Scholes formulas for delta for European options
  - **CDO tranches:** a formula based on Basel benchmarking exercise

$$\delta_i = \pm \frac{15}{(1+14A_i)\cdot(1+14D_i)}$$

Risk Weights

- For each trade, the ***risk weight*** is expressed as

$$\mathrm{RW}_i = \mathrm{SF}_{k(i)} \cdot \mathrm{MF}_i$$

  - where $k(i)$ means the ***primary risk factor*** for trade i

- ***Supervisory factor*** SF_k is a measure of variability of risk factor k over a standard **1-*year*** horizon
  - It is based on ***expected exposure*** measure produced by a single unit-size trade that is linear in this risk factor and has the current value of zero

- ***Maturity factor*** MF_i scales down (if necessary) the standard ***1-year horizon*** to the ***risk horizon*** appropriate for the trade
  - **Non-margined:** $\mathrm{MF}_i = \sqrt{\min\{M_i;1\}}$, where M_i is the remaining maturity
  - **Margined:** $\mathrm{MF}_i = \dfrac{3}{2}\sqrt{\mathrm{MPoR}_{\mathrm{MA}(i)}}$, where $\mathrm{MPoR}_{\mathrm{MA}(i)}$ is the ***margin period of risk*** of the margin agreement MA(i) that trade i belongs to

Shortcomings of SA-CCR

- ***Regulatory*** sensitivities are used
  - Regulatory sensitivities are not suitable for many products
  - BCBS already uses internal sensitivities in FRTB
- Mapping each trade to a ***single*** "primary" risk factor
  - Most derivatives depend on multiple risk factors
  - SA-CCR cannot handle basis trades
- ***Compressing*** time dimension of exposure at ***trade*** level
  - Exposure can be meaningfully aggregated only for a fixed default time
  - Otherwise, non-economic artifacts are possible
    - **Example:** a short-term trade can perfectly offset a long-term trade
- Crude treatment of VM ***thresholds***
  - H_C is added to margined PFE, while H_B is ignored

Modeling fundamentals of the proposed framework

Inputs

- We are interested in EAD of bank **B** to counterparty **C**
- ***External*** inputs (potentially provided by regulators)
  - A set of standard ***risk factors*** $\{X_k\}$ that span all asset classes
  - For each risk factor k: risk factor ***volatility*** σ_k
  - For each pair of risk factors k and l: ***correlation*** ρ_{kl} between them
- ***Internal*** inputs (provided by **B**)
  - For each trade i: the current ***market value*** $V_i(0)$
  - For each trade i: the remaining ***maturity*** M_i
  - For each trade i: the ***sensitivity*** $s_{ik}(0) \equiv \partial V_i(0)/\partial x_k$ to each risk factor k
  - The schedule of the conventional ***independent amount*** IA(t)
  - The amount of ***initial margin*** IM(0) subject to the ***uncleared margin requirements*** (UMR) that **B** currently holds

Dynamics for Individual Transactions

- **Assumption #1:** ***risk factors*** follow driftless Brownian motions

$$X_k(t) = X_k(0) + \sigma_k w_k(t)$$

  - ***volatility*** for risk factor k is equal to the regulatory volatility σ_k
  - ***correlation*** between w_k and w_l is equal to the regulatory correlation ρ_{kl}

- **Assumption #2:** ***market value*** $V_i(t)$ of trade i at time t is

$$V_i(t) = V_i(0 \mid t) + \sum_k s_{ik}(t)\left[X_k(t) - X_k(0)\right]$$

- Two quantities appear in this specification
  - $V_i(0 \mid t)$ is the expectation of $V_i(t)$ measured today
  - $s_{ik}(t)$ is the sensitivity of $V_i(t)$ to risk factor k measured today

- Both quantities have to be determined from the ***available*** inputs

Forward Projections of Market Values

- Ideally, we would like to set $V_i(0|t)$ equal to the ***forward*** to time t market value of trade i
  - Forward to time t market value is the expectation of $V_i(t)$ under the forward to time t probability measure
- Calculations of forward market values would be ***unfeasible***, so we need an alternative, simpler specification of $V_i(0|t)$
- Primary risk factors are ***prices*** (P) (FX, equity, commodity)

$$V_i^{(P)}(0|t) = 1_{\{t \le M_i\}} V_i^{(P)}(0)$$

- Primary risk factors are ***rates*** or ***spreads*** (R) (IR, credit)

$$V_i^{(R)}(0|t) = \frac{\max\{t, E_i\} - \max\{t, S_i\}}{E_i - S_i} 1_{\{t \le M_i\}} V_i^{(R)}(0)$$

  - S_i and E_i are ***start date*** and ***end date*** of the period referenced by rates

Forward Projections of Sensitivities

- In reality, the dependence of $V_i(t)$ on the risk factors would often be ***non-linear***
  - The future sensitivity $\partial V_i(t) / \partial X_k$ would be ***uncertain*** in such cases
- We define ***deterministic*** sensitivity $s_{ik}(t)$ as the expectation of the future sensitivity

$$s_{ik}(t) \equiv \mathrm{E}\left[\frac{\partial V_i(t)}{\partial X_k(t)} \right]$$

- We divide all ***risk factors*** $\{X_k\}$ into three categories
  - **(P)** representing ***prices*** (FX, equity, commodity)
  - **(R)** representing ***rates*** or ***spreads*** applied to time intervals (IR, credit)
  - **(V)** representing option ***volatilities***

Forward Projections of Sensitivities

- **(P) risk factors:** forward projection is set equal to the spot sensitivity until trade maturity

$$s_{ik}^{(P)}(t) = 1_{\{t \le M_i\}} s_{ik}^{(P)}(0)$$

- **(R) risk factors:** differentiating $V_i(t)$ with respect to a rate referencing period $(t_1, t_2]$ would produce a factor of $t_2 - t_1$ today, or a factor of $\max\{t, t_2\} - \max\{t, t_1\}$ at time t

$$s_{ik}^{(R)}(t) = \frac{\max\{t, t_2\} - \max\{t, t_1\}}{t_2 - t_1} 1_{\{t \le M_i\}} s_{ik}^{(R)}(0)$$

- **(V) risk factors:** calculating the expectation of the future vega sensitivity for a European option results in a linear time decay

$$s_{ik}^{(V)}(t) = \max\left(1 - \frac{t}{T_i}, 0\right) s_{ik}^{(V)}(0)$$

  - T_i can be set to the latest possible option exercise date

Dynamics for Portfolio

- Recall that ***market value*** $V_i(t)$ of trade i at time t is

$$V_i(t) = V_i(0|t) + \sum_k s_{ik}(t)\left[X_k(t) - X_k(0)\right]$$

  – Now we can calculate $V_i(0|t)$ and $s_{ik}(t)$ from the available inputs

- Substituting the dynamics of X_k and summing across all trades:

$$V(t) = V(0|t) + \sum_k s_k(t)\sigma_k w_k(t)$$

- The portfolio-level quantities are defined as follows

  – Market value of the portfolio projected forward to time t

$$V(0|t) \equiv \sum_i V_i(0|t)$$

  – Sensitivity of the portfolio market value projected forward to time t

$$s_k(t) \equiv \sum_i s_{ik}(t)$$

Expected exposure and exposure at default

Exposure

- ***Exposure*** $E(t)$ of **B** to **C** at time t:

$$E(t) = \max\left\{V[t_{\text{co}}(t)] + \text{TF}[t, t_{\text{co}}(t)] - \text{VM}(t) - \text{IM}(t) - \text{IA}(t), 0\right\}$$

  - We assume that **C** defaults at time t, and closeout occurs at time $t_{\text{co}}(t)$
  - We assume that no trade payments are made in time interval $(t, t_{\text{co}}(t)]$
  - $\text{TF}(t, u)$ is the value at time t of all trade flows scheduled for interval $(t, u]$

- Amounts of ***margin*** available to **B** at time t
  - **VM(t):** we model VM based on the portfolio market value and thresholds
  - **IA(t):** the schedule of independent amount is known today
  - **IM(t):** the schedule of initial margin subject to the UMR is unknown
    - we will specify the IM schedule later; for now, we pretend that it is known

- We incorporate $\text{TF}(t, u)$ into the "clean P&L" $\delta\tilde{V}(t,u)$

$$\delta\tilde{V}(t,u) \equiv V(u) - V(t) + \text{TF}(t,u) \approx \sum_k s_k(t)\sigma_k\left[w_k(u) - w_k(t)\right]$$

Specifying Variation Margin

- Assume a generalized two-way **VM *agreement*** between **B** and **C**
  - **VM *thresholds***: $H_C \geq 0$ for **C** and $H_B \leq 0$ for **B**
  - ***Infinite*** threshold for **B** (or **C**) means VM is ***never*** posted by **B** (or **C**)
- ***Exposure*** under different scenarios for the portfolio market value
  - $V(t) > H_C$: **B** is entitled to $\mathrm{VM}(t) = V(t) - H_C > 0$ (**B** receives VM)

$$E(t) = \max\left\{H_C + \delta\tilde{V}[t, t_{\mathrm{co}}(t)] - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$

  - $V(t) < H_B$: **B** is entitled to $\mathrm{VM}(t) = V(t) - H_B < 0$ (**B** posts VM)

$$E(t) = \max\left\{H_B + \delta\tilde{V}[t, t_{\mathrm{co}}(t)] - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$

  - $H_B \leq V(t) \leq H_C$: **B** is entitled to $\mathrm{VM}(t) = 0$ (**B** neither posts nor receives)

$$E(t) = \max\left\{V[t_{\mathrm{co}}(t)] + \mathrm{TF}[t, t_{\mathrm{co}}(t)] - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$

- Note that we assume ***zero*** minimum transfer amount

Specifying Closeout Time

- We specify the ***closeout time*** as follows
  - **B** posts or receives non-zero VM: $t_{\mathrm{co}}(t) = t + \delta$, where δ is the **MPoR**
  - **B** neither posts nor receives VM: $t_{\mathrm{co}}(t) = t$ (instantaneous closeout)
- ***Exposure*** becomes

$$E(t) = 1_{\{V(t)>H_C\}} \max\left\{H_C + \delta\tilde{V}(t,t+\delta) - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$
$$+ 1_{\{V(t)<H_B\}} \max\left\{H_B + \delta\tilde{V}(t,t+\delta) - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$
$$+ 1_{\{H_B \le V(t) \le H_C\}} \max\left\{V(t) - \mathrm{IM}(t) - \mathrm{IA}(t), 0\right\}$$

- We have independent ***normally*** distributed $V(t)$ and $\delta\tilde{V}(t,t+\delta)$:

$$V(t) = V(0\,|\,t) + \sigma(t)\sqrt{t}\,X \qquad \delta\tilde{V}(t,t+\delta) = \sigma(t)\sqrt{\delta}\,Z$$

$$\sigma(t) \equiv \left(\sum_k \sum_l \rho_{kl}\, s_k(t) s_l(t) \sigma_k \sigma_l\right)^{\frac{1}{2}}$$

Expected Exposure

- Calculating the ***expectation*** of exposure results in

$$
\begin{aligned}
\mathrm{EE}(t) = &\left(1-\Phi[d_C^0(t)]\right)\sigma(t)\sqrt{\delta}\left(d_C^1(t)\Phi[d_C^1(t)]+\varphi[d_C^1(t)]\right) \\
&+\Phi[d_B^0(t)]\sigma(t)\sqrt{\delta}\left(d_B^1(t)\Phi[d_B^1(t)]+\varphi[d_B^1(t)]\right) \\
&+\left(V(0\,|\,t)-\mathrm{IM}(t)-\mathrm{IA}(t)\right)\left(\Phi[d_C^0(t)]-\Phi[\max\{d_B^0(t),d_{\mathrm{IA}}^0(t)\}]\right)1_{\{\mathrm{IM}(t)+\mathrm{IA}(t)<H_C\}} \\
&-\sigma(t)\sqrt{t}\left(\varphi[d_C^0(t)]-\varphi[\max\{d_B^0(t),d_{\mathrm{IA}}^0(t)\}]\right)1_{\{\mathrm{IM}(t)+\mathrm{IA}(t)<H_C\}}
\end{aligned}
$$

where

$$
d_{B,C}^0(t) \equiv \frac{H_{B,C}-V(0\,|\,t)}{\sigma(t)\sqrt{t}} \qquad d_{\mathrm{IA}}^0(t) \equiv \frac{\mathrm{IM}(t)+\mathrm{IA}(t)-V(0\,|\,t)}{\sigma(t)\sqrt{t}}
$$

$$
d_{B,C}^1(t) \equiv \frac{H_{B,C}-\mathrm{IM}(t)-\mathrm{IA}(t)}{\sigma(t)\sqrt{\delta}}
$$

Projecting initial margin

- We only know IM subject to the UMR available today (at $t=0$)
- The UMR IM is based on 99th percentile of the "clean P&L"
  - In a Gaussian model, future IM requirement defined as P&L quantile is proportional to the future P&L volatility and is, therefore, deterministic
- We specify IM forward projection via ***scaling*** IM(0) by volatility

$$\mathrm{IM}(t) = \mathrm{IM}(0)\frac{\sigma^{\mathrm{UMR}}(t)}{\sigma^{\mathrm{UMR}}(0)}$$

where

$$\sigma^{\mathrm{UMR}}(u) \equiv \left(\sum_k \sum_l \rho_{kl}\, s_k^{\mathrm{UMR}}(u) s_l^{\mathrm{UMR}}(u) \sigma_k \sigma_l\right)^{\frac{1}{2}}$$

and

$$s_k^{\mathrm{UMR}}(u) \equiv \sum_{i \in \mathrm{UMR}} s_{ik}(t)$$

Exposure at Default

- Regulators may potentially provide a set of time points

$$0 = t_0 < t_1 < \ldots < t_{N-1} < t_N = 1\,\text{year}$$

- For each time point t_n from this set, calculate $\mathrm{EE}(t_n)$
- For each time point t_n from this set, calculate ***effective*** **EE** by applying the ***non-decreasing constraint*** to the EE profile

$$\mathrm{EffEE}(t_0) = \mathrm{EE}(t_0)$$

$$\mathrm{EffEE}(t_n) = \max\left\{\mathrm{EffEE}(t_{n-1}), \mathrm{EE}(t_n)\right\}$$

- Calculate EAD as the ***time average*** of the EffEE profile

$$\mathrm{EAD} = \alpha \sum_{n=1}^{N} \mathrm{EffEE}(t_n)(t_n - t_{n-1})$$

  – If one wants this EAD to be at least as conservative as EAD for the same NS under IMM, the value of α should be no less than the one used in IMM

Examples

Examples

- To illustrate the performance of the proposed framework, we consider several simple examples covering **IR** and **FX** risks
  - A single interest rate swap
  - A portfolio of short-term FX forward and a long-term cross-currency swap
  - A single bought FX European call option
  - A portfolio of bought FX European call and sold FX European put options

- To facilitate comparisons with SA-CCR, the risk factor ***volatilities*** for both the framework and "IMM" are implied by the **SA-CCR *supervisory factors*** for IR (0.5%) and FX (4%)

$$\sigma_k = \frac{3}{2} \frac{\mathrm{SF}_k}{\varphi(0)}$$

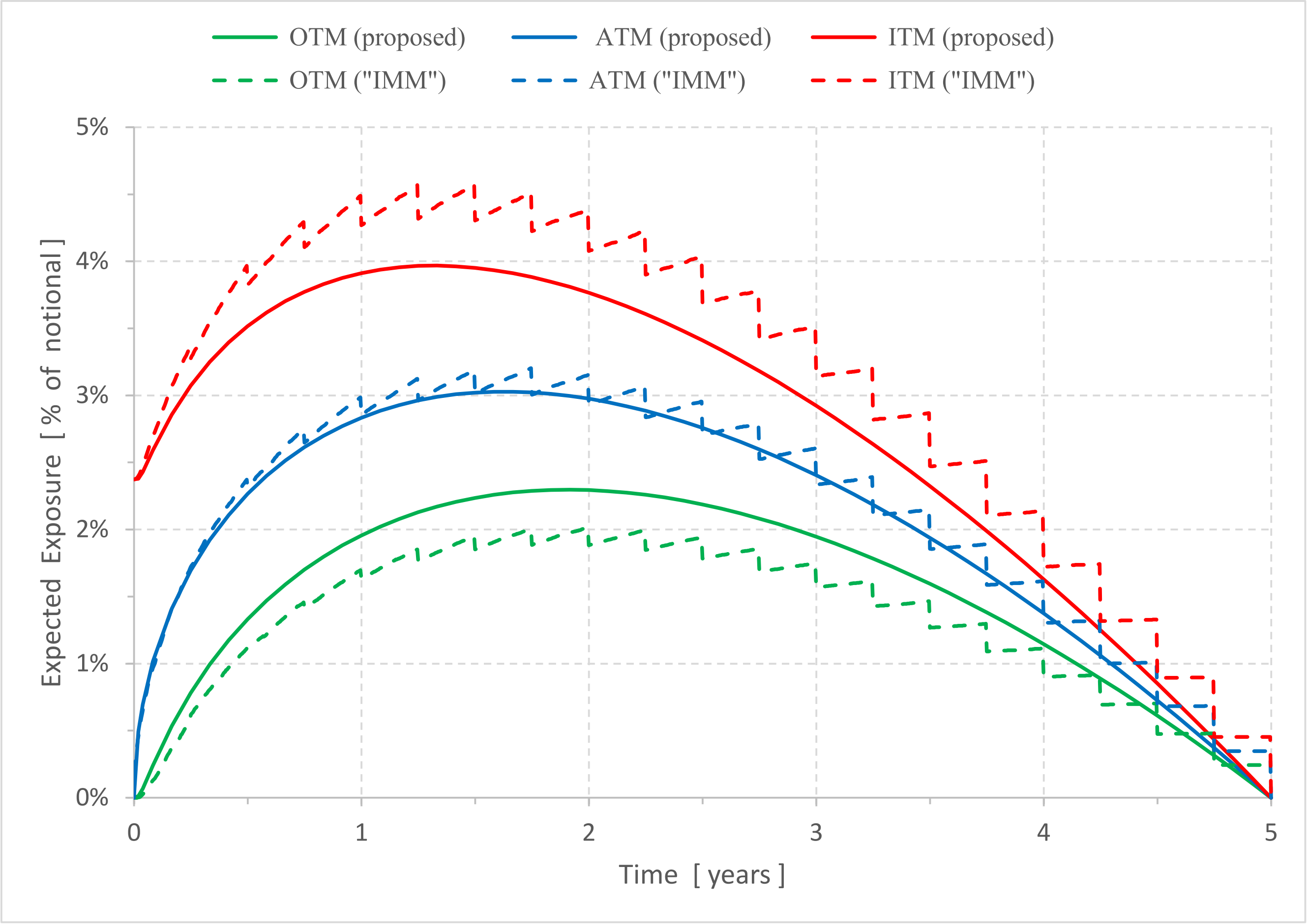
  - BCBS (2014), *Foundations of the Standardised Approach for Measuring Counterparty Credit Risk Exposures*, August (Working Paper No. 26)

Example 1: Interest Rate Swap

- We consider a 5-year interest rate swap
  - The current term structure of quarterly forward rates is flat at **2%**
  - **B** pays floating rate quarterly and receives fixed rate quarterly
    - The values of the fixed rate considered are **1.5%** (OTM), **2.0%** (ATM), **2.5%** (ITM)
- Assumptions for the ***proposed*** framework
  - Cumulative zero-coupon yields with quarterly tenors as IR risk factors
  - Perfect correlation between the risk factors
  - Absolute volatility of **1.88%** implied by the SA-CCR's IR SF of **0.5%**
  - The floating rate is the discounting rate (for the price and sensitivities)
- Assumptions for "**IMM**" exposure simulation
  - The short rate that follows driftless geometric Brownian motion
  - Relative volatility of the short rate is: 1.88% / 2% = **94%**

Interest Rate Swap, EE (Unmargined)

- Values of the fixed rate: **1.5%** (OTM), **2.0%** (ATM), **2.5%** (ITM)
  - "IMM" exposure is simulated with 5000 paths



Interest Rate Swap, EAD (Unmargined)

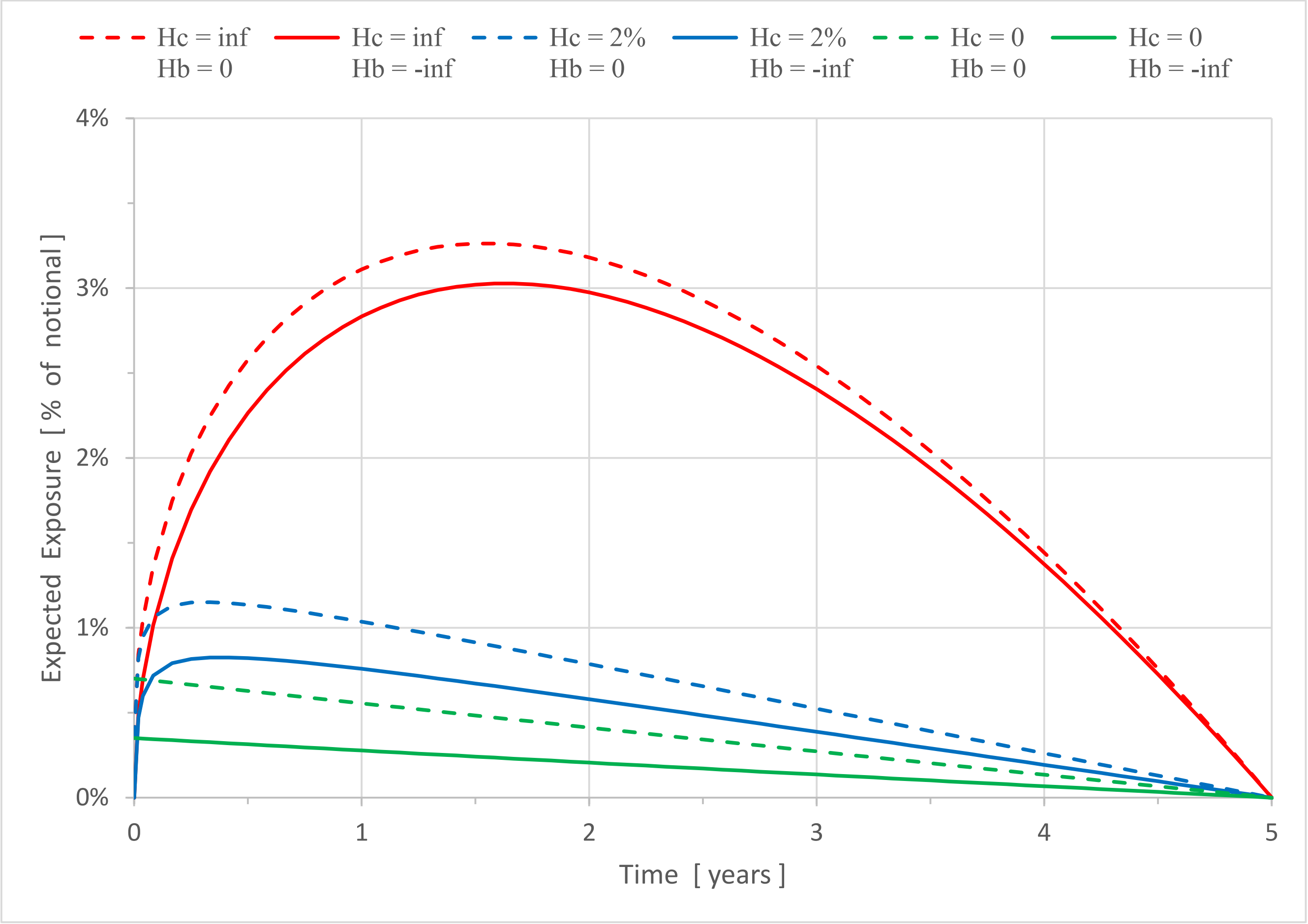
- EAD comparison with "**IMM**" and **SA-CCR**

Quantity	$R = 1.5\%$	$R = 2.0\%$	$R = 2.5\%$
EAD (proposed)	1.28%	2.17%	3.44%
EAD ("IMM")	1.00%	2.15%	3.74%
EAD (SA-CCR)	1.31%	2.21%	4.59%

- Reasonable agreement with "IMM" for all cases
  - Agreement would be better for smaller values of the IR volatility
- Good agreement with SA-CCR for the OTM and ATM cases
- SA-CCR overstates EAD for the ITM case ($R = 2.5\%$), as expected
  - The "implied PFE" (defined as EffEPE – RC) in the proposed framework and "IMM" decreases as the NS goes deeper ITM, while the PFE under SA-CCR is constant

Interest Rate Swap, EE (Margined)

- Framework **EE** for combinations of VM thresholds for **B** and **C**
  - VM posted by **B** results in higher EE



Interest Rate Swap, EAD (Margined)

- EAD comparison between the ***proposed framework*** and **SA-CCR**

Quantity	$H_C = \infty$		$H_C = 2\%$		$H_C = 0$	
	$H_B = 0$	$H_B = -\infty$	$H_B = 0$	$H_B = -\infty$	$H_B = 0$	$H_B = -\infty$
EAD (proposed)	2.48%	2.17%	1.18%	0.86%	0.70%	0.35%
EAD (SA-CCR)	2.21%	2.21%	2.21%	2.21%	0.65%	0.65%

$$\mathrm{EAD}_{\mathrm{margin}}^{\mathrm{SA\text{-}CCR}} = \max\left\{V(0) - \mathrm{VM}(0),\, H_C, 0\right\} + A_{\mathrm{NS}}^{\mathrm{margin}} \cdot \mathrm{Multiplier}\left(\frac{V(0) - \mathrm{VM}(0)}{A_{\mathrm{NS}}^{\mathrm{margin}}}\right)$$

– SA-CCR does not explicitly recognize **B**'s threshold in EAD calculations
  - **B**'s threshold may affect the currently available VM for OTM netting sets ($V(0) < 0$) and, thus, implicitly enter the PFE multiplier calculations via negative VM(0)

– SA-CCR recognizes **C**'s threshold in a crude and conservative manner, so it has to cap EAD for a margined NS with EAD of the unmargined NS
  - For the case $H_C = 2\%$, the cap is applied: $\mathrm{EAD}_{\mathrm{margin}}^{\mathrm{SA\text{-}CCR}} = H_C + A_{\mathrm{swap}}^{\mathrm{margin}} = 2\% + 0.65\% = 2.65\%$

Example 2: CC Swap & FX Forward

- The NS consists of two trades
  - **Cross-currency swap:** remaining maturity $M_{\text{swap}} > 1$ year
    - **B** pays to **C** floating interest rate on USD 110,000
    - **B** receives from **C** floating interest rate on EUR 100,000
    - **B** and **C** exchange notional at maturity
  - **FX forward:** remaining maturity $M_{\text{fwd}} = 1/16$ year
    - **B** pays to **C** EUR 400,000 at maturity
    - **B** receives from **C** USD 440,000 at maturity
- Assumptions for the ***proposed*** framework
  - The price of CC swap does not depend on IR (discounting by floating rate)
  - Dependence of the FX forward price on IR is neglected (short maturity)
  - The current EUR/USD exchange rate is equal to **1.10**, so that $V(0) = 0$
  - The relative volatility of the EUR/USD exchange rate is equal to **15%**, implied by the SA-CCR's FX SF of **4%**

CC Swap & FX Forward, SA-CCR EAD

- Assuming that the NS is ***unmargined***, the EAD under SA-CCR is

$$\mathrm{EAD}_{\text{un-marg}} = \left(\delta_{\text{swap}} d_{\text{swap}} \mathrm{MF}_{\text{swap}} + \delta_{\text{fwd}} d_{\text{fwd}} \mathrm{MF}_{\text{fwd}}\right) \mathrm{SF}_{\text{FX}}$$

- The components of this calculation are
  - **Supervisory factor:** $\mathrm{SF}_{\text{FX}} = 4\%$
  - **Supervisory delta adjustment:** $\delta_{\text{swap}} = 1;\ \ \delta_{\text{fwd}} = -1$
  - **Adjusted notional:** $d_{\text{swap}} = \$110{,}000;\ \ d_{\text{fwd}} = \$440{,}000$
  - **Maturity factor:** $\mathrm{MF}_{\text{swap}} = \sqrt{\min\{M_{\text{swap}}, 1\}} = 1\,;\ \ \mathrm{MF}_{\text{fwd}} = \sqrt{\min\{1/16, 1\}} = 1/4$

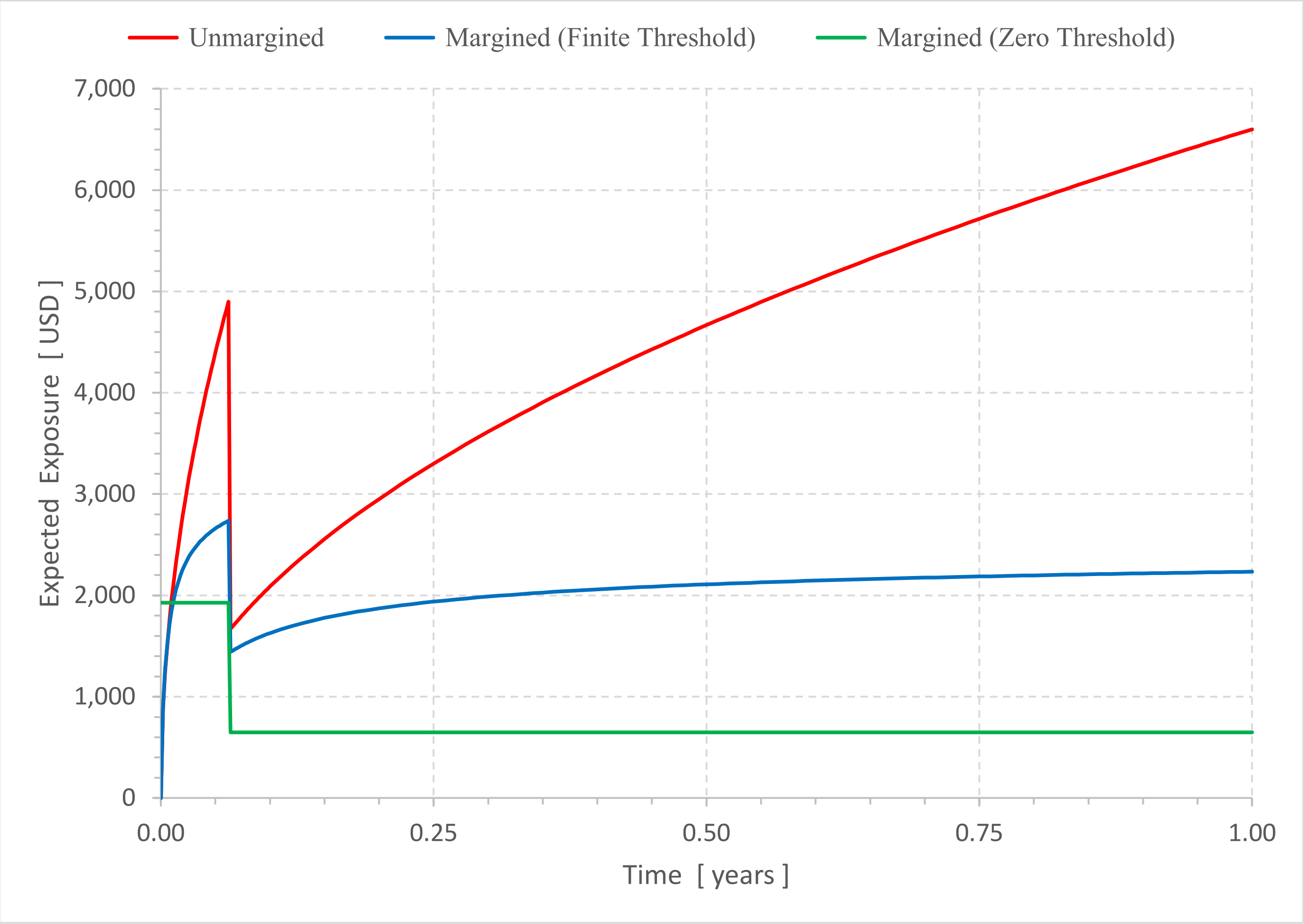
- Substituting the inputs in the EAD formula, we have

$$\mathrm{EAD}_{\text{un-marg}} = \left(1 \cdot \$110{,}000 \cdot 1 + (-1) \cdot \$440{,}000 \cdot 1/4\right) \cdot 4\% = \$0$$

- EAD of a margined NS is ***capped*** by the EAD of the otherwise equivalent unmargined NS
  - SA-CCR EAD of this portfolio is ***zero*** for any margin configuration!

CC Swap & FX Forward, EE

- Framework **EE** for three levels of H_C: $\$\infty;\ \$5{,}000;\ \$0$
  - **B** does not post VM in these examples (i.e., $H_B \to -\infty$)



CC Swap & FX Forward, EAD

- EAD comparison between the ***proposed framework*** and **SA-CCR**

Quantity	$H_B = -\infty$		
	$H_C = \infty$	$H_C = \$5,000$	$H_C = 0$
EAD (proposed)	5,211	2,710	1,929
EAD (SA-CCR)	0	0	0

  – SA-CCR ***caps*** the EAD of a margined NS by the EAD of the otherwise equivalent unmargined NS, which is ***zero*** in this case

- SA-CCR averages exposure contributions of individual trades over time ***prior*** to aggregation across trades
  – This incorrect order of operations can lead to non-economic results
- The proposed framework performs aggregation of exposure contributions across trades and risk factors at each time point

Example 3: FX Options

- **Example 3a:** a single European option bought by **B** from **C**
  - **B bought from C:** a European option that gives **B** a right to exchange USD 110,000 for EUR 100,000 in 5 years
- **Example 3b:** a portfolio of bought and sold European options
  - **B bought from C:** a European option that gives **B** a right to exchange USD 110,000 for EUR 100,000 in 5 years
  - **B sold to C:** a European option that gives **C** a right to exchange EUR 100,000 for USD 110,000 in 5 years
- Assumptions for the ***proposed*** framework and "IMM"
  - All interest rates are ***zero*** in both EUR and USD
  - The current EUR/USD exchange rate is equal to **1.10**
  - Relative volatility of the EUR/USD exchange rate equal to **15%** (SA-CCR)
  - European options are priced via the Black-Scholes formula

EE Calculations under "IMM"

- All **EE** calculations under "IMM" are done ***analytically*** assuming the ***risk neutral*** probability measure
- **Example 3a:** a single European option bought by **B** from **C**
  - With zero interest rates, the option price is a ***martingale***
  - Since the option price is always ***positive***, the EE is equal to the expected market value of the option, which is equal to the option's current value:

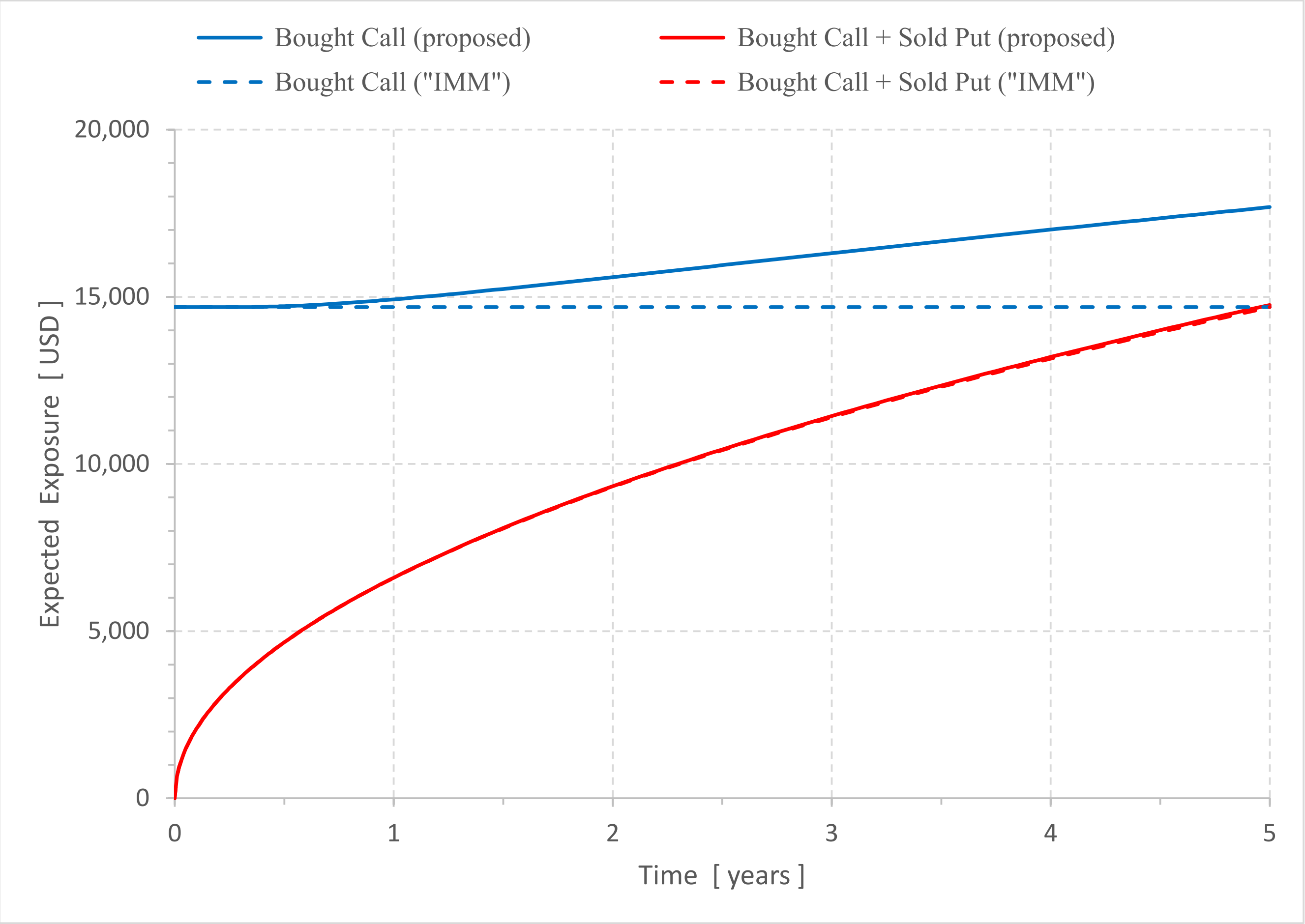
$$\mathrm{EE}(t) = \mathrm{E}[\max\{V_{\text{option}}(t \mid M), 0\}] = \mathrm{E}[V_{\text{option}}(t \mid M)] = V_{\text{option}}(0 \mid M)$$

- **Example 3b:** a portfolio of bought and sold European options
  - This portfolio is equivalent to a ***forward***, where **B** and **C** must exchange payments in 5 years: **B** pays USD 110,000 and receives EUR 100,000
  - EE(t) for a forward is equal to today's price of an option expiring at time t:

$$\mathrm{EE}(t) = \mathrm{E}\left[\max\left\{V_{\text{fwd}}(t \mid M), 0\right\}\right] = \mathrm{E}\left[\max\left\{\mathrm{E}_t[N_{\text{EUR}}\mathrm{FX}_{\text{EUR}}(M) - N_{\text{USD}}], 0\right\}\right]$$
$$= \mathrm{E}\left[\max\left\{N_{\text{EUR}}\,\mathrm{FX}_{\text{EUR}}(t) - N_{\text{USD}}, 0\right\}\right] = V_{\text{option}}(0 \mid t)$$

FX Options, EE (Unmargined)

- **EE** comparison between the ***proposed framework*** and "**IMM**"
  - The red curves compare ***Bachelier*** and ***Black-Scholes*** option pricing!



Summary

- While being more risk sensitive than CEM, SA-CCR may lack sufficient risk sensitivity needed for more complex instruments
- The shortcomings of SA-CCR include
  - reliance on regulatory sensitivities (adjusted notional and supervisory delta)
  - mapping of each trade to a single "primary" risk factor
  - compressing the time dimension of exposure prior to trade aggregation
  - crude treatment of VM thresholds
- A more risk sensitive framework for EAD is possible
  - A bank's internal trade value sensitivities to multiple risk factors are used
  - Exposure aggregation across both trades and risk factors is performed for each time point separately; then, averaging over time follows (as in IMM)
  - VM thresholds for both the bank and the counterparty are incorporated in EAD in a risk sensitive manner