High Throughput Portfolio Processing on Heterogeneous Boards

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My research path

- 1998-2003 Classified and used analytically solvable pricing models. Became unhappy because of numerical instabilities in low precision arithmetics and a seemingly unsurmountable memory bottleneck.
- 2003-2006 Developed an algebraic formalism for finance and implemented it on multi-core CPUs
- 2006-2009 Used multi-GPU equipment for CDOs and interest rate exotics
- 2009-2011 Developed an architecture for high throughput portfolio processing on heterogeneous boards for global portfolios of netting sets
- 2011-current Proposed margin lending structures as a way to take the technology to fruition and am now working at developing the margin lending business.

Based on the papers

- C.Albanese, D.Brigo and F. Oertel, *"Restructuring Counterparty Credit Risk"*, Bundesbank Working Paper Series, November 2011
- C.Albanese, T.Bellaj, G.Gimonet and G.Pietronero, *Coherent Global Market Simulations and Securitization Measures for Counterparty Credit Risk*, Quantitative Finance, January 2011, Vol. 50, pages 1-20.
- C.Albanese, T.Bellaj and G.Pietronero, *Optimal Funding Strategies for Counterparty Credit Risk Liabilities*, Journal of Governance and Regulation, to appear.

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Outline

- Bits of News

  Valuation of Defaultable Claims

  Risk Analysis

  Model Implementations

Bits of News: OTC markets are being pushed toward Clearing Houses

The design of the controversial credit value adjustment (CVA) charge due to be implemented in the Basel III regime was subject to political pressure aimed at penalising the over-the-counter derivatives market and pushing it towards central counterparties (CCPs).

Benedikt Binz, Swiss regulator at the Quant Congress 2010

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Bits of News: Clearing Houses demand full collateral margining

US Companies may face $1 trillion in additional capital and liquidity requirements as a result of the Financial Regulatory Reform

ISDA

New margin rules under Dodd Frank could cost over-the-counter (OTC) interest rate derivatives market participants up to $1.4 trillion in capital charges over the next three to five years

E Paul Rowady Jr, Senior Analyst at TABB, October 2011

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Bits of News: Collateral is very costly and difficult to manage

Many hedge funds cite their operational limitations and do not have the software or ability to do daily margin calls .

Neil Murphy, Algorithmics.

We expect earnings to become more volatile - not because of unpredictable passenger numbers, interest rates or jet fuel prices, but because it does not post collateral in its derivatives transactions.

Roland Kern, Head of Finance, Lufthansa, October 2011

A trade that used to cost 7bp in counterparty credit charge, could now be 30bp.

Trader with RBS

Bits of News: Margin calls trigger bankruptcies

In the bankruptcy court filing, MF Global also said the credit-rating downgrades last week "sparked an increase in margin calls against MFGI, threatening overall liquidity."

Wall Street Journal October 31, 2011

Federal regulators have discovered that hundreds of millions of dollars in customer money has gone missing from MF Global in recent days, prompting an investigation into the brokerage firm.

New York Times, October 31, 2011

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Outline

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Fundamental Theorem for non-defaultable transactions

- The fair value M_t of a transaction between non-defaultable counterparties, satisfies the principle of no-arbitrage if and only if it can be expressed as a discounted expectation of future payoffs with respect to any chosen numeraire g_t can be expressed in the form

$$M_t(B) = -M_t(C) = E_t^Q\left[\int_t^T e^{-\int_t^s r_u du}\Phi_s(ds)\right]. \qquad (1)$$

- Here B and C are two parties exchanging a cash flow stream $\Phi_s(ds)$.
- Q is a probability measure **globally defined** across all assets in the economy.

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Valuation of Defaultable Claims

- Defaultable claims can be valued by interpreting them as portfolios of claims between non-defaultable counterparties including the riskless claim and mutual default protection contracts.
- Party B sells to party C default protection on C contingent to an amount specified by a **close-out rule**, and viceversa.
- In formulas:

$$V_t(B) = M_t(B) - CVA_t(B, C) + DVA_t(B, C), \tag{2}$$

$$V_t(C) = M_t(C) - CVA_t(C, B) + DVA_t(C, B), \tag{3}$$

where

  - $M_t(B)$ is the mark to market to B in case both B and C are default-free;
  - $CVA_t(B; C)$ is the value of default protection that B sells to C contingent on the default of C;
  - $DVA_t(B; C)$ is the value of default protection that C sells to B contingent on the default of B.
  - Similar definitions extend in case $B \leftrightarrow C$.

Three inconsistent market standards

- Prior to 2006, the standard was to use unilateral CVA only

$$CVA_t(B;C) = E_t\left[e^{-\int_t^{\tau_B} r_s ds}(M_{\tau_B}(B))^-(1 - R_{\tau_B}(B))\right] \quad (4)$$

  Since the DVA term was ignored. This was inconsistent as an asset for one party should be realized as a liability for the other party.

- In 2006, accounting standards IAS39, FASB 256 and 257 were introduced asking that banks record a DVA entry so that the DVA of one party is the CVA of the other

$$DVA_t(C;B) = CVA_t(B;C) \quad (5)$$

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Substitution close-out

- This introduced a valuation inconsistency: upon the default of C, B looses the DVA but does not account for the loss consistently in its definition of CVA
- To remedy in part the inconsistency, in 2009, the ISDA introduced a substitution close-out rule which allows B to recover in part from C the lost DVA.
- However, the recovery is only partial and a partial loss still remains unaccounted for in the CVA.

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Approximations neglecting correlations

- The often implemented strategy to value the unilateral CVA is to compute

$$CVA_t = \sum_i Z_t(T_i) EE_t(T_i) \cdot PD_t(T_i) \cdot LGD_t(T_i) \quad (6)$$

  where $EE_t(T_i)$ is the expected exposure in the period $[T_i, T_{i+1}]$, $PD_t(T_i)$ is the probability of default and $LGD_t(T_i)$ is the loss given default
- The Basel III document introduced further approximations to this formula based on a mapping to bond portfolios

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Consistent CVA/DVA accounting

- First-to-default CVA
- Portable CVA
- Tri-partite structures with one-sided collateralization and margin lending
- Quadri-partite structures with two-sided collateralization and margin lending
- CCP structures with margin lending

First-to-default CVA

- Bilateral CVA with first-to-default clause is defined as follows:

$$CVA_t(B;C) = E_t\left[1(\tau_B < \tau_C)e^{-\int_t^{\tau_B} r_s ds}(M_{\tau_B}(B))^-(1 - R_{\tau_B}(B))\right] \quad (7)$$

- If $\tau_B < \tau_C$, we have that $CVA_{\tau_B}(B;C) = DVA_{\tau_B}(C;B) = 0$. Hence, conditions C_1 and C_2 are actually equivalent in this case and they are both satisfied.
- Bilateral CVA with first to default is substantially lower than unilateral CVA
- If B approaches default, its CVA goes to zero, i.e. bilateral CVA is unhedgeable

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Portable CVA

Start off by setting

$$CVA_t^{(0)}(B; C) = DVA_t^{(0)}(C; B) = \Gamma_t^{(0)}(B, C). \tag{8}$$

where

$$\Gamma_t^{(0)}(B, C) = E_t\left[e^{-\int_t^{\tau_C} r_s ds}(M_{\tau_C}(C))^-(1 - R_{\tau_C}(C))\right] \tag{9}$$

and similarly for $B \leftrightarrow C$.
This expression is not correct as it does not take into account the closeout conditions, under neither the risk-free nor the substitution close-out rule.

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Adjusting to obey the risk-free close-out rule

To eliminate the inconsistency, we have party B subtract from its fair value calculation the discounted value of the DVA of C that B would be liable to pay upon defaulting, in case B defaults prior to C, i.e. we set

$$CVA_t^{(1)}(C,B) = \Gamma_t^{(0)}(C,B) + \Gamma_t^{(1)}(C;B) \tag{10}$$

where

$$\Gamma_t^{(1)}(C,B) = E_t\left[1_{\tau_B<\tau_C} e^{-\int_t^{\tau_B} r_u du} \Gamma_{\tau_B}^{(0)}(B,C)\right]. \tag{11}$$

Similar equations apply to the case $B \leftrightarrow C$.

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Adjusting to obey the risk-free close-out rule

To restore the principle of money conservation, we also set

$$DVA_t^{(1)}(C,B) = \Gamma_t^{(0)}(B,C) + \Gamma_t^{(1)}(B,C) \quad \text{and} \quad B \leftrightarrow C. \tag{12}$$

Since

$$\Gamma_{\tau_C}^{(1)}(B,C) = 0 \tag{13}$$

by construction, the risk-free close-out condition is satisfied.

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Adjusting to obey the substitution close-out rule

To eliminate the inconsistency in this case, we have party B subtract from its fair value calculation the discounted value of the DVA of C that B would be liable to pay upon defaulting, in case B defaults prior to C, i.e. we set

$$CVA_t^{(1)}(C, B) = \Gamma_t^{(0)}(C, B) + \Gamma_t^{(1)}(C; B) \tag{14}$$

where

$$\Gamma_t^{(1)}(C, B) = \tag{15}$$

$$E_t \left[1_{\tau_B < \tau_C} e^{-\int_t^{\tau_B} r_u du} \left(\left(M_{\tau_B}(C) + \Gamma_{\tau_B}^{(0)}(B, C) \right)^+ - (M_{\tau_B}(C))^+ \right) (1 - R_{\tau_B}(B) \right. \tag{16}$$

Then proceed similarly to what done with the risk-free rule.

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Lack of uniqueness

- The arbitrage free condition leads to fixed point equations with an infinite number of solutions
- The quantitative impact of the indeterminacy is unbounded in relative terms (e.g. first-to-default CVA can be arbitrarily smaller than adjusted unilateral CVA)
- Because of the lack of uniqueness, the language in the ISDA standard CSA agreement is ambiguous and flawed
- The ambiguity is currently a source of widespread market miss-pricings of the CVA
- The only way to resolve the ambiguity is to either prescribe a particular CVA construction by regulation (as attempted by Basel III albeit not in a fully consistent fashion) or to get rid of the CVA altogether by imposing full collateralization (as also encouraged by Basel III)

Eliminating CVA volatility by margin lending

- Investment bank *B* enters in derivative transactions with counterparty *C* and both edge the mutual counterparty credit risk by entering into collateral revolvers with liquidity providers *A* and *D*.
- *B* can either be a bank or a CCP.
- This funding strategy is the only viable one for CCPs but extends to the non-cleared OTC space.
- With margin financing, CVA volatility is nil by construction.

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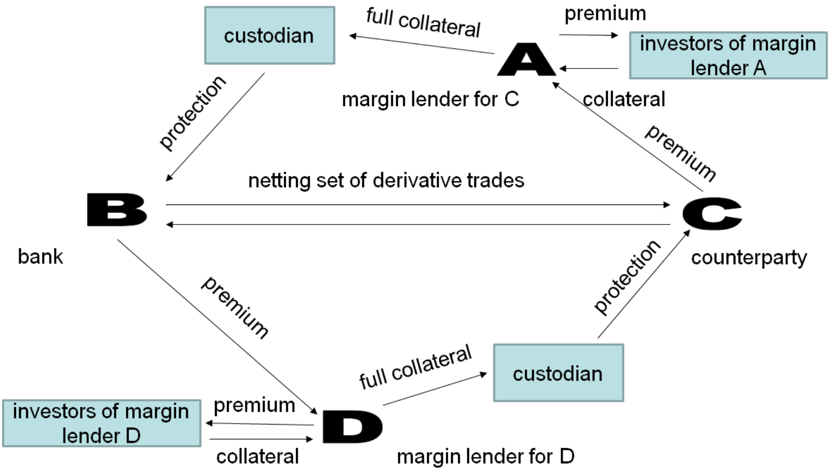
Quadri-partite structure with margin lending



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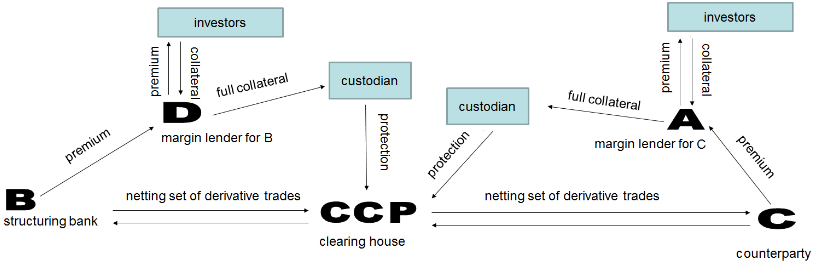
CCP structure with margin lending



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Secured quadri-partite transactions with continuous resets

- secured transactions reset periodically in time whereby C buys default insurance from a margin lender A and B buys default insurance from a margin lender D.
- In the case of continuous time resets, the contractual structures are designed in such a way to keep valuations are constantly kept at the following equilibrium levels at all times:

$$V_t(A) = 0 \tag{17}$$

$$V_t(B) = M_t(B), \tag{18}$$

$$V_t(C) = M_t(C), \tag{19}$$

$$V_t(D) = 0. \tag{20}$$

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Secured quadri-partite transactions with continuous resets

- The margin lender A secures in a segregated custodian account a sufficient amount of collateral to guarantee that the amount $(M_t(C))^-$ is paid to B in case C defaults, thus offsetting the counterparty credit risk that C would otherwise pose to B.
- C pays to A a continuous stream of premia $d\Pi_t(A, C; t)$.
- Symmetrically, B pays a cash flow stream $d\Pi_t(D, B; t)$ to D so to ensure that C is immunized from the risk of default of B.
- fair premia are give by the following condition:

$$E_t[dV_t(A) + 1_{t<\tau_C<t+dt}(1 - R_{\tau_C}(C))(M_{\tau_C}(C))^- + d\Pi_{\tau_C}(A, C)] = 0, \tag{21}$$

$$E_t[dV_t(D) + 1_{t<\tau_B<t+dt}(1 - R_{\tau_B}(B))(M_{\tau_C}(B))^- + d\Pi_{\tau_B}(D, B)] = 0. \tag{22}$$

for all $t < \tau_B \wedge \tau_C$;

Secured quadri-partite transactions with periodic resets

In the case of periodic resets at times T_i, $i = 0, 1, 2, ...$, the fair value of the position to the margin lenders is zero only at the reset dates T_i. However, margin lender sells default protection to C, a contract whose value is $CVA_t(A, C)$. Similarly does D.

$$V_t(A) = e^{\int_{T_i}^{t} r_s ds} \Pi_{T_i}(A, C) - CVA_t(A, C), \tag{23}$$

$$V_t(B) = M_t(B) + DVA_t(B, D), \tag{24}$$

$$V_t(C) = M_t(C) + DVA_t(C, A), \tag{25}$$

$$V_t(D) = e^{\int_{T_i}^{t} r_s ds} \Pi_{T_i}(D, B) - CVA_t(D, B) \tag{26}$$

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Secured quadri-partite transactions with periodic resets

- For all $t \in [T_i, T_{i+1}]$, the CVA satisfy

$$CVA_t(A, C) = E_t[e^{-\int_t^{\tau_C} r_s ds} 1_{\tau_C < \tau_B} 1_{\tau_C < T_{i+1}} (1 - R_{\tau_C}(C))(M_{\tau_C}(C))^-], \quad (27)$$

$$CVA_t(D, B) = E_t[e^{-\int_t^{\tau_B} r_s ds} 1_{\tau_B < \tau_C} 1_{\tau_B < T_{i+1}} (1 - R_{\tau_B}(B))(M_{\tau_B}(B))^-] \quad (28)$$

and the premia are computed so that

$$\Pi_{T_i}(A, C) = CVA_t(A, C), \quad \Pi_{T_i}(D, B) = CVA_t(D, B) \quad (29)$$

- Money conservation until default:

$$CVA_t(A, C) = DVA_t(C, A), \quad CVA_t(D, B) = DVA_t(B, D), \quad (30)$$

for all $t < \tau_B \wedge \tau_C$,

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Secured tri-partite transactions with periodic resets

In the case of periodic resets at times $T_i, i = 0, 1, 2, ...$, the fair value of the position to the margin lenders is zero only at the reset dates T_i. However, margin lender sells default protection to C, a contract whose value is $CVA_t(A, C)$. Similarly does D.

$$V_t(A) = e^{\int_{T_i}^{t} r_s ds} \Pi_{T_i}(A, C) - CVA_t(A, C), \quad (31)$$

$$V_t(B) = M_t(B) + DVA_t(B, C), \quad (32)$$

$$V_t(C) = M_t(C) - CVA_t(C, B) + DVA_t(C, A), \quad (33)$$

$$(34)$$

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Secured tri-partite transactions with periodic resets

- For all $t \in [T_i, T_{i+1}]$, the CVA terms satisfy the equation

$$CVA_t(A, C) = E_t[e^{-\int_t^{\tau_C} r_s ds} 1_{\tau_C < \tau_B} 1_{\tau_C < T_{i+1}} (1 - R_{\tau_C}(C))(M_{\tau_C}(C))^-], \quad (35)$$

$$CVA_t(C, B) = E_t[e^{-\int_t^{\tau_B} r_s ds} (1 - R_{\tau_B}(B))(M_{\tau_B}(B))^-] \quad (36)$$

and the premium received by A from C is computed so that

$$\Pi_{T_i}(A, C) = CVA_t(A, C), \quad (37)$$

- Money conservation until default:

$$CVA_t(A, C) = DVA_t(C, A), \quad (38)$$

$$CVA_t(C, B) = DVA_t(B, C), \quad (39)$$

for all $t < \tau_B \wedge \tau_C$,

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Multi-partite structures

- Tri-partite, quadri-partite and CCP structures admit unambiguous fair valuation
- CCP clearing is favored by regulators
- Non cleared exotic transaction benefit to an even greater extend from full collateralization and margin lending than cleared transactions
- In our experience, the average cost of counterparty credit risk protection from a margin lender is 2-4 times lower than in the CVA case as CVA VaR capital charges are avoided

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Funding: no alternative to securitization

- The 90% of new swap and CDS transactions are expected to move on to CCPs by the year 2012.
- This represents a substantial portion of a market of size exceeding 700 trillion dollars.
- According to the ISDA, "US Companies may face US $1 trillion in additional capital and liquidity requirements as a result of the Financial Regulatory Reform".
- On a global scale, starting from the year 2012 margin revolvers will be a cash market of size in the trillions of dollars.
- The challenge financial institutions will face is to intermediate the re-allocation and sterilization of trillions worth of capitals toward collateral accounts attached to derivative netting sets.
- There doesn’t seem to be any alternative for funding but securitization

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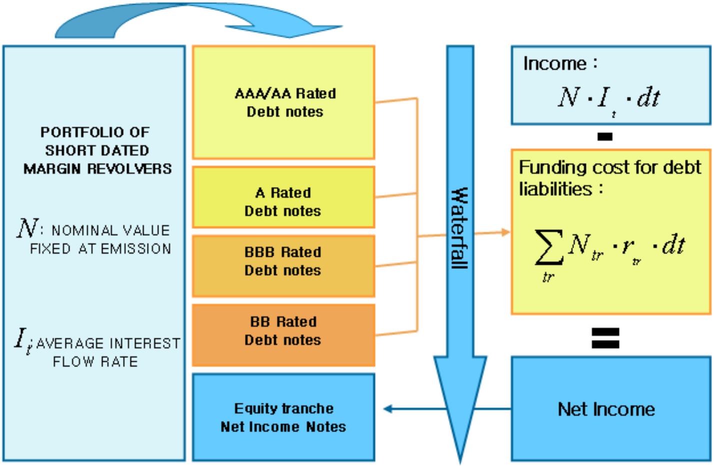
Securitization of margin lending portfolios



Advantages of margin lending

- Collateral allocation over a basket of netting sets benefits from diversification (by about 45% in the case study below)
- The CVA VaR capital charge for banks is not applicable because volatility risk is transferred to the counterparty
- Premia for the counterparty are lower by an estimated factor 4-6
- Margin lending through hypotechs does not have a balance-sheet impact

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Outline

Bits of News

Valuation of Defaultable Claims

- Risk Analysis

Model Implementations

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Risk Analysis

- In our counterparty credit risk solution, we analyse global portfolios of netting sets over long time horizons by means of **global market simulations** under the risk neutral measure.
- All credit and market factors are modelled dynamically.
- Current instrument coverage currently includes derivatives that can be valued by backward induction such as (callable) swaps, FX options and CDSs.
- Basket options, CDO tranches, etc.., require nested simulations and are work in progress.

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Global Valuation

- According to the Fundamental Theorem, global valuation is **the only sensible and theoretically justified procedure** for portfolio valuation, hedging and replication.
- But there's more: there's no fully rigorous alternative to valuing portfolios globally and as a whole!
- In the presence of netting agreements and funding costs, **arbitrage free pricing is not additive across transactions.**
- The price of a transaction in isolation is not equal to the marginal price of a transaction as it is added to a portfolio.
- **Rigor and efficiency go together:** Pricing portfolios as a whole on a single node and under a globally defined martingale measure allows one to share computational building blocks and achieve a markedly **sub-linear performance ratios** (the more instruments are there the shorter the execution time on a per instrument basis).

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Analytics for global portfolios of netting sets (and sub-portfolios thereof)

- Point-in-time loss distributions.
- **Cumulative loss distributions** for cash waterfalls including:
  - losses arising from counterparty defaults,
  - funding costs,
  - collateral (modeled dynamically),
  - multi-tiered liabilities .
- Sensitivities of loss distributions and macro hedge ratios.
- **Risk resolutions of outliers** in the tail of the loss distribution and risk concentration hedging.
- Risk resolution at the individual instrument level.
- **EPE and CVA statistics are a biproduct**, not the main focus of the analysis.

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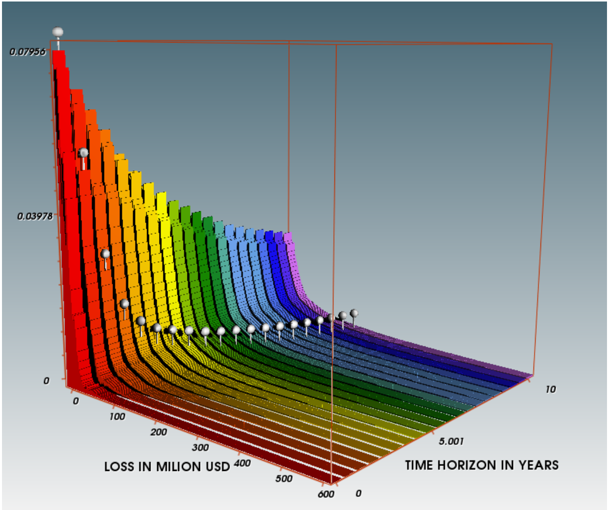
Example of a Cumulative Loss Distribution for a Global Portfolio of 302 Netting Sets



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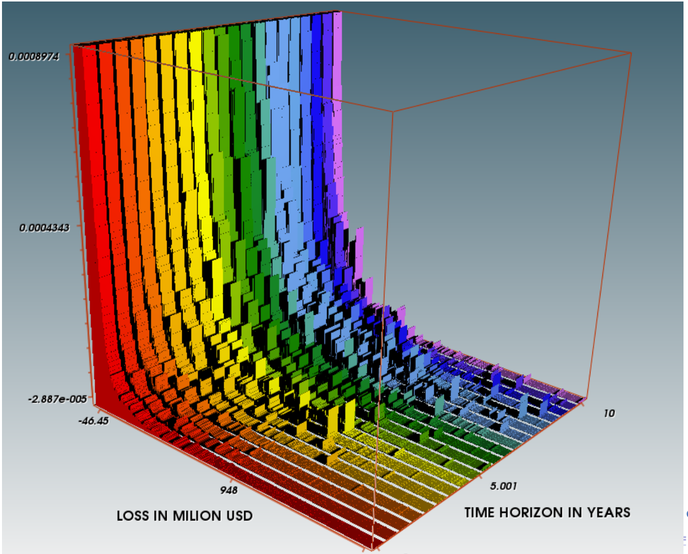
Point in time loss distribution for a CCR portfolio of 302 netting sets.



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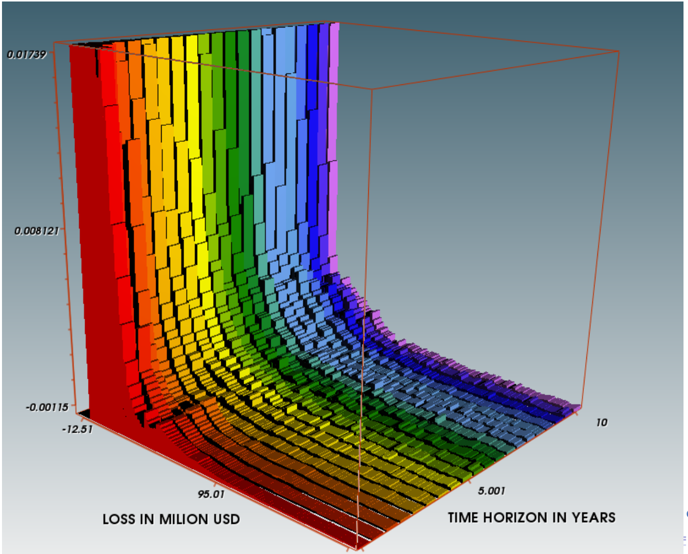
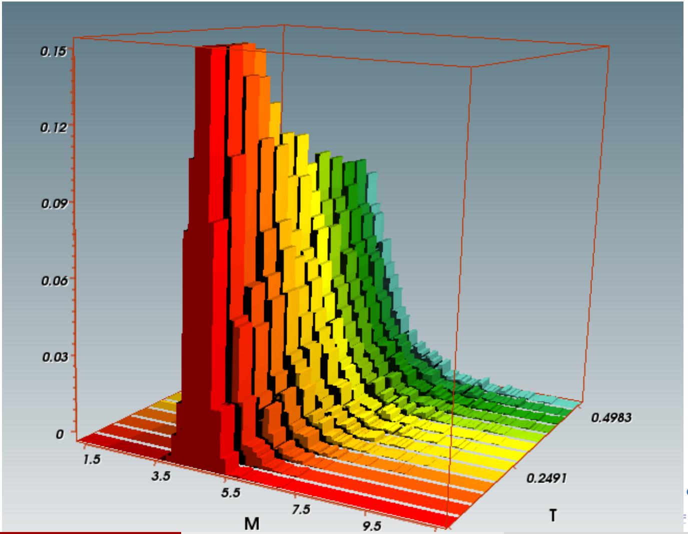
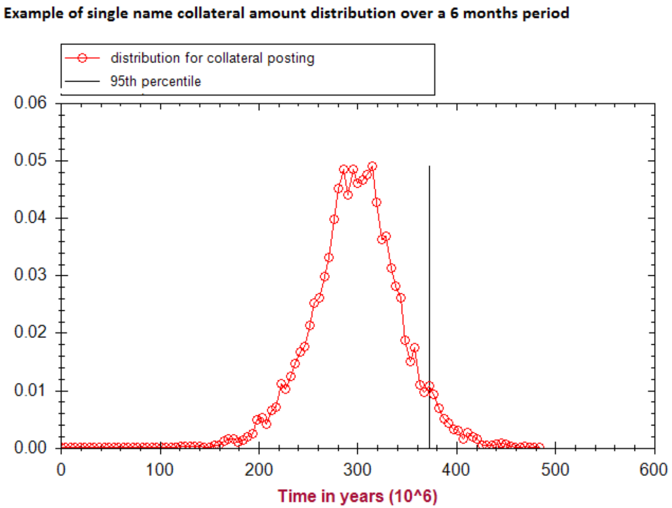
A different view on the same point in time loss distribution emphasizing the equity tranche



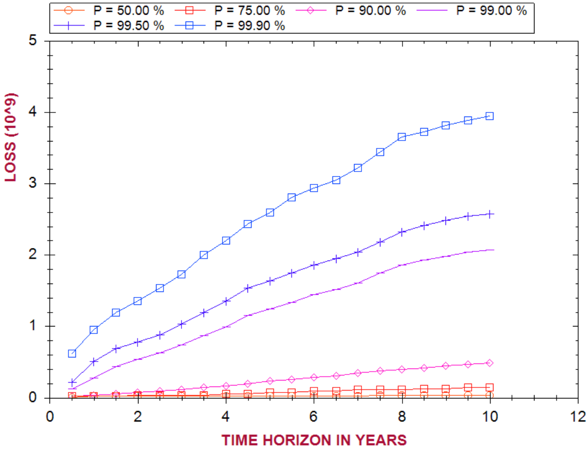
Collateral utilization distribution for a margin lending portfolio over a 6 months period



Collateral utilization distribution for a single name over a 6 months period



Percentile Comparisons, high correlation



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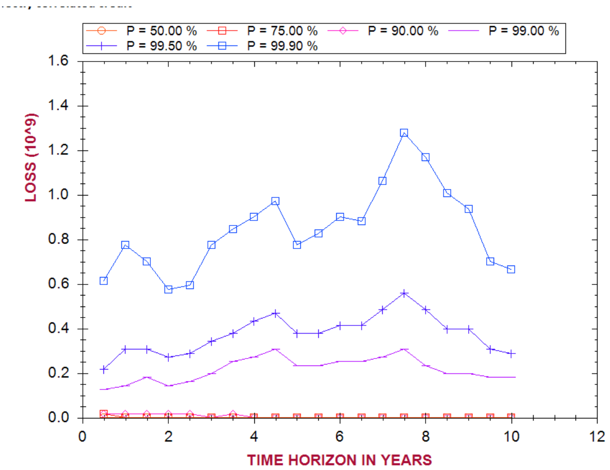
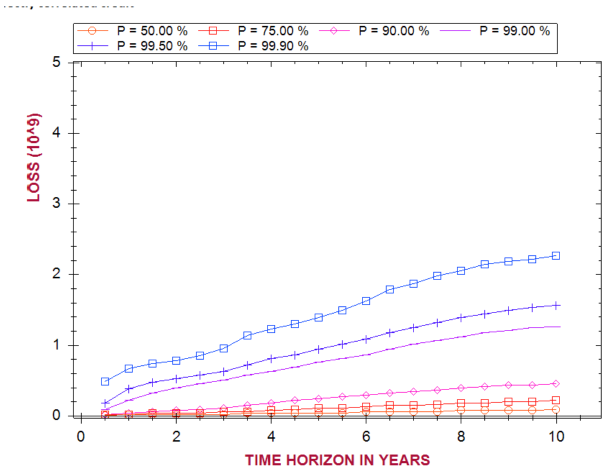
Percentile Comparisons, high correlation



Percentile Comparisons, low correlation



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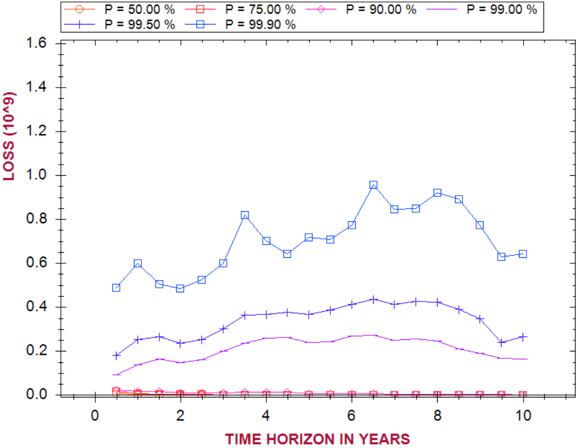
Percentile Comparisons, low correlation



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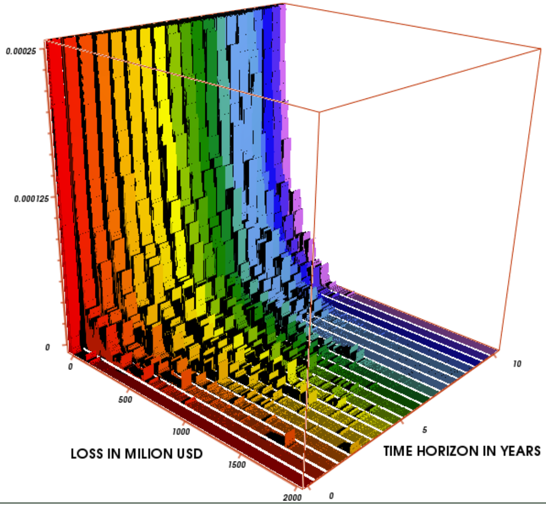
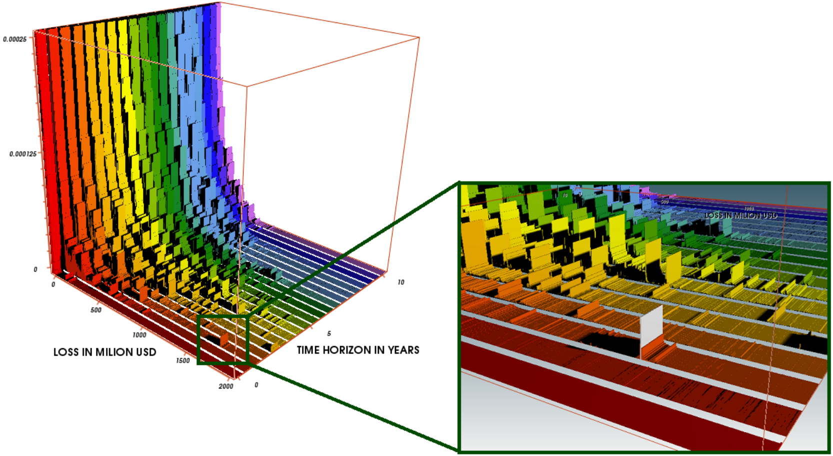
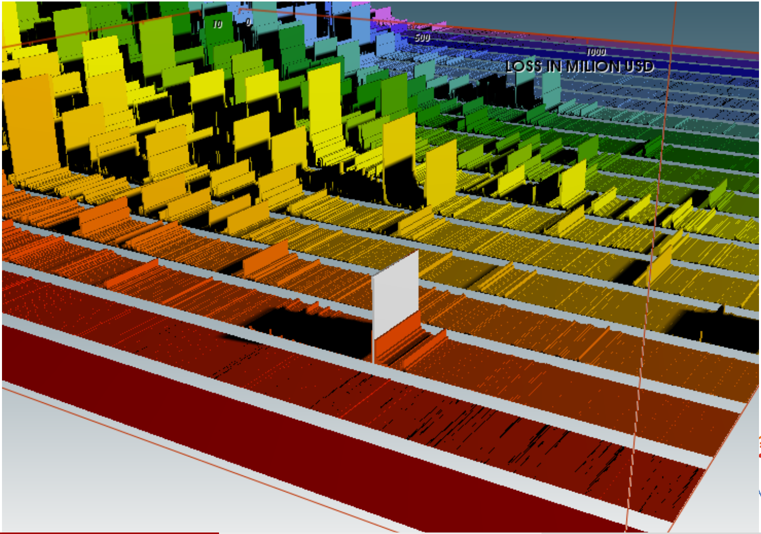
Loss distribution for the EUR denominated sub-portfolio



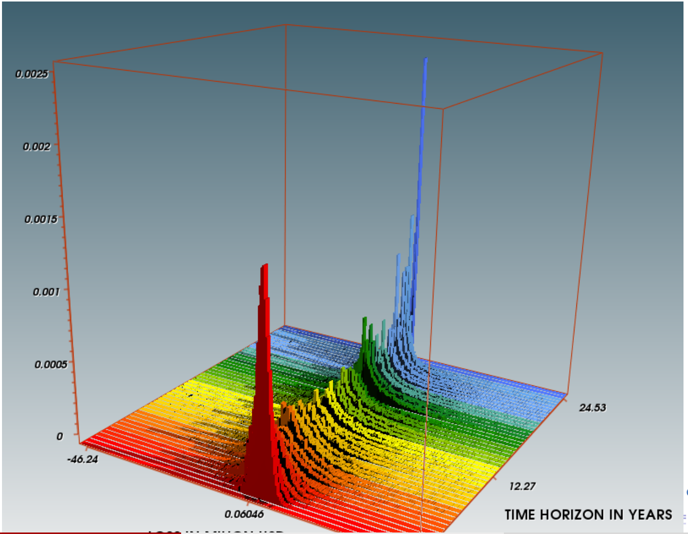
Risk resolution and stress testing: Zooming on an outlier for the EUR denominated sub-portfolio



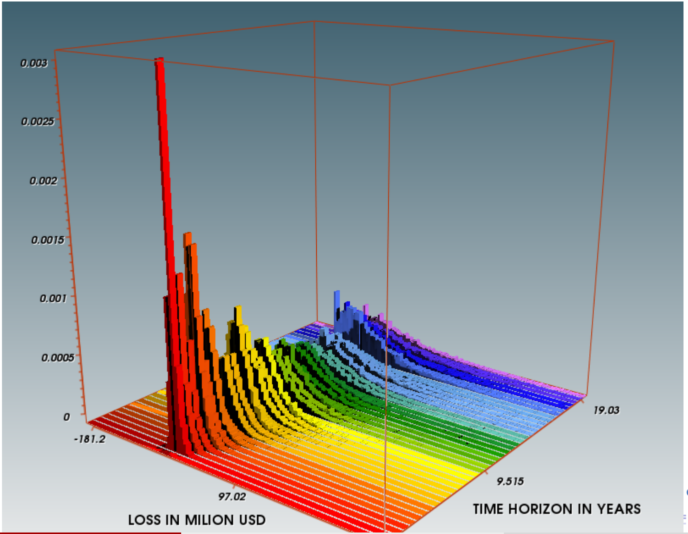
Risk resolution and stress testing: Zooming on an outlier for the EUR denominated sub-portfolio



Loss distribution a EUR denominated fix-for-float swap



Loss distribution for a cross-currency EUR-USD swap with nominal exchange at maturity



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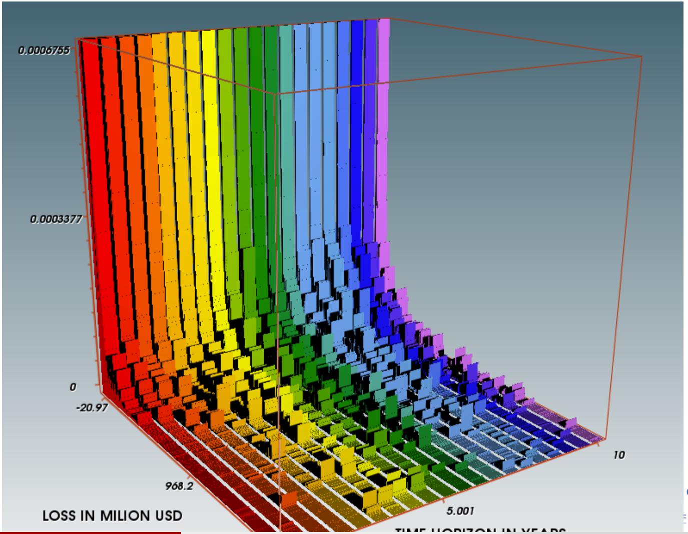
Loss distribution for a portfolio of 62 netting sets for counterparties in the financial sector.



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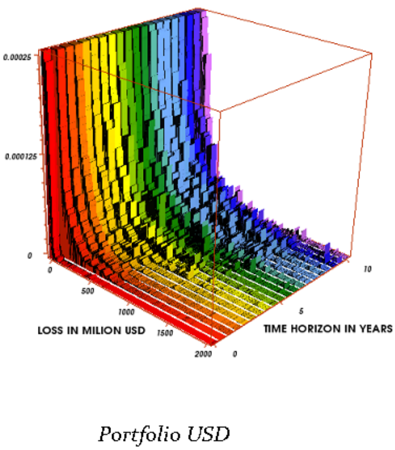
Comparison of loss distributions for the USD and EUR denominated subportfolios.



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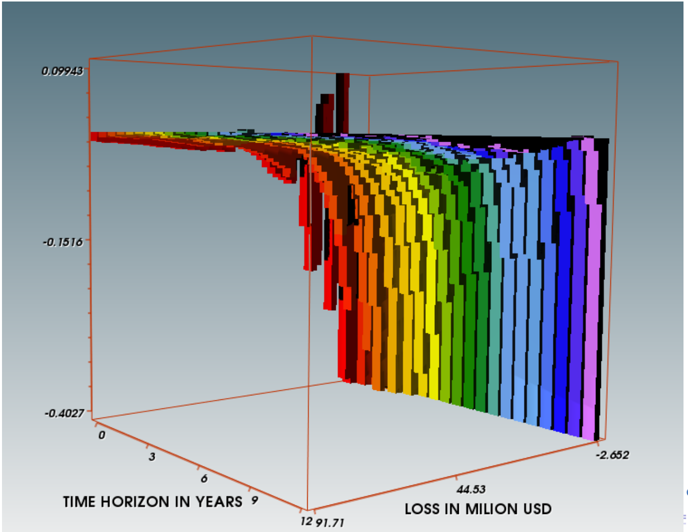
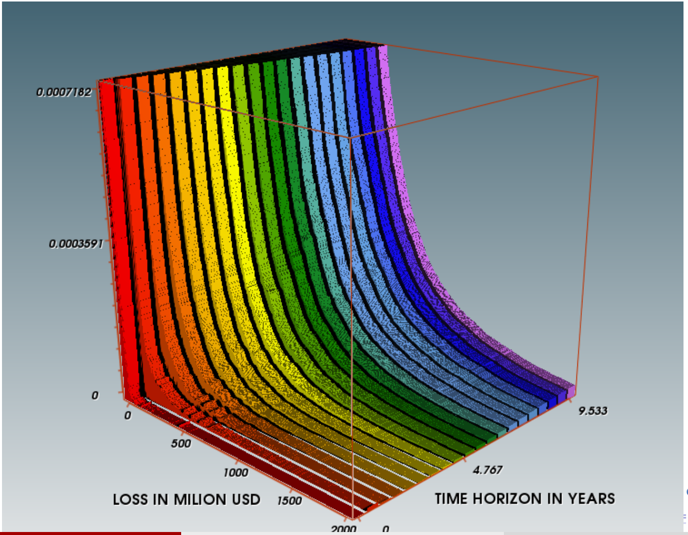
Sensitivities to a parallel shift in the USD curve for the loss distributions corresponding to the entire portfolio.



Cumulative loss distribution for the entire CCR portfolio with 302 counterparties



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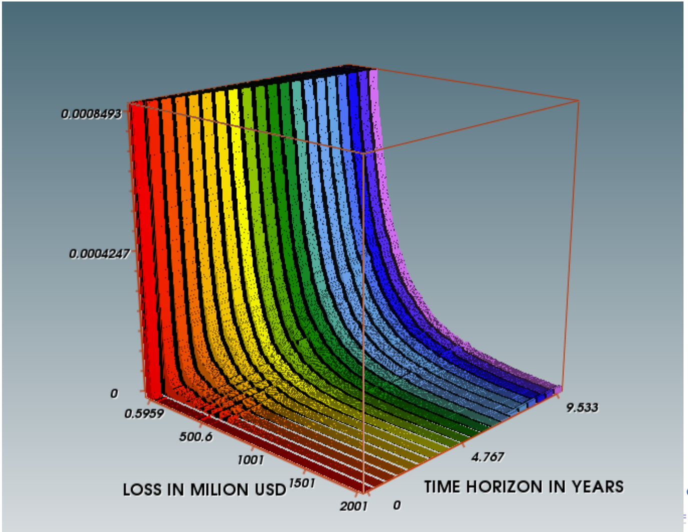
Cumulative loss distribution for the corporate CCR sub-portfolio



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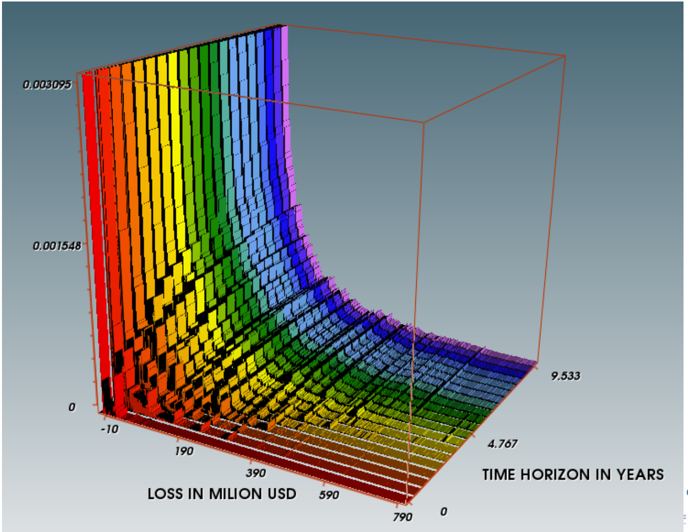
Cumulative loss distribution for the sovereign CCR sub-portfolio



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Outline

Bits of News

Valuation of Defaultable Claims

Risk Analysis

- Model Implementations

Model Implementations

- **Technology** comes first (and always did)

$$\Downarrow$$

- The **Mathematical Framework** is adapted to technology

$$\Downarrow$$

- **Models** are formulated by means of the mathematical framework

$$\Downarrow$$

- **Regulations and business models** are organized around models

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From grid computing to the CVA

- **Technology**: grid computing

$$\Downarrow$$

- **Mathematical Framework**: based on stochastic calculus and aimed at constructing partially solvable processes

$$\Downarrow$$

- **Models**: tailored to individual instruments in isolation while ignoring the Fundamental Theorem at the portfolio level

$$\Downarrow$$

- **Regulations and business models**: based on the EPE-CVA methodology and single instrument processing

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From single node technologies to coherent global market simulations

- **Technology**: large computing boards capable to process entire global bank portfolios at once

$$\Downarrow$$

- **Mathematical Framework**: based on an algebraic formalism aimed at bypassing the memory bottleneck of current microprocessor architectures

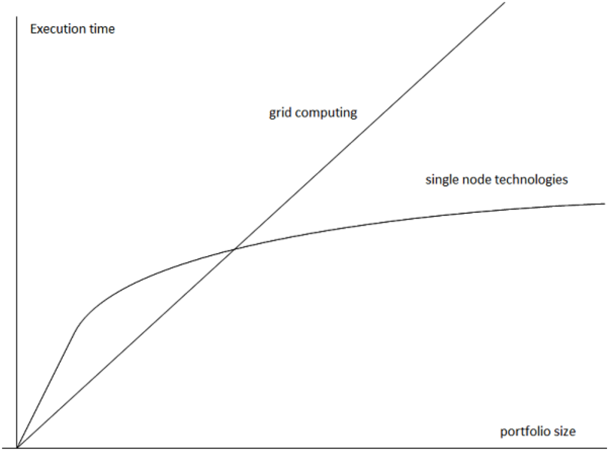
$$\Downarrow$$

- **Models**: flexibly specified and econometrically realistic, solved numerically and calibrated globally, suitable for high throughput portfolio processing

$$\Downarrow$$

- **Regulations and business models**: based on portfolio processing and marginal instrument valuation, real time access to coherent global market simulations, 3d risk visualization tools, risk resolution and portfolio level hedging

It's all about achieving sublinear scaling without uncontrollable approximations



Single node technologies

- The system architecture is based on a single node design pattern whereby large portfolios are loaded entirely on a large board with with dozens of CPU cores, several GPU coprocessors and TB scale memory
- Having bypassed the network bottleneck at the root, we implement a number of portfolio level algorithmic optimizations to achieve **sublinear scaling**, such as
  - globally defined, high quality models for all risk factors
  - sharing of proxy models across minor currencies and credit processes
  - dictionaries of elementary building blocks for derivative valuation that is possible to compute just once and share globally at the portfolio level

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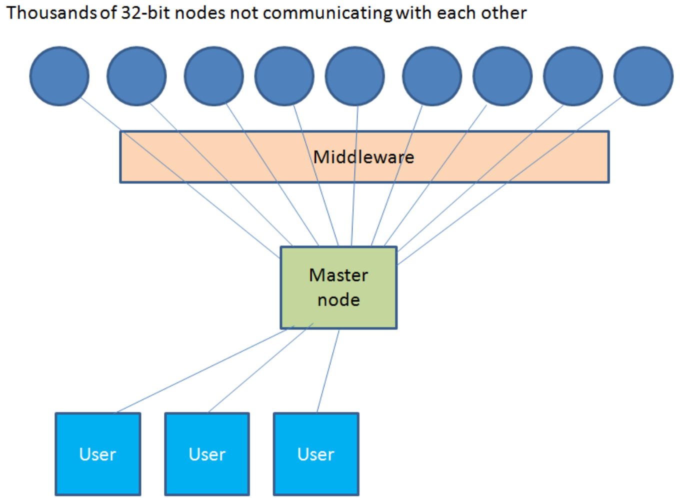
Heritage Grid Farms



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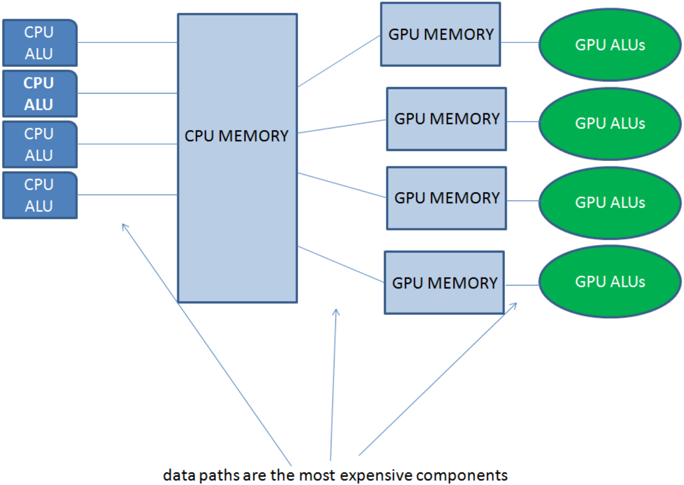
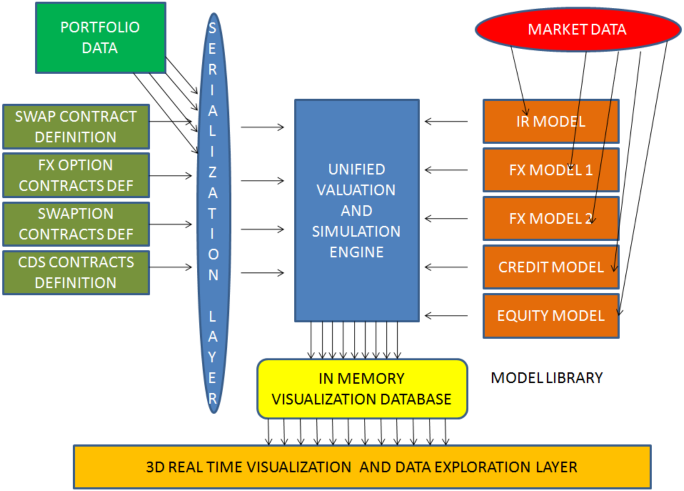
Current boards: lots of memory, many cores and narrow data paths



Outline of a Global Valuation System Architecture



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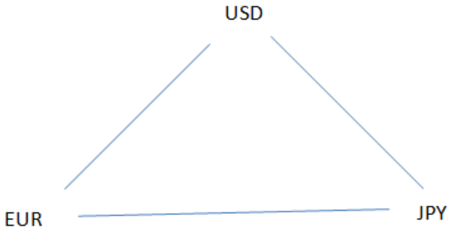
Global Calibration of FX Models

Global multi-currency portfolio are an example of failure of local models for individual crosses as these ignore triangular and polygonal relations.



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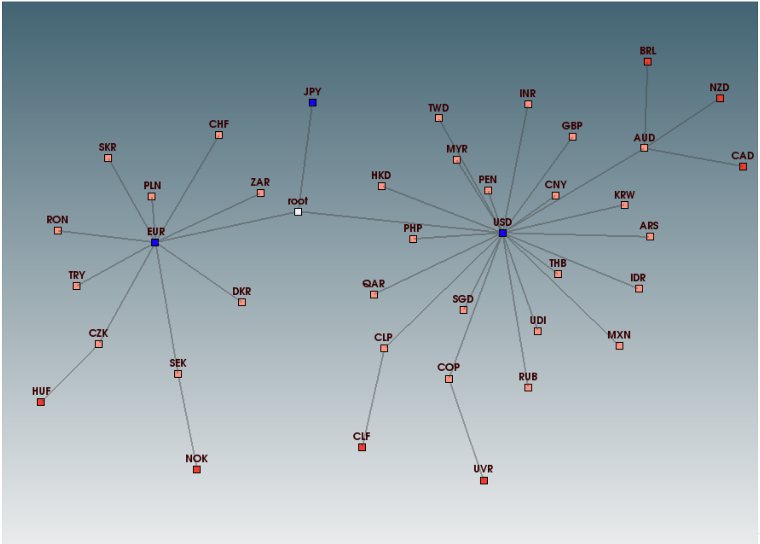
A Minimum Spanning Tree for Global Currency Modelling



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Calibration of Global FX Models

A consistent model can still use local models but as parts in a hierarchy of controllable approximations.

- The tree is devised in such a way to achieve stable historical correlations and to minimize volatilities of crosses in the tree
- The USD-EUR-JPY triangle needs to be calibrated separately by fixing the interest rate processes in the three currencies and optimizing the ROOT centered crosses
- All other crosses in the minimum spanning tree are calibrated separately
- Crosses not in the tree are implied

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Calibration of Global Credit Models

- Global credit correlations are estimated to achieve simultaneous consistency with the CDX-IG, ITX-IG and the CDX-HY index tranche spreads
- Recognizing the great importance of **credit vegas**, the credit processes are calibrated also against CDS index options
- The credit model assumes stochastic interest rates and correlates recovery rates to the interest rate and credit cycle

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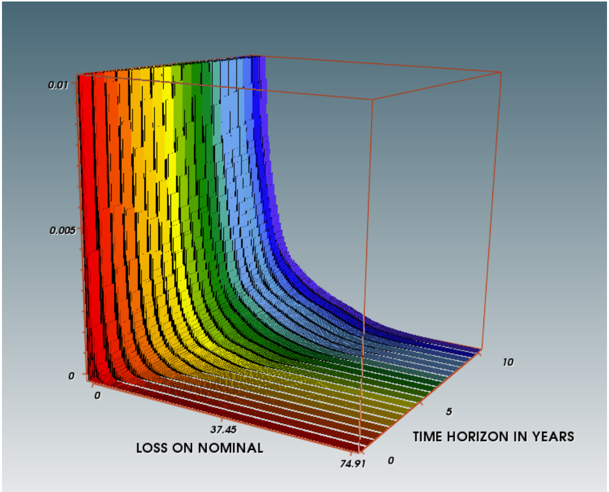
Cumulative loss distribution for the CDX-IG index CDO



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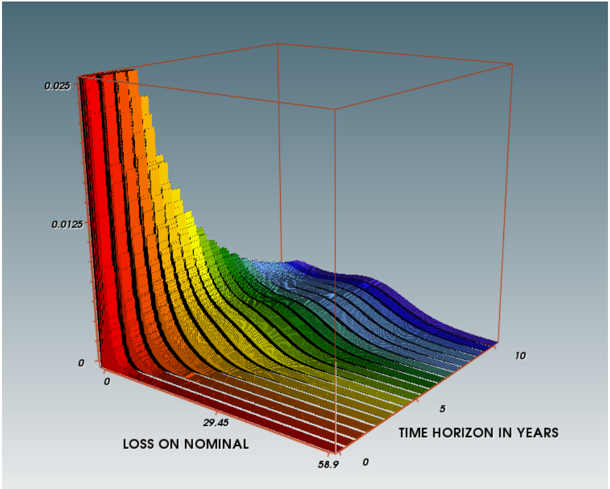
Cumulative loss distribution for the CDX-HY index CDO



Conclusions

- We propose to resolve counterparty credit risk of global portfolios of netting sets against a multi-tiered capital structure by means of **coherent global market simulations** under the risk neutral measure
- We achieved **sub-linear scaling and real time performance** by leveraging on a rigorous application of the Fundamental Theorem of Finance and single node technologies
- Our approach goes beyond the EPE/CVA methodology
- Banking is the very last industry sector that didn't make a high tech transition yet. This is now overdue!
- We believe that the impact of technology innovation on banking practices, business models, mathematical models and software architectures will soon occur

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References

- Our software architecture is described in the paper

  C.Albanese, T.Bellaj, G.Gimonet and G.Pietronero, *Coherent Global Market Simulations and Securitization Measures for Counterparty Credit Risk*, Quantitative Finance, January 2011, Vol. 50, pages 1-20.

- Margin financing and securitization are discussed in more detail in the paper

  C.Albanese, T.Bellaj and G.Pietronero, *Optimal Funding Strategies for Counterparty Credit Risk Liabilities*, preprint

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