Nonlinear Valuation:
Funding Costs, Margining and Gap Credit Risk


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Based on Joint Work with Co-Authors listed in the References

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HPC: New Thinking in Finance
Agenda I

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Presentation based on the Recent Book

Counterparty credit risk, collateral and funding
With Pricing Cases for All Asset Classes

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An online colloquial survey

For an introductory dialogue on Counterparty Risk, illustrating the themes of the book, see

Credit Risk and CVA Q&A

Funding and CCPs Q&A
D. Brigo, A. Pallavicini (2013). CCPs, Central Clearing, CSA, Credit Collateral and Funding Costs Valuation FAQ

See also References at the end of this presentation.

Of our many works on CVA–DVA over 2002-2014, we recall the following key feature:
PAYOFF RISK

The exact payout corresponding with the Credit and Debit valuation adjustment is not clear.

- DVA or not?
- Which Closeout?
- First to default risk or not?
- How are collateral and funding accounted for? (Next part)

Worse than model risk: Payout risk. WHICH PAYOUT?

At a recent industry panel (WBS) on CVA it was stated that 5 banks might compute CVA in 15 different ways.
Collateral Management and Gap Risk

Collateral (CSA) is considered to be the solution to counterparty risk. Periodically, the position is re-valued ("marked to market") and a quantity related to the change in value is posted on the collateral account from the party who is penalized by the change in value.

This way, the collateral account, at the periodic dates, contains an amount that is close to the actual value of the portfolio and if one counterparty were to default, the amount would be used by the surviving party as a guarantee (and vice versa).

Gap Risk is the residual risk that is left due to the fact that the realigning is only periodical. If the market were to move a lot between two realigning ("margining") dates, a significant loss would still be faced.

Folklore: Collateral completely kills CVA and gap risk is negligible.
Collateral Management and Gap Risk I

Folklore: Collateral completely kills CVA and gap risk is negligible.

We are going to show that there are cases where this is not the case at all (B. Capponi and Pallavicini 2012, Mathematical Finance)

- Risk-neutral evaluation of counterparty risk in presence of collateral management can be a difficult task, due to the complexity of clauses.
- Only few papers in the literature deal with it. Among them we cite Cherubini (2005), Yi (2009), Assefa *et al.* (2009), Brigo *et al* (2011) and citations therein.
- Example: Collateralized bilateral CVA for a netted portfolio of IRS with 10y maturity and 1y coupon tenor for different default-time correlations with (and without) collateral re-hypothecation. See B, Capponi, Pallavicini and Papatheodorou (2011)
Figure explanation

Bilateral valuation adjustment, margining and rehypotecation

The figure shows the BVA(DVA-CVA) for a ten-year IRS under collateralization through margining as a function of the update frequency $\delta$ with zero correlation between rates and counterparty spread, zero correlation between rates and investor spread, and zero correlation between the counterparty and the investor defaults. The model allows for nonzero correlations as well.

**Continuous lines** represent the re-hypothecation case, while **dotted lines** represent the opposite case. The **red line** represents an investor riskier than the counterparty, while the **blue line** represents an investor less risky than the counterparty. All values are in basis points.

Figure explanation

From the fig, we see that the case of an investor riskier than the counterparty (M/H) leads to positive value for DVA-CVA, while the case of an investor less risky than the counterparty has the opposite behaviour. If we inspect the DVA and CVA terms as in the paper we see that when the investor is riskier the DVA part of the correction dominates, while when the investor is less risky the counterparty has the opposite behaviour.

Re-hypothecation enhances the absolute size of the correction, a reasonable behaviour, since, in such case, each party has a greater risk because of being unsecured on the collateral amount posted to the other party in case of default.

Let us now look at a case with more contagion: a CDS.
Payer–CVA ($S_1 = 100$ bps)

- **P–CVA**
- **P–CCVA$^c$**
- **P–CCVA$^d$**
- **P–CCVA–RE$^c$**
- **P–CCVA–RE$^d$**

basis points

$r_{0,1} = r_{0,2} = r_{1,2}$

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Collateral Management and Gap Risk II

The figure refers to a payer CDS contract as underlying. See the full paper by Brigo, Capponi and Pallavicini (2011) for more cases.

If the investor holds a payer CDS, he is buying protection from the counterparty, i.e. he is a protection buyer.

We assume that the spread in the fixed leg of the CDS is 100 while the initial equilibrium spread is about 250.

Given that the payer CDS will be positive in most scenarios, when the investor defaults it is quite unlikely that the net present value be in favor of the counterparty.

We then expect the CVA term to be relevant, given that the related option will be mostly in the money. This is confirmed by our outputs.
We see in the figure a relevant CVA component (part of the bilateral DVA - CVA) starting at 10 and ending up at 60 bps when under high correlation.

We also see that, for zero correlation, collateralization succeeds in completely removing CVA, which goes from 10 to 0 basis points.

However, collateralization seems to become less effective as default dependence grows, in that collateralized and uncollateralized CVA become closer and closer, and for high correlations we still get 60 basis points of CVA, even under collateralization.

The reason for this is the instantaneous default contagion that, under positive dependency, pushes up the intensity of the survived entities, as soon as there is a default of the counterparty.
Indeed, the term structure of the on-default survival probabilities (see paper) lies significantly below the one of the pre-default survival probabilities conditioned on $G_{\tau-}$, especially for large default correlation. The result is that the default leg of the CDS will increase in value due to contagion, and instantaneously the Payer CDS will be worth more. This will instantly increase the loss to the investor, and most of the CVA value will come from this jump.

Given the instantaneous nature of the jump, the value at default will be quite different from the value at the last date of collateral posting, before the jump, and this explains the limited effectiveness of collateral under significantly positive default dependence.
Basic Payout plus Credit and Collateral: Cash Flows I

- We calculate prices by discounting cash-flows under the pricing measure. Collateral and funding are modeled as additional cashflows (as for CVA and DVA).
- We start from derivative’s basic cash flows without credit, collateral of funding risks

\[
\tilde{V}_t(C; F) := \mathbb{E}_t[\Pi(t, T \wedge \tau) + \ldots]
\]

where

\[\tau := \tau_C \wedge \tau_I\] is the first default time, and

\[\Pi(t, u)\] is the sum of all discounted payoff terms up from \(t\) to \(u\),

Cash flows are stopped either at the first default or at portfolio’s expiry if defaults happen later.
As second contribution we consider the collateralization procedure and we add its cash flows.

\[ \bar{V}_t := E_t[\prod(t, T \wedge \tau)] + E_t[\gamma(t, T \wedge \tau; C) + \ldots] \]

where

\( \rightarrow C_t \) is the collateral account defined by the CSA,
\( \rightarrow \gamma(t, u; C) \) are the collateral margining costs up to time \( u \).

Notice that when applying close-out netting rules, first we will net the exposure against \( C_{\tau-} \), then we will treat any remaining collateral as an unsecured claim.

If \( C > 0 \) collateral has been overall posted by the counterparty to protect us, and we have to pay interest \( c^+ \).

If \( C < 0 \) we posted collateral for the counterparty (and we are remunerated at interest \( c^- \)).
Basic Payout plus Credit and Collateral: Cash Flows III

The cash flows due to the margining procedure on the time grid \( \{t_k\} \) are equal to

\[
\gamma(t, u; C) := - \sum_{k=1}^{n-1} 1\{t \leq t_k < u\} D(t, t_k) C_{t_k} \left( P_{t_k}(t_{k+1})(1 + \alpha_k \tilde{c}_{t_k}(t_{k+1})) - 1 \right)
\]

where \( \alpha_k = t_{k+1} - t_k \) and the collateral accrual rates are given by

\[
\tilde{c}_t := c_t^+ 1\{c_t > 0\} + c_t^- 1\{c_t < 0\}
\]

Then, according to CSA, we introduce the pre-default value of the collateral account \( C_{\tau^-} \) as

\[
C_{\tau^-} := \sum_{k=1}^{n-1} 1\{t_k < \tau < t_{k+1}\} C_{t_k} \left( 1 + \alpha_k \tilde{c}_{t_k}(t_{k+1}) \right) P_{\tau}(t_{k+1})
\]
As third contribution we consider the cash flow happening at 1st default, and we have

\[
V_t := E_t[ \Pi(t, T \wedge \tau) ] + E_t[ \gamma(t, T \wedge \tau; C) ] + E_t \left[ 1_{\{\tau<T\}} D(t, \tau) \theta_\tau(C, \varepsilon) + \ldots \right]
\]

where

\[ \varepsilon_\tau \] is the close-out amount, or residual value of the deal at default, and
\[ \theta_\tau(C, \varepsilon) \] is the on-default cash flow.

\[ \theta_\tau \] will contain collateral adjusted CVA and DVA payouts for the instrument cash flows.

We define \[ \theta_\tau \] including the pre-default value of the collateral account since it is used by the close-out netting rule to reduce exposure.
The close-out amount is not a symmetric quantity w.r.t. the exchange of the role of two parties, since it is valued by one party after the default of the other one.

\[ \varepsilon_\tau := 1_{\{\tau = \tau_C\}} \varepsilon_{I,\tau} + 1_{\{\tau = \tau_I\}} \varepsilon_{C,\tau} \]

Without entering into the detail of close-out valuation we can assume a close-out amount equal to the risk-free price of remaining cash flows inclusive of collateralization and funding costs. More details in the examples.


\[ \rightarrow \] See, for detailed examples, Parker and McGarry (2009) or Weeber and Robson (2009).

\[ \rightarrow \] See, for a review, Brigo, Morini, Pallavicini (2013).
Close-Out: Trading-CVA/DVA under Collateral – III

- At transaction maturity, or after applying close-out netting, the originating party expects to get back the remaining collateral.

- Yet, prevailing legislation’s may give to the Collateral Taker some rights on the collateral itself.
  - In presence of re-hypothecation the collateral account may be used for funding, so that cash requirements are reduced, but counterparty risk may increase.
  - See Brigo, Capponi, Pallavicini and Papatheodorou (2011).

- In case of collateral re-hypothecation the surviving party must consider the possibility to recover only a fraction of his collateral.
  - We name such recovery rate $R_{EC}'_I$, if the investor is the Collateral Taker, or $R_{EC}'_C$ in the other case.
  - In the worst case the surviving party has no precedence on other creditors to get back his collateral, so that

\[
R_{EC'I} \leq R_{EC}' \leq 1, \quad R_{EC'C} \leq R_{EC}' \leq 1
\]
The on-default cash flow $\theta_\tau(C, \varepsilon)$ can be calculated by following ISDA documentation. We obtain

$$
\begin{align*}
\theta_\tau(C, \varepsilon) & := 1_{\{\tau_\tau C_\tau < \tau_I\}} \left( \varepsilon_{I, \tau} - L_{GD_C}(\varepsilon_{I, \tau}^+ - C_{\tau-}^+) + L_{GD_C}'(\varepsilon_{I, \tau}^- - C_{\tau-}^-)^+ \right) \\
& \quad + 1_{\{\tau = \tau_I < \tau_C\}} \left( \varepsilon_{C, \tau} - L_{GD_I}(\varepsilon_{C, \tau}^- - C_{\tau-}^-)^- - L_{GD_I}'(\varepsilon_{C, \tau}^+ - C_{\tau-}^+)^- \right)
\end{align*}
$$

where loss-given-defaults are defined as $L_{GD_C} := 1 - R_{EC_C}$, and so on.

If both parties agree on exposure, namely $\varepsilon_{I, \tau} = \varepsilon_{C, \tau} = \varepsilon_\tau$ then

$$
\begin{align*}
\theta_\tau(C, \varepsilon) & := \varepsilon_\tau - 1_{\{\tau_\tau C_\tau < \tau_I\}} \prod_{CVA} + 1_{\{\tau = \tau_I < \tau_C\}} \prod_{DVA} \\
\prod_{CVA} & = L_{GD_C}(\varepsilon_\tau^+ - C_{\tau-}^+) + L_{GD_C}'(\varepsilon_\tau^- - C_{\tau-}^-)^+ \\
\prod_{DVA} & = L_{GD_I}((-\varepsilon_\tau)^+ - (-C_{\tau-})^+)^+ + L_{GD_I}'(C_{\tau-}^+ - \varepsilon_\tau^+)^+
\end{align*}
$$
In case of re-hypothecation, when $L_{GD_C} = L_{GD_C}'$ and $L_{GD_I} = L_{GD_I}'$, we obtain a simpler relationship

$$
\theta_\tau(C, \varepsilon) := \varepsilon_\tau
$$

$$
- 1\{\tau = \tau_C < \tau_I\} L_{GD_C}(\varepsilon_I, \tau - C_{\tau^{-}})^+
$$

$$
- 1\{\tau = \tau_I < \tau_C\} L_{GD_I}(\varepsilon_C, \tau - C_{\tau^{-}})^-
$$
Funding and Hedging – I

As fourth and last contribution we consider the funding and hedging procedures and we add their cash flows.

\[
\bar{V}_t(C; F) := \mathbb{E}_t[\Pi(t, T \wedge \tau)] \\
+ \mathbb{E}_t[\gamma(t, T \wedge \tau; C) + 1_{\tau<T}D(t, \tau)\theta_{\tau}(C, \varepsilon)] \\
+ \mathbb{E}_t[\phi(t, T \wedge \tau; F, H)]
\]

where

- \( \rightarrow F_t \) is the cash account for the hedging strategy of the trade,
- \( \rightarrow H_t \) is the risky-asset account implementing the hedging strategy,
- \( \phi(t, u; F, H) \) are the cash \( F \) and hedging \( H \) funding costs up to \( u \).

In classical Black Scholes on Equity, for a call option (no credit risk, no collateral, no funding costs),

\[
\bar{V}_t^{\text{Call}} = \Delta_t S_t + \eta_t B_t =: H_t + F_t, \quad \tau = +\infty, \quad C = \gamma = \varphi = 0.
\]
The cash flows due to the funding and hedging strategy on the time grid \( \{t_j\} \) are equal to

\[
\varphi(t, u) := - \sum_{j=1}^{m-1} 1_{\{t \leq t_j < u\}} D(t, t_j) (F_{t_j} + H_{t_j}) \left( P_{t_j}(t_{j+1})(1 + \alpha_k \tilde{f}_t(t_{j+1})) - 1 \right) \\
+ \sum_{j=1}^{m-1} 1_{\{t \leq t_j < u\}} D(t, t_j) H_{t_j} \left( P_{t_j}(t_{j+1})(1 + \alpha_k \tilde{h}_t(t_{j+1})) - 1 \right)
\]

where the funding and lending rates for \( F \) and \( H \) are given by

\[
\tilde{f}_t := f_t^+ 1_{\{F_t > 0\}} + f_t^- 1_{\{F_t < 0\}} , \quad \tilde{h}_t := h_t^+ 1_{\{H_t > 0\}} + h_t^- 1_{\{H_t < 0\}}
\]
Funding and Hedging – III

Cash is borrowed $F > 0$ from the treasury at an interest $f^+$ (cost) or is lent $F < 0$ at a rate $f^-$ (revenue).

Risky Hedge asset is worth $H$. Cash needed to buy $H > 0$ ie the risky hedge is borrowed at an interest $f$ from the treasury; in this case $H$ can be used for asset lending (Repo for example) at a rate $h^+$ (revenue);

On the other hand if risky hedge is worth $H < 0$, meaning that we should hedge via a short position in the risky asset, we may borrow from the repo market by posting the asset $H$ as guarantee (rate $h^-$, cost), and lend the obtained cash to the treasury to be remunerated at a rate $f$.

It is possible to include the risk of default of the funder and funded, leading to CVA and DVA adjustments for the funding position, see PPB.
Funding rates depend on Treasury policies

- In real applications the funding rate \( \tilde{f}_t \) is determined by the party managing the funding account for the investor, e.g., the bank’s treasury:
  - trading positions may be netted before funding on the mkt
  - a Funds Transfer Pricing (FTP) process may be implemented to gauge the performances of different business units;
  - a maturity transformation rule can be used to link portfolios to effective maturity dates;
  - sources of funding can be mixed into the internal funding curve ...

- In part of the literature the role of the treasury is usually neglected, leading to controversial results particularly when the funding positions are not distinguished from the trading positions.

- See partial claims “funding costs = DVA”, or “there are no funding costs”, cited in the literature (Hull White, ”FVA =0”)

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Adding Collateral Margining Costs and Funding rigorously

The recursive non-decomposable nature of adjusted prices

Recursive non-decomposable Nature of Pricing – I

\[(\ast) \quad \bar{V}_t = \mathbb{E}_t[\Pi(t, T \wedge \tau) + \gamma(t, T \wedge \tau) + 1_{\{\tau < T\}} D(t, \tau)\theta_T(C, \varepsilon) + \varphi(t, T \wedge \tau)]\]

Can we interpret:

\[\mathbb{E}_t[\Pi(t, T \wedge \tau) + 1_{\{\tau < T\}} D(t, \tau)\theta_T(C, \varepsilon)]: \text{RiskFree Price + DVA - CVA?}\]

\[\mathbb{E}_t[\gamma(t, T \wedge \tau) + \varphi(t, T \wedge \tau; F, H)]: \text{Funding adjustment FVA?}\]

Not really. This is not a decomposition. It is an equation. In fact since

\[\bar{V}_t = F_t + H_t(+C_t) \quad \text{(re–hypo)}\]

we see that the \(\varphi\) present value term depends on future

\[F_t = \bar{V}_t - H_t(-C_t)\]

and generally the closeout \(\theta\), via \(\varepsilon\) and \(C\), depends

on future \(\bar{V}\) too. All terms feed each other and there is no neat separation of risks. \textit{Recursive pricing: Nonlinear PDE's / BSDEs for} \(\bar{V}\)

\textit{”FinalPrice = RiskFreePrice (+ DVA?) - CVA - FVA” not possible.}\n
Recursive non-decomposable Nature of Pricing – II

We can obtain a valuation PDE (and BSDE) by further steps:

- Write the equation for $\bar{V}_{t_j}$ starting from $\bar{V}_{t_{j+1}}$, backwards.
- Take the continuous time limit, where funding happens instantaneously and collateral is posted continuously (still gap risk, unless you assume NPV to be left continuous)
- Immersion hypothesis for credit risk: work under default-free filtration $\mathcal{F}_t$, where $\lambda$ is the first-to-default intensity.
- Write the equality in terms of conditional expectations as a BSDEs by completing a martingale term.
- Assume a Markovian vector of underlying assets $S$ (pre-credit and funding) with diffusive generator $\mathcal{L}$, whose second order part is $\mathcal{L}_2$. Let this be associated with a brownian $W$.
- Use Ito’s formula on $\bar{V}(t, S)$ and match $dt$ (and $dW$) terms: obtain PDE (& explicit representation for BSDE term $ZdW$).
Recursive non-decomposable Nature of Pricing – III

This leads to the following PDE with terminal condition \( \bar{V}_T = 0 \).

\[
(\partial_t - \tilde{f}_t - \lambda_t + \mathcal{L}_2) \bar{V}_t + \tilde{f}_t H_t + (\tilde{f}_t - \tilde{c}_t) C_t + \pi_t + \lambda_t \theta(C_t, \bar{V}_t) = 0,
\]

\[
H_t = S_t \frac{\partial \bar{V}_t}{\partial S} \quad \text{(delta hedging)}, \quad \bar{V}_t = H_t + F_t + C_t, \quad \pi_t \, dt = \mathbb{E}_t[\prod(t, t + dt)]
\]

where we assumed \( \tilde{h} = \tilde{f} \) and \( \varepsilon_t = \bar{V}_t \) (replacement closeout).

Alternatively, the funding/credit risk free price can be used for closeout, simplifying calculations.

This PDE is NON-LINEAR not only because of \( \theta \), but especially because \( \tilde{f} \) depends on \( F \), and hence on \( \bar{V} \) itself.

**IMPORTANT:** THIS PDE DOES NOT DEPEND ON \( r \).
The recursive non-decomposable nature of adjusted prices

The structure can be explored further by assuming for example

\[ C_t = \alpha_t \tilde{V}_t, \] with \( \alpha \) being \( \mathcal{F}_t \) adapted and positive

\[ \tilde{f}_t = f_+ 1_{F \geq 0} + f_- 1_{F \leq 0}, \quad \tilde{c}_t = c_+ 1_{\tilde{V}_t \geq 0} + c_- 1_{\tilde{V}_t \leq 0}, \quad f_+, - \text{ and } c_+, - \text{ constants.} \]

One obtains

\[
\partial_t V - f_+ (V - S_t \partial_S V_t - \alpha V)^+ + f_- (-V + S_t \partial_S V_t + \alpha V)^+ - \lambda_t V + \\
+ \frac{1}{2} \sigma^2 S^2 \partial^2_S V - c_+ \alpha_t (V_t)^+ + c_- \alpha_t (-V_t)^+ + \pi_t + \lambda_t \theta_t (V_t) = 0
\]

**NONLINEAR PDE (SEMILINEAR).** \( \lambda \) is the first to default intensity, \( \pi \) is the ongoing dividend cash flow process of the payout, \( \theta \) are the complex optional contractual cash flows at default. \( c_+ \) and \( c_- \) are the borrowing and lending rates for collateral.
We can use Lipschitz coefficients results to investigate \( \exists! \) of viscosity solutions. Classical solutions may also be found but require much stronger assumptions and regularizations.
Recursive non-decomposable Nature of Pricing – VI

Notice that

- if $f_+ = f_- = r$ (symmetric borrowing and lending at the risk free rate),
- $\alpha = 0$ (no collateral),
- $\lambda = 0$ (no credit risk),

then we get back the Black Scholes LINEAR PDE.
Funding: A paradigm shift? 1

NONLINEAR PDEs cannot be solved as Feynman Kac expectations.

Backward Stochastic Differential Equations (BSDEs)
For NPDEs, the correct translation in stochastic terms are BSDEs. The equations have a recursive nature and simulation is quite complicated.

Aggregation–dependent and asymmetric valuation
Valuation of a portfolio is (i) aggregation dependent and (ii) is different for the two parties in a deal. In the classical Black Scholes theory, if we have 2 or more derivatives in a portfolio we can price each separately and then add up (additive decomposition), so (i) is not an issue; moreover, the price to one entity is minus the price to the other one (symmetry), so (ii) is not an issue. Here however (i) and (ii) stand.

Aggregation levels decided a priori and somewhat arbitrarily.
Consistent global modeling across asset classes and risks

Once the level of aggregation is set, the funding valuation problem is non-separable. An holistic approach is needed and consistent modeling across trading desks and asset classes is needed. Internal competition in banks does not favour this.

The law of one price

Charging ”FVA” to the counterparty is controversial, and FVA cannot be bilateral (no symmetry), since we do not know the funding policy of our counterparties. So even if DVA was giving us some hope to realign symmetry of prices under CVA, funding breaks the law of one price and makes prices a matter of perspective. Bid Ask? Equilibrium approach?
Is the funding inclusive “price” a real price? Price and Value

- Each entity computes a different funding adjusted price for the same product.
- The funding adjusted “price” is not a price in the conventional sense, but perhaps it can be reabsorbed into bid offer proceedings implicitly?
- Or we may use it for internal cost/profitability analysis and internal FTP.
- Does it make sense to charge it to a client explicitly? Why should the client pay for our funding inefficiencies?
- Is it more a “value” than a “price”?
Are nonlinearities and aggregation-dependent valuation unavoidable?

- The recursive feature of pricing equations can be avoided by simplified approaches starting either from simplistic spreads in discounting, or from simplistic collateral/closeout rules and symmetric funding rates (FVA).

- This involves double counting and inaccurate valuation but is operationally much simpler, and allows to work through a centralized ”FVA Desk” in a more realistic way.

However, in the accurate picture, the classical transaction-independent arbitrage free price is lost, now the price depends on the specific entities trading the product and on their policies.
Conclusions I

- Shift from complex products on single risk classes to simple products under complex interconnected risks.
- Requires broader culture on bank structure, economics, core finance, etc.; One cannot be a quant by only knowing maths, PDEs, probability and statistics any more.
- Highly specialized hybrid modeling framework. MODEL RISK.
- Bilateral CVA requires a choice of closeout? First to default risk? PAYOUT RISK.
- Gap risk in collateralization remains relevant in presence of strong contagion.
- ... Credit Debit and Funding costs are NOT separable...
- Indeed Funding Costs induce important nonlinearities that make valuation aggregation dependent and the pricing measure deal-dependent.
Conclusions II

- The Funding and Credit adjustments can be included implicitly in term structure models for multiple curve LIBOR vs OIS (B. and Pallavicini, 2013)
- ... and can alter the structure of the bank organization and are politically sensitive
- Basel III will make CVA capital requirements rather severe
- Not clear what will happen to FVA in terms of regulation or fair value accounting rules
- Proper valuation and management of CVA/DVA/FVA requires a Consistent Global Valuation approach because these risks are all INTERCONNECTED.
- CCP onset will prompt for checking initial margins calculations and uncollateralized CVA gap risk MTM over the margin period.
- This is one of the Quantitative Finance challenges of our times

Thank you for your attention!
References I


References IV


References VII


References IX


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Conclusions and References

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