Counterparty Credit Exposure Calculation under IMM

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SIAM Student Day
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Introduction (1/4)

• Big Picture Post-crisis:
  − Regulation reforms:
    o Basel 2.5 (IRC: market risk due to credit deterioration in bond issuers)
    o Basel 3 (higher capital ratio; CVA RC)
    o Fundamental Review of Trading Book (new market risk RC framework: VaR to ES, IRC to IDR, etc.)
    o On-going revision of CCR RC, CVA RC, etc.
  − Single Supervisory Mechanism (since Dec 2014)
    o Direct supervision by ECB instead of DNB
    o Stricter regulation: Asset Quality Review; On-site investigation
  − Regarding pricing:
    o Exotic products are less (more standardized products)
    o Pricing for simple products is more complicated (multi-curve)
    o Short-term interest rates can be negative
Introduction (2/4)

• Topic for today: Credit exposure calculation under IMM (key component for RC CCR and CVA)

• What is counterparty credit risk (CCR)?
  – The risk that the counterparty will fail to fulfill their side of the agreements

• Difference to credit risk in loans
  – Exposures are not known in advance

• Difference to market risk
  – Market risk: loss in mark-to-market values due to market movements
  – CCR: loss due to default of counterparty
Introduction (3/4)

- Counterparty credit exposure metrics:
  - Expected Exposure (EE)
  - Potential Future Exposure (PFE)
  - Expected Positive Exposure (EPE)
  - Eff. Expected Positive Exposure (EEPE)
Introduction (4/4)

• Means to manage/mitigate CCR
  – Enter collateral agreement: transfer CCR to liquidity risk
  – Set up credit limits in trading activities (needs PFE)
  – Hedging: not always possible
  – Price-in CCR when trading: CVA, DVA (needs EE)

• Regulation requirements:
  – RC for CCR (needs EEPE); Allow own calculation on EE under Internal Model Method (BASEL II)
  – RC for CVA (BASEL III; needs EE)
Counterparty Credit Exposure Calculation (1/2)

Simulation
- EUR 1y
- USD 1y
- FX EUR/USD

Pricing
- FX forward
- Swap
- FX option

Aggregation
- Netting Pool
- Profile
Counterparty Credit Exposure Calculation (2/2)

• Main challenges:
  – Selection of risk factor models and calibration of model parameters: main source for model risks
    ○ Simplest model but complicated enough to capture main properties of the underlying risk factors
    ○ Calibration of model parameters
  – Pricing: balance between calculation speed and accuracy
    ○ More assumption thus deviate from front-office price
    ○ double validation standard

• Risk neutral or real-world?
  – For PFE calculation: P in risk factor simulation, Q in pricing
  – For CVA calculation: Q in both
Example (1/5)

• CMS cap/floor
  – A series of caplets/floorlets, which are call/put options on constant swap rate.
  – Commonly traded options on CMS rates; used to hedge instruments with long maturities

• Needed main risk factors:
  – Yield curve(s)

• Value at time $t$ under forward measure:

• Payoff:

$$V_t = \delta N P_d(t, \tau_0) \mathbb{E}^{T_d,0} \left[ P_d(\tau_0, T_p) R_i(\tau_0) \bigg| \mathcal{F}_t \right],$$

$$R_i(\tau_0) = \left[ w \cdot (S_F(\tau_0; \tau_0, \tau_n) - K) \right]^+$$
Example (2/5)

• Forward swap rate:

\[ S_F(t; \tau_0, \tau_n) := \frac{\sum_{j=1}^{n} \gamma_j^L P_d(t, \tau_j) F(t; \tau_{j-1}, \tau_j)}{\sum_{j=1}^{n} \gamma_j^F P_d(t, \tau_j)} \]

• Forward Libor rate: (assuming Libor rate is martingale under discount-forward measure)

\[ F(t; T_s, T_e) := \mathbb{E}^{T_{d,e}} [L(T_s, T_e)|\mathcal{F}_t] \]

\[ F(T_s; T_s, T_e) := L(T_s, T_e) \]

• Libor rate:

\[ L(t, T) := \frac{1 - P_f(t, T)}{\tau P_f(t, T)} \]
Example (3/5)

• Change to annuity measure (because swaption-vols are quoted as such):

\[ V_t = \delta NA(t; \tau_0, \tau_n) \mathbb{E}^A \left[ \frac{P_d(\tau_0, T_p) R_i(\tau_0)}{A(\tau_0; \tau_0, \tau_n)} \bigg| \mathcal{F}_t \right] \]

\[ A(t; \tau_0, \tau_n) := \sum_{j=1}^{n} \gamma_j^F P_d(t, \tau_j) \]

• Assuming shifted lognormal for forward swap rate:

\[ \bar{S}_F(t; T_s, T_e) := S_F(t; T_s, T_e) + \theta \]

\[ d\bar{S}_F(t; T_s, T_e) = \bar{S}_F(t; T_s, T_e) \bar{\sigma} dW_t \]

• Rewrite payoff in terms of shifted swap rate:

\[ (S_F(\tau_0; \tau_0, \tau_n) - K)^+ = (\bar{S}_F(\tau_0; \tau_0, \tau_n) - \bar{K})^+ \]
Example (4/5)

- Assume linear swap rate model:

\[
\frac{P_d(\tau_0, T_p)}{A(\tau_0; \tau_0, \tau_n)} = \alpha + \beta_p \bar{S}_F(\tau_0; \tau_0, \tau_n)
\]

- Inserting this into the expectation:

\[
\mathbb{E}^A \left[ \frac{P_d(\tau_0, T_p)R_i(\tau_0)}{A(\tau_0; \tau_0, \tau_n)} \bigg| \mathcal{F}_t \right]
\]

\[
= \mathbb{E}^A \left[ (\alpha + \beta_p \bar{S}_F(\tau_0; \tau_0, \tau_n)) (\bar{S}_F(\tau_0; \tau_0, \tau_n) - \bar{K})^+ \bigg| \mathcal{F}_t \right]
\]

\[
= \alpha \cdot \text{Opt}_{BS} (\bar{S}_F(t; \tau_0, \tau_n), \bar{K}, \bar{\sigma}) + \beta_p \bar{S}_F(t; \tau_0, \tau_n) \cdot \text{Opt}_{BS} (\bar{S}^*_F(t; \tau_0, \tau_n), \bar{K}, \bar{\sigma})
\]

\[
\bar{S}^*_F(t; \tau_0, \tau_n) := \bar{S}_F(t; \tau_0, \tau_n) \cdot \exp (\bar{\sigma}^2(\tau_0 - t))
\]
Example (5/5)

• Calculation steps:
  – Simulate yield curves for a few forecasting dates
  – Loop though all forecasting dates, whereby
    – Loop through all simulated yield curve scenarios, whereby
      – Generate a date strip of the cap/floor and loop though each coupon (caplet/floorlet) period, whereby
      – Generate a data strip of the underlying swap and loop though each Libor period; then aggregate Libor rates according to forward swap rate formula;
      – Apply the CMS caplet/floorlet formula on the swap rate to return the coupon value
    – Sum up discounted coupons to get the MtM value at this forecasting date and for this scenario.

• In the end, we get MtM distributions for all forecasting dates.
• What’s more?(Collateral;netting)
Latest Developments in Regulations

- [https://www.bis.org/bcbs/publ/d362.pdf](https://www.bis.org/bcbs/publ/d362.pdf)
  - EE from IMM is not allowed for CVA VaR any more
  - There might be a floor to CCR RC based on standardized method