

# OPTIMAL FUNDING STRATEGIES FOR COUNTERPARTY CREDIT RISK LIABILITIES

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ABSTRACT. The Dodd-Frank Act [9] and the recently proposed Basel Committee regulatory framework for CCPs [15] are a game changer for counterparty credit risk management. The practice of charging an upfront fee as a Credit Valuation Adjustment (CVA) to provision against counterparty credit risk liabilities is being abandoned as it was deemed responsible for as much as two thirds of the losses recorded during the financial crisis. Instead, a key role will be played by margin financing, whereby periodically marked-to-market revolving lines of credit are used to cover margin variations on a cross-product basis.

The emerging pay-as-you-go funding strategy for counterparty credit risk liabilities has a fair value equal to the CVA upfront fee but an entirely different risk profile. Using margin financing, the process for expected loss is locked at zero by construction and CVA volatility risk is passed on to the counterparties themselves. As a side effect, wealth is transferred from bankrupt entities to healthy ones. Moreover, in a Dodd-Frank world, there is no DVA because there is no counterparty credit risk and the paradoxes of DVA accounting and CSA discounting are removed.

To further optimize the funding strategy, interest inflows from portfolios of margin revolvers can be redirected through securitization vehicles to a hierarchy of bond holders to which tranches of risk are apportioned. With this construction, banks can purchase nearly full counterparty default protection from capital markets at a fair cost equal to the CVA, the theoretical optimum. The only remaining risk is concentrated in the equity tranche as there could be a mismatch between interest inflows and outflows.

## 1. INTRODUCTION

According to the Basel Committee [13], "roughly two-thirds of counterparty credit risk losses were due to CVA losses and only about one-third were due to actual defaults". In other words, CVA mark-to-market volatility was the single most important source of systemic risk during the crisis, far outweighing the impact of default losses incurred by banks, either in the form of counterparty defaults or through CDO participation. Managing CVA volatility is thus arguably one of the most prominent challenges facing financial institutions at the moment, if not the single most prominent one.

The CVA of a netting set is a price process and as such one should theoretically be able to replicate it given a sufficient number of hedging instruments. Robust replication is however difficult to achieve using macro hedges. A simpler and more effective strategy is to tackle the problem at the structuring level. As we discuss in this article, strategies based on margin financing can be used to achieve robust replication and to immunize bank portfolios from CVA volatility risk.

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Banks typically organize derivative transactions with counterparties under an overarching netting agreement contemplating also a collateral policy. Collateral posting rules are a function of the mark-to-market valuation of the netting set. Problems arise because, typically, the collateral that is posted does not cover the entire mark-to-market variation. Instead, collateral covers only the portion of the mark-to-market gap in excess of a certain trigger level that is either contractually fixed or depends on the rating of the posting counterparty. At all times, there is thus a collateral gap that needs to be risk managed.

The typical solution to manage the collateral gap is for banks to charge a CVA fee on an upfront basis, either explicitly by requesting a cash payment or (more frequently) implicitly by structuring deals off equilibrium and with a non-zero initial fair value designed to precisely offset the fair value of the CVA charge. Although the CVA is the fair cost of replication of counterparty risk liabilities, the CVA charge extracted upfront is often not used for replication but is just posted as a blunt capital reserve. Furthermore, by receiving CVA upfront, banks accept the responsibility of marking-to-market the fair CVA and either replicate its variation or provision additional capital to keep the posted CVA amount at fair level over the life of the netting set. As we discuss below, this strategy results in frequent small gains and occasional large losses which can actually be very sizeable. Although the discounted value of gains and losses average out to zero, at least theoretically, the potential for large losses makes the strategy far from optimal from a liquidity management standpoint as the uninsured rare losses need to be covered at equity cost of funding.

The financial crisis demonstrated that banks' exposure to CVA volatility can be so extreme that they may destabilize the global financial system: as the creditworthiness of counterparties degraded during the crisis, banks were unable to replicate the CVA and had to augment their CVA provision, thus drying up system liquidity in a period when costs of funding were at all time highs.

The Basel III Accord [14] pursues a four-pronged attack in an effort to resolve this difficulty. The final version of the Accord released in December 2010

- supports the industry practice of provisioning CVA upfront and formalizes it as an explicit capital charge,
- introduces an additional capital charge to provision against CVA volatility which is additive across netting sets,
- reasserts the need of posting a separate capital charge to cover unhedged default risk,
- introduces a regulatory framework for Central Counterparties (CCPs) which operate on the basis of full collateralization and are thus exempt from CVA charges altogether.

The Dodd-Frank Act [9] introduces legislation which is expected to induce the 90% of swap transactions to be cleared through CCPs going forward. The timelines for implementation foresee the activation of CCPs worldwide between the second half of the year 2011 and the first half of 2012, see [3]. Even in the non-cleared OTC space, a swaps dealer must collect initial margin and variation margin at levels to be set by CFTC and SEC rule-making ("not less than" comparable cleared trades, with the implication that these levels will be higher than those applicable to comparable cleared trades).

In view of Dodd-Frank and similar legislation being ratified around the world, the Basel III provisions regarding CVA and CVA volatility charges appear to be just a temporary stop-gap solution to ensure a degree of continuity when handling old contracts. Going forward, the current standard of CVA upfront charges will be effectively outlawed and replaced by a full collateralization provision.

Interestingly, the previous March 2010 draft of the Basel III Accord did not include a charge against CVA volatility but envisaged instead a multiplier by a factor 5 to be applied to the baseline CVA charge. Although theoretically the CVA should be sufficient to provide full default protection, the factor 5 was meant to be an empirical adjustment to account for CVA volatility, whose impact was estimated to require a buffer 4 times the size of baseline CVA. The huge size of this buffer reflects how CVA volatility is identified as being truly the element of overwhelming concern for the regulator and the legislator.

Since the CVA is the theoretical optimal cost of replication, the capital charges for CVA volatility and additional charges for default risk exposure reflect the inefficiencies intrinsic in the traditional funding strategy based on CVA upfront fees. In this article, we propose to tackle the problem at the structuring level and show that it is indeed possible to eliminate CVA volatility risk robustly by shifting to a funding strategy based on margin financing which is very natural in a Dodd-Frank world. Securitization and dynamic hedging can then be used to address default risk.

The paper is organized as follows. In section 2, we elaborate on the introduction of central clearing through CCPs and the repercussions this will have on funding strategies for counterparty credit risk liabilities. In section 3, we discuss the mechanics of margin financing and the valuation of margin revolvers. Securitization is discussed in section 4. In section 5, we review additional reasons why the CVA is a faulty risk measure. Conclusions are drawn in section 7.

## 2. IMPACT OF CENTRAL CLEARING ON FUNDING STRATEGIES

In a Dodd-Frank world, most OTC transactions are cleared through a CCP. The margining policy followed by CCPs holds the expected loss to CCPs rigorously at zero and thus eliminates CVA volatility risk to the CCP by passing it on to counterparties. Full collateralization moves the signposts of risk as CVA volatility morphs into variation margin volatility on derivative accounts.

This shift is far from trivial. Firstly, as Duffie explains in [10], CCPs facilitate deal novations in case of an event of default of a market participants, a critical function especially in case the party defaulting is a large derivatives dealer. Secondly, the introduction of CCPs has the equally momentous consequence of eliminating the CVA volatility problem at its root by triggering a radical shift in funding strategies.

Non-bank entities typically own illiquid collateral such as physical assets, while CCPs require them to post highly liquid cash assets. Margin financing is an essential collateral transformation service to provide revolving lines of credit and post collateral on the counterparties' behalf. By the very nature of revolvers, a margin lender would naturally not charge upfront for the service over the lifetime of an individual transaction as is commonly done with CVA fees. Instead, a margin lender would collect a floating rate for funding in the form of LIBOR plus a variable spread which is a function of the counterparties' creditworthiness. Furthermore, margin lending is most naturally implemented on a cross-product basis across an entire netting set, as advocated also in [11]. This structure offsets CVA volatility risk from a bank perspective by transferring the risk to clients themselves, thus cancelling the Basel III capital charges for CVA volatility. Liquidity providers end up retaining only the pure default portion of counterparty credit risk. The risk of portfolios of revolving lines of credit attached to margin accounts is dominated by credit correlation risk and is indifferent to CVA volatility risk. In this scenario, the challenge of CVA hedging and replication vanishes and is replaced by the task of securitizing the cashflow

waterfalls from margin interest payments in such a way to synthesize full protection against default risk.

According to the ISDA [12], "US Companies may face US \$1 trillion in additional capital and liquidity requirements as a result of the Financial Regulatory Reform". On a world scale, the amounts of collateral needed will run in several trillions. The sheer magnitude of the capitals required presents formidable challenges. Although the monetary supply grew throughout the crisis, moneys were not injected as collateral to derivative contracts. Since the emerging regulations foresee that collateral needs to be placed with a custodian and cannot be re-hypothecated, the sterilization of capitals of the required magnitude will undoubtedly have macro-economic effects, offsetting at least in part inflationary pressures. It seems to us that the only viable path for this massive capital reallocation and sterilization to occur is through securitization of counterparty credit risk.

CVA volatility risk is an impediment to even start addressing the problem of optimal funding for default risk and as such it needs to be eliminated first. But even if the CVA was not volatile, CVA provisioning would still be a highly inefficient strategy to fund default risk as it would amount to blunt posting of an equity capital buffer. The optimal funding strategy for default risk instead involves bucketing the loss distribution and funding each bucket separately at a cost given by the corresponding probability of default.

Remarkably enough, in a CCP scenario with margin financing, securitization is implemented naturally as margin interest payments generate a regular flow of interest income which is directed to offset costs of funding on the liability side. Theoretically and assuming arbitrage freedom, the offset is exact on average, except of course that there is a risk that in any given scenario the interest income from margin revolvers does not precisely match the interest outflow on the liabilities side.

Notice that interest income from margin revolvers is anticyclical, i.e. is greater in case of global credit deterioration. In case interest rates on the liabilities side are structured as LIBOR plus a floating spread, a dynamic hedging strategy for interest flows involves going long credit indices, as tightening spreads can give rise to a shortfall in interest income. Since banks are already naturally long credit in aggregate, they could perhaps even choose to avoid active hedging. This is in stark contrast with the current CVA hedging practice which requires banks to short credits, a practice that amplifies systemic risk.

Margin financing is a very natural idea in the CCP context as it is an indispensable transformation tool to make it possible for CCPs to interface with non-bank counterparties. However, in principle the idea of margin financing applies also to non-cleared OTC positions and the benefits from a liquidity management standpoint are the same. From a regulatory angle, if one implements margin financing at the structuring level, the Basel III CVA volatility charge disappears as one achieves perfect hedging by construction. The net fair value of the CVA charge is precisely the same as the net fair value of interest income from margin financing and there is thus no regulation arbitrage on a fair value basis on that front. However, securitization strategies which become viable under margin financing ensure complete protection against default risk and thus avoid the additional default risk charge under Basel III. Once these benefits are fully appreciated and a multi-trillion dollar market for margin financing and revolver securitization structures is established for CCP cleared trades, we predict that margin financing will extend across the entire OTC space and trigger industry-wide restructuring of management practices for counterparty credit risk.

### 3. MARGIN FINANCING

Consider a situation where bank  $B$  and counterparty  $C$  enter into derivative transactions covered by a single netting agreement whose value to  $B$  at time  $t$  is  $N_t$ . Suppose that the netting agreement requires that  $C$  provides full margin coverage at any time, i.e. that  $C$  posts collateral in cash worth  $\max(V_t^C, 0)$  at any time  $t$ . By reciprocity, bank  $B$  posts at all times collateral worth  $\max(-V_t^C, 0)$  to  $C$ , thus immunizing  $C$  from the risk of default by  $B$ .

In order to meet its obligations, counterparty  $C$  asks for margin financing to bank  $A$  and  $A$  agrees to post collateral worth  $\max(V_t^C, 0)$  at any time  $t$  to bank  $B$ . On any given day, as the mark-to-market of the netting set  $V_t^C$  is recomputed, bank  $A$  will post variation margins to bank  $B$ . As a compensation, bank  $A$  receives from counterparty  $C$  an interest payment in the form of LIBOR plus a variable spread which is periodically reset to reflect the creditworthiness of counterparty  $C$ . Similarly, a third bank  $D$  provides a credit revolver to bank  $B$ , posts the amount  $\max(-V_t^C, 0)$  to counterparty  $C$  and is remunerated by bank  $B$  that LIBOR plus a variable funding spread.

Several variations on this scheme are possible.

Bank  $B$  would ideally be replaced by a CCP. Although this is not strictly necessary, a CCP would be best equipped to manage deal novation in case either  $B$  or  $C$  actually default.

Banks  $A$  and  $D$  could also be the same as bank  $B$ , but this is not the only possibility. For instance,  $A$  could be an SPV managed by a private equity fund. The SPV issues liabilities in capital markets, thus effectively securitizing the exposure to attain nearly full default risk protection, while the manager retains a controlling stake in the equity piece.

The credit revolvers could possibly be syndicated and involve several providers. From a pricing standpoint, credit revolvers could be revalued on a daily basis or, to avoid liquidity risk, they could be re-negotiated periodically, e.g. semiannually.

Bank clients often complain of massive pricing differences on trades as a result of CVA fees, possibly a result of inconsistencies in the way CVA fees are calculated across the industry.

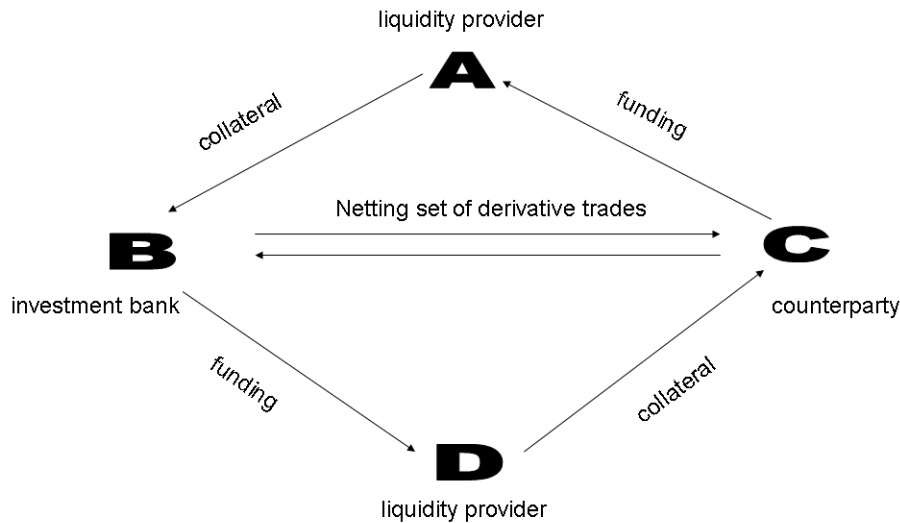


FIGURE 1. Investment bank  $B$  enters in derivative transactions with counterparty  $C$  and both edge the mutual counterparty credit risk by entering into collateral revolvers with liquidity providers  $A$  and  $D$ .

Margin financing resolves the problem at its root as it virtually decouples the role of structurer played by bank *B* from the role of liquidity provider played by bank *A*, thus making it possible for counterparty *C* to request competitive bids for funding rates.

An additional source of risk for bank *B* is to the obligation to pay funding on its own margin financing to bank *D*. If *B* has little exposure to counterparty credit risk, its funding rate could justifiably be low. In case party *B* is actually a CCP, Basel III stipulates that *B* should be considered default-free and it would thus simply post cash collateral in full to cover its negative mark-to-market.

In case *B* is a CCP and *C* is a bank, according to Basel III the bank would not be subject to any CVA capital charge. However, bank *C* still has a liquidity management issue as it is required to post collateral to cover its negative mark-to-market exposure. For this purpose, bank *C* can arrange for margin financing from a third party. This strategy for the bank is essentially equivalent to shorting its own credit, i.e. to buying protection on itself.

In case the CVA is paid upfront and a symmetric DVA charge is subtracted, DVA hedging from the bank standpoint effectively also amounts to buying protection on itself. However, in the case of margin financing this purchase by *C* effectively immunizes *C*'s counterparties from *C*'s default risk. Instead, DVA hedging has the opposite effect as it enhances the competitiveness of lesser creditworthy banks who can offer a discount on the premise that they may walk out from their own commitments!

One can hardly conceive of a situation where a counterparty had an appetite for exposure to the risk of default of bank *B*, especially since *C* is a client of *B*. Forcing *C* to buy such an exposure in exchange for cash upfront in the form of DVA is certainly not clever and it is understandable that the Dodd-Frank act eliminates this practice.

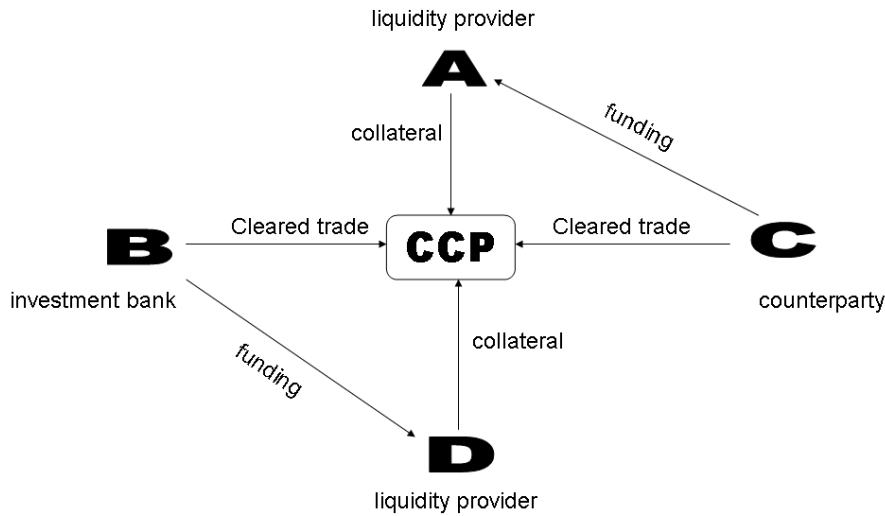


FIGURE 2. Market structure from the standpoint of a CCP.

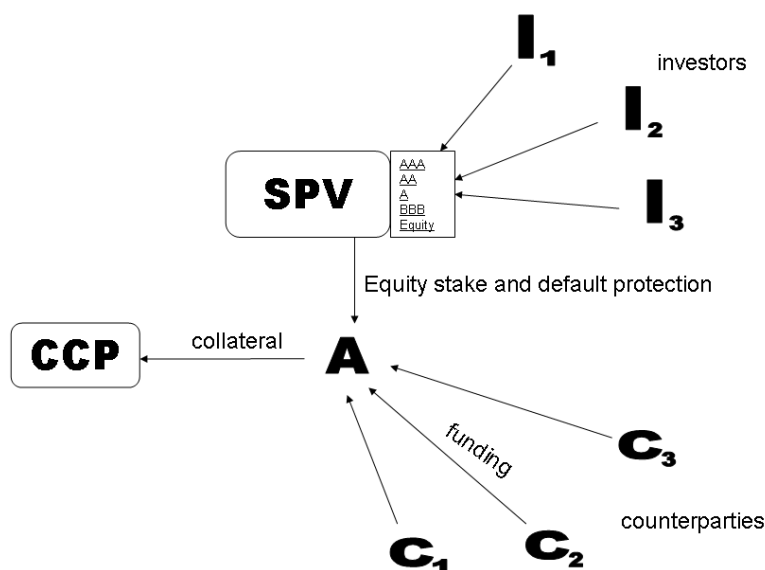


FIGURE 3. Market structure from the standpoint of the provider of margin revolvers.

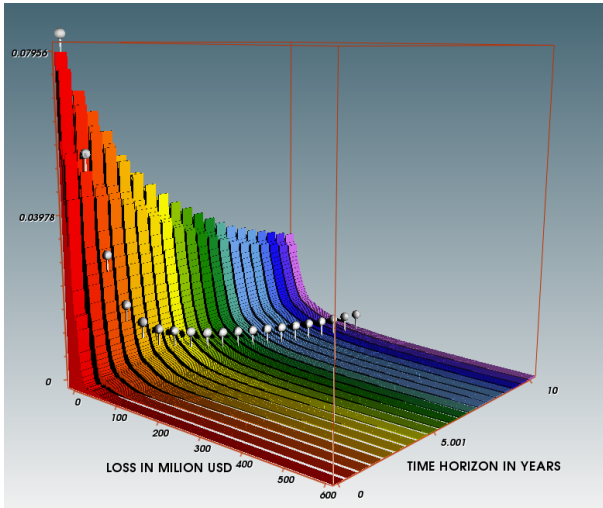
There is also a major difference from the standpoint of accounting treatments: while upon the occurrence of a credit deterioration event for bank  $C$  the mark-to-market variation of the DVA causes a very fictitious paper profit to materialize on  $C$ 's balance sheet, in case one uses margin financing the profit does not exist and instead bank  $C$  is subject to higher funding costs on its own netting sets with negative mark-to-market. On the other hand, in case the credit quality of bank  $C$  improves, no fictitious loss gets recorded on the balance sheet to penalize  $C$  but instead  $C$  witnesses an improvement in its funding costs. In summary, all the paradoxes of DVA accounting are entirely resolved by margin financing.

Since CCPs will operate with daily calls for variation margins, a margin revolver designed for OTC derivatives would naturally involve daily interest payments proportional to the negative mark-to-market. The fair value funding costs for such revolvers of course depend on the credit worthiness of the counterparty and would naturally be allowed to change with time. However, a daily revision of funding costs is not practical and may result in liquidity risk.

A compromise solution is to envisage the use of a stream of revolvers renegotiated periodically, e.g. semiannually, each holding a fixed funding rate within a given period. The structuring of such margin revolvers can take various forms as for instance they may be capped or floored or have both features. Pricing depends on the counterparty credit-worthiness, the underlying derivative exposure and the correlation between the two factors.

#### 4. SECURITIZATION

The strategy of charging the CVA fee upfront not only exposes a bank to CVA volatility risk, but also provides a capital coverage against default risk which is both insufficient and expensive. The figure on the left-hand-side of 5 shows the cumulative loss distribution of a global portfolio of 302 margin revolvers compared with the CVA. The CVA covers counterparty default risk



Rating	1 Year	3Years	5 Years	7 Years	10 Years
AA	302.1 ml	370.8 ml	402.21 ml	441.46 ml	425.76 ml
A	278.54 ml	337.43 ml	374.73 ml	404.17 ml	380.62 ml
BBB	253.03 ml	284.43 ml	309.95 ml	329.58 ml	306.03 ml
BB	80.29 ml	97.96 ml	103.85 ml	107.77 ml	113.66 ml
B	68.52 ml	66.55 ml	66.55 ml	70.48 ml	70.48 ml
CCC	7.67 ml	11.59 ml	13.55 ml	9.63 ml	11.59 ml
CVA	21.59 ml	58.36 ml	105.38 ml	147.22 ml	189.42 ml

FIGURE 4. On the left is the cumulative loss distribution for a portfolio of 302 netting sets. On the right is a table indicating the rating achieved as a function of the capital posted against the portfolio.

on average. However, the extreme skew of the loss distribution and fatness of the tail implies that in most cases the bank seizes a small gain while, more rarely, the bank incurs in a very large loss. In case the loss exceeds the CVA, the bank's treasury will need to post additional capital unexpectedly paying for it the funding rate for equity capital. This is highly inefficient: it amounts to funding default risk entirely at the cost of equity. In this sense, securitization captures funding arbitrage because by passing on tail risk to investors, this is funded at market rates which are much lower by orders of magnitude.

The table on the right hand side in Fig. 5 shows the capital requirement to attain a given rating over various time horizons ranging to up to 10 years for the same global portfolio used to generate the graph on the left hand side. The capital requirements are estimated by taking a rating specific average spread curve and matching the implied probabilities of default. Notice that posting CVA capital achieves a meager CCC rating over 1-3 years horizons and BB rating over maturities in the 5-10 years range.

In a scenario whereby one makes use of margin financing to hedge CVA volatility robustly, default risk still remains lingering and is in fact the dominant source of risk left. The liquidity provider issuing the revolving lines of credit accrues capital buffers from funding interest flows and is then faced with the problem of covering default risk. In this case, the answer to devising an optimal funding strategy will take the form of a securitization structure: the provider will issue a series of liabilities of various different seniority and establish cash waterfall rules to both direct interest income and apportion default losses.

A multi-buffer arrangement as in Fig. 4 is essential for a bank to acquire the broadest risk protection while minimizing funding costs. While the strategy of posting CVA capital exposes the bank to the risk of gains and shortfalls which offset each other on average, securitization allows the bank to minimize the uncertainty deriving from default risk at the cost of spending the entire CVA capital to pay for funding.

The combination of margin financing and securitization is ultimately in the interest of clients themselves and the economy in general. If a bank extracts the CVA fee from a client over time and uses it optimally, it ends up with very little residual risk. In this scenario, the client is fairly

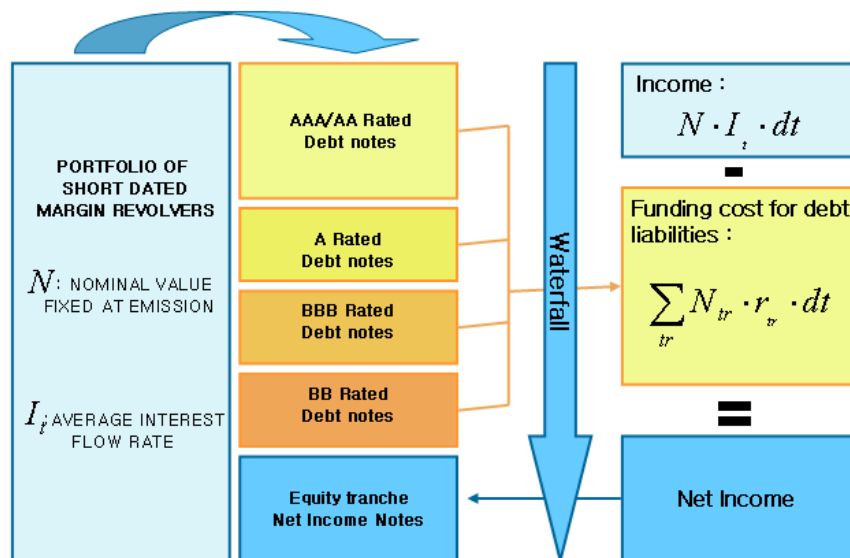


FIGURE 5. Default losses and interest waterfall of a securitization structure for a portfolio of margin revolvers.

charged the cost of the liability engendered by the possibility of its own default. However, his bankruptcy costs will be higher since, on the path to default, the client will need to pay higher and higher funding costs on its portfolio of derivative transactions.

Instead, if the CVA is charged upfront, then additional capital charges to cover for CVA volatility and default risk need to be ultimately passed on to clients. In this scenario, clients are charged much more than the fair value of their own default risk liability. These excess payments are then won back by clients that actually default as, in a system with upfront CVA payment, their bankruptcy costs are lower. With upfront fees and without securitization, CVA volatility and default risk thus becomes a forced lottery deciding major wealth transfer among market participants whereby the winners are the ones who go bankrupt! It is of little consolation that the lottery has even odds: the existence of random wealth transfer toward bankrupt companies greatly reduces the economic benefit of market completion that derives from derivative trading.

## 5. OTHER REASONS WHY THE CVA IS A FAULTY RISK MEASURE

In this article, we showed how a switch to margin financing allows one to optimally fund counterparty default risk liabilities without the need of additional capital. Within Basel III, this can be achieved by either interfacing with CCPs or mimicking CCPs policy of full collateralization. Unless one adopts margin financing though, if one insists on charging CVA upfront one incurs into charges for CVA volatility and counterparty default risk.

The CVA is the theoretical cost of replication of counterparty credit risk. It was introduced for pricing purposes in Sorensen and Bollier [19] and developed in Brigo and Masetti [5] and Brigo and Pallavicini [6] [7] for interest rate swaps and exotics underlyings. Leung and Kwok [16] and Brigo and Chourdakis [4] worked on counterparty risk for credit (CDS) underlyings.

After the crisis, the CVA was elevated to the rank of risk measure for global portfolios of netting sets in an approximate version whereby the CVA figure is fudged from the EPE. Since the CVA is the cost of replication, there should be a mechanism for the bank to receive a cash

flow stream equivalent to CVA, either upfront or via margin financing. However, problems arise when there are *additional* capital requirements determined as a function of the CVA or CVA volatility.

The CVA is inadequate as a risk measure for counterparty risk at the portfolio level primarily because it is additive across netting sets. Only the 1988 version of Basel I used additive risk measures, but that choice was then highly criticized as additive risk measures are blind to diversification. The 1994 Amendment for market risk and in Basel II for credit risk are based on VaR which is a measure for tail risk and is not additive. CVA-based capital rules revert back to a 1980s type of situation.

As an example of the consequences of additive risk measures, consider a case with a Good Bank and a Bad Bank, both holding the same derivatives portfolio  $P$ . Suppose that Bad Bank holds all the exposures in  $P$  against a single counterparty, while Good Bank holds the portfolio  $P$  but is well diversified across thousands of counterparties. Good Bank is more diversified but receives no benefit for that since additive risk measures are indifferent to diversification and correlation. On the other hand, Bad Bank receives the full benefit of netting and is thus required to post less capital than Good Bank. This example shows that, the anti-diversification effect of netting actually rewards risk concentration.

Even the notion of CVA of an individual transaction should actually be questioned. In fact, in the presence of netting agreements, the marginal value of a derivative contract in the background of a portfolio of current holdings is not equal to the value of the contract in isolation. To rigorously value the counterparty risk adjustment for a single instrument, one needs nothing short of a global market simulation for the entire portfolio of holdings and to implement background pricing.

Finally, efforts to hedge and optimize CVA volatility directly as opposed to intervene at the structuring level can also give rise to systemic risk. As Fig. 5 shows, the cumulative loss distribution has a very long tail to the right of the CVA. Most of the mass of the distribution is concentrated upfront in the region of small losses. Hence an effective tactic to mitigate CVA volatility is to transfer risk from the first loss region to tail risk. This sort of procedure should not be encouraged and could possibly give rise to systemic risk as they create moral hazard situations. To mitigate systemic risk one should instead encourage the the transfer of tail risk and reward diversified portfolios where tail risk is properly managed.

## 6. MODELS

The implementation of the hedging strategies in this paper depends on the use of global valuation models and global market simulations to price margin revolvers and to form securitization structures, see [1] for details. We work exclusively under the risk neutral measure, a prudent choice which overstates default risk. No major or uncontrollable mathematical approximations are introduced as every risk factor is modelled dynamically. Of course there is model risk, as in any calibrated model, but we make an effort to minimize it by choosing high quality models, free from the analytic solvability constraint, and estimate models so that they fit derivative prices and are in qualitative agreement with historical time series.

In recent time, there has been much debate in the literature about the propriety of using risk neutral discounting for derivatives valuation in a situation where one accounts for counterparty credit risk. On the one hand, Pieterbarg notices in [18] that if a deductible entity attempts replication, they will be subject to a cost of unsecured funding for borrowing which is strictly higher than the risk free rate. He thus proposes to view derivative price processes are discounted

martingales not with respect to the risk free interest rate process, but with respect to the process for an unsecured money market account. In formulas, one would use the formula

$$(6.1) \quad A_t = E_t \left[ e^{-\int_t^T r_s^F ds} A_T \right]$$

where  $t < T$  and  $r_t^F$  is the short rate for unsecured funding for bank B.

In [17], Morini and Prampolini notice that accounting for the DVA charge is precisely equivalent to introducing CSA discounting in the special case of a bond, while in the more general case of an arbitrary payoff there are differences. A bit of a puzzle turns up in this context as in a Dodd-Frank world, the DVA disappears and is replaced with margin financing fees.

In case B is a bank and replicates perfectly, its global portfolio is worth zero at all times and as a consequence B pays no margin financing fees. Hence, a derivatives dealer that replicates should value derivatives using the risk-free discount rate. On the other hand, a derivatives dealer who does not replicate perfectly or is engaged in other risky activities and thus is subject to default risk, cannot execute perfect replication strategies as replication might be compromised by its own default. Hence, a defaultable entity cannot value a derivative as its cost of replication.

In case B is a CCP, B will post derivative prices at all times and be ready to trade at these prices. In this case, prices are subject to the non-arbitrage consistency condition and de Finetti's Fundamental Theorem of Finance holds, see [8] or also [2] for a modern account. In this case replicability does not enter and the arbitrage free value of a derivative is given by the discounted expectation of future payoffs under the risk-free risk neutral measure. It is not possible to use the unsecured cost of funding in equation 6.1 as the unsecured deposit account with daily interest updates borrowed by a defaultable entity is not an acceptable numeraire as it can possibly vanish with non-zero probability.

We conclude that only risk free discounting using fully collateralized borrowing and lending is legitimate for the valuation of derivative transactions.

Global valuation is another issue that comes to bear in this context. According to de Finetti's Fundamental Theorem [8], the only consistent way of valuing a derivative portfolio is to infer a unique martingale measure under which to price all assets. Instead, in [1] Lipton, Pieterbarg and Bergomi advocate the practice of local valuation whereby a portfolio is priced using a different model for each transaction. A theoretical justification of local valuation may be attempted in the situation in which B is a CCP and it has several member banks which provide competitive quotes for a number of derivatives whose prices are posted by the CCP. Even under the Fundamental Theorem, each member bank is legitimated to use a different valuation model since the martingale measure is required only to exist, but there is no guarantee that it is unique.

An arbitrageur interfacing with the CCP will use a global model to take advantage of pricing inconsistencies. Moreover, local valuation is not an option for dealer A who has to manage a portfolio of margin revolvers. From A's viewpoint, the only valuation task which makes sense is the valuation of a netting set: in fact the marginal price of a derivative transaction added to a netting set depends on the netting set itself, i.e. pricing is not linear from A's standpoint.

Another reason why global valuation is essential for A is computing performance. As explained in the technical paper [1], the task of pricing and securitizing large portfolios of netting sets accounting for credit correlations is computationally very challenging. The scale of the task is such that scaling properties of valuation algorithms is an essential part of the solution of the problem. The standard grid computing architectures which are commonly used assure linear scaling in the best case scenario. Our experience is that linear scaling is not sufficient. In order

to tackle global portfolios of netting sets, one needs to optimize the valuation algorithm in such a way to achieve markedly sub-linear scaling properties, so that the incremental cost of pricing another derivative decreases rapidly with the portfolio size. The key to achieve sub-linearity is to split out valuation tasks into a number of elementary computational building blocks which can be recycled across many individual transactions in the portfolios. To achieve this objective, one requires to move from a grid farm to single node technology in a shared memory architecture and to use a global valuation model.

## 7. CONCLUSIONS

This article discusses funding strategies for counterparty credit risk based on margin financing and securitization. We argue that such strategies allow banks to efficiently lay off both CVA volatility risk and counterparty default risk with minimal residual risk.

Much of the risk can be transferred by proper structuring. Global market simulation engines for global portfolios are needed to project out cumulative loss distribution of cash waterfalls and assist with structuring and risk management.

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