Being two-faced over counterparty credit risk

*A recent trend in quantifying counterparty credit risk for over-the-counter derivatives has involved taking into account the bilateral nature of the risk so that an institution would consider their counterparty risk to be reduced in line with their own default probability. This can cause a derivatives portfolio with counterparty risk to be more valuable than the equivalent risk-free positions. In this article, **Jon Gregory** discusses the bilateral pricing of counterparty risk and presents an approach that accounts for default of both parties. He derives pricing formulas and then argues that the full implications of pricing bilateral counterparty risk must be carefully considered before it is naively applied for risk quantification and pricing purposes*

Counterparty credit risk is the risk that a counterparty in a financial contract will default prior to the expiry of the contract and fail to make future payments. Counterparty risk is taken by each party in an over-the-counter derivatives contract and is present in all asset classes, including interest rates, foreign exchange, equity derivatives, commodities and credit derivatives. Given the recent decline in credit quality and heterogeneous concentration of credit exposure, the high-profile defaults of Enron, Parmalat, Bear Stearns and Lehman Brothers, and writedowns associated with insurance purchased from monoline insurance companies, the topic of counterparty risk management remains ever-important.

A typical financial institution, while making use of risk mitigants such as collateralisation and netting, will still take a significant amount of counterparty risk, which needs to be priced and risk-managed appropriately. Over the past decade, some financial institutions have built up their capabilities for handling counterparty risk and active hedging has also become common, largely in the form of buying credit default swap (CDS) protection to mitigate large exposures (or future exposures). Some financial institutions have a dedicated unit that charges a premium to each business line and in return takes on the counterparty risk of each new trade, taking advantage of portfolio-level risk mitigants such as netting and collateralisation. Such units might operate partly on an actuarial basis, utilising the diversification benefits of the exposures, and partly on a risk-neutral basis, hedging key risks such as default and forex volatility.

A typical counterparty risk business line will have significant reserves held against some proportion of expected and unexpected losses, taking into account hedges. The recent significant increases in credit spreads, especially in the financial markets, will have increased such reserves and/or future hedging costs associated with counterparty risk. It is perhaps not surprising that many institutions, notably banks, are increasingly considering the two-sided or bilateral nature when quantifying counterparty risk. A clear advantage of doing this is that it will dampen the impact of credit spread increases by offsetting mark-to-market losses arising, for example, from increases in required reserves. However, it requires an institution to attach economic value to its own default, just as it may expect to make an economic loss when one of its counterparties defaults. While it is true a corporation does 'gain' from its own default, it might seem strange to take this into account from a pricing perspective. In this article, we will make a quantitative analysis of the pricing of counterparty risk and use this to draw conclusions about the validity of bilateral pricing.

Unilateral counterparty risk

The reader is referred to Pykhtin & Zhu (2006) for an excellent overview of measuring counterparty risk. We denote by $V(s, T)$ the value at time s of a derivatives position with a final maturity date of T. The value of the position is known with certainty at the current time $t(< s \leq T)$. We note that the analysis is general in the sense that $V(s, T)$ could indicate the value of a single derivatives position or a portfolio of netted positions[1], and could also incorporate effects such as collateralisation. In the event of default, an institution must consider the following two situations:

- $V(s, T) > 0$. In this case, since the netted trades are in the institution's favour (positive present value), it will close out the position but retrieve only a recovery value, $V(s, T)\delta_C$, with δ_C a percentage recovery fraction.
- $V(s, T) \leq 0$. In this case, since the netted trades are valued against the institution, it is still obliged to settle the outstanding amount (it does not gain from the counterparty defaulting).

[1] *We note that since exposures within netted portfolios are linear then this case is suitably general*

We can therefore write the payout[2] in default as $\delta_C V(\tau_C, T)^+ + V(\tau_C, T)^-$ where τ_C is the default time of the counterparty. The risky value of a trade or portfolio of trades where the counterparty may default at some time in the future is then:

$$\tilde{V}(t,T) = E_t\Big[1_{\tau_C > T} V(t,T) + 1_{\tau_C \le T} \Big(V(t,\tau_C) + \delta_C V(\tau_C,T)^+ + V(\tau_C,T)^-\Big)\Big] \quad (1)$$

The first term in the expectation is simply the risk-free value conditional upon no default before the final maturity. The second component $1_{\tau_C \le T} V(t, \tau_C)$ corresponds to the cashflows paid up to[3] the default time. The final components can be identified as the default payout as described above.

Rearranging the above equation, we obtain:

$$\begin{aligned}
&\tilde{V}(t,T) \\
&= E_t\Big[1_{\tau_C > T} V(t,T) + 1_{\tau_C \le T} \Big(V(t,\tau_C) + \delta_C V(\tau_C,T)^+ + V(\tau_C,T) - V(\tau_C,T)^+\Big)\Big] \\
&= E_t\Big[1_{\tau_C > T} V(t,T) + 1_{\tau_C \le T} V(t,T) + 1_{\tau_C \le T}\Big(\delta_C V(\tau_C,T)^+ - V(\tau_C,T)^+\Big)\Big] \\
&= V(t,T) - E_t\Big[1_{\tau_C \le T}(1-\delta_C) V(\tau_C,T)^+\Big]
\end{aligned} \quad (2)$$

This allows us to express the risky value as the risk-free value less an additional component. This component is often referred to (see, for example, Pykhtin & Zhu, 2006) as the credit value adjustment (CVA). As first discussed by Sorensen & Bollier (1994), an analogy is often made that the counterparty is long a series of options. Let us denote the standard CVA in this unilateral case as:

$$CVA_{unilateral} = E_t\Big[1_{\tau_C \le T}(1-\delta_C) V(\tau,T)^+\Big] \quad (3)$$

We might calculate the expectation under the risk-neutral (Q) or the real probability measure (P), in the latter case using historical analysis rather than market-implied parameters. Traditionally, the real measure is used in risk management applications involving modelling future events such as exposures. However, since the default component of the CVA is likely to be hedged, the risk-neutral measure is more appropriate. Since most counterparty risk books may hedge only the major risks and are therefore part risk-neutral, part real we can note that the choice of measure to use in equation (3) is a rather subtle point.

Bilateral counterparty risk – no simultaneous defaults

The unilateral treatment neglects the fact that an institution may default before its counterparty, in which case the latter default would become irrelevant. Furthermore, the institution actually gains following its own default since it will pay the counterparty only a fraction of the value of the contract. The payout to the institution in its own default is $\delta_I V(\tau_I, T)^- + V(\tau_I, T)^+$ with τ_I and δ_I representing its own default time and associated recovery percentage (to its counterparties) respectively.

Denoting by $\tau^1 = \min(\tau_C, \tau_I)$ the 'first-to-default' time of both the institution and counterparty, and assuming that simultaneous defaults are not possible, the valuation equation becomes:

$$\begin{aligned}
&\tilde{V}(t,T) \\
&= E_t\left[1_{\tau^1 > T} V(t,T) + 1_{\tau^1 \le T}\begin{pmatrix} V(t,\tau^1) + \\ 1_{\tau^1 = \tau_C}\Big(\delta_C V(\tau^1,T)^+ + V(\tau^1,T)^-\Big) + \\ 1_{\tau^1 = \tau_I}\Big(\delta_I V(\tau^1,T)^- + V(\tau^1,T)^+\Big)\end{pmatrix}\right] \\
&= V(t,T) \\
&- E_t\Big[1_{\tau^1 \le T}\Big(1_{\tau^1 = \tau_C}(1-\delta_C) V(\tau^1,T)^+ + 1_{\tau^1 = \tau_I}(1-\delta_I) V(\tau^1,T)^-\Big)\Big]
\end{aligned} \quad (4)$$

We can identify the first component in equation (4) as being the same adjustment as before conditioned on no default of the institution. The additional term corresponds to the gain made by the institution in the event of its default (conditional on no previous counterparty default). Using the Sorensen & Bollier (1994) analogy, the institution is then also long a series of options on the reverse contract. We note that the mean of the future distribution of $V(\tau^1, T)$ (for example, due to forward rates being far from spot rates) will be important in determining the relative value of the two terms above in addition to the individual default probabilities.

Bilateral counterparty risk – with simultaneous defaults

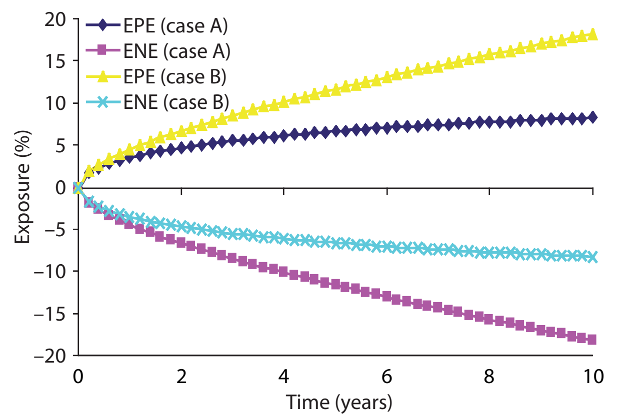
For the reader to gain some insight into bilateral CVA, we extend the formula to allow for a simultaneous default of both parties at a time denoted by τ. One motivation for this is that super-senior tranched credit protection has for the past year traded at significant premiums. For example, in the case of the 30–100% tranche on the CDX IG index, 54 out of 125 investment-grade defaults[4] are required to cause a loss on the tranche and yet the five-year maturity tranche has for the past year traded at a premium of around 50 basis points a year (a significant proportion of many financial spreads). The price of such protection is often modelled through a catastrophic event causing many simultaneous (or closely clustered) default events. The joint default representation can also be thought of as a simple way to introduce systemic over idiosyncratic risk.

With joint default of the counterparty and institution, the valuation formula becomes:

$$\begin{aligned}
&\tilde{V}(t,T) \\
&= E_t\left[1_{\tau^1 > T} V(t,T) + 1_{\tau^1 \le T}\begin{pmatrix} V(t,\tau^1) + \\ 1_{\tau^1 = \tau_C}\Big(\delta_C V(\tau^1,T)^+ + V(\tau^1,T)^-\Big) + \\ 1_{\tau^1 = \tau_A}\Big(\delta_I V(\tau^1,T)^- + V(\tau^1,T)^+\Big) + \\ 1_{\tau^1 = \tau}\Big(\delta_C V(\tau^1,T)^+ + \delta_I V(\tau^1,T)^-\Big)\end{pmatrix}\right] \\
&= V(t,T) \\
&- E_t\left[1_{\tau^1 \le T}\begin{pmatrix} 1_{\tau^1 = \tau_C}(1-\delta_C) V(\tau^1,T)^+ + \\ 1_{\tau^1 = \tau_A}(1-\delta_I) V(\tau^1,T)^- \\ 1_{\tau^1 = \tau}\Big(V(\tau^1,T) - \delta_C V(\tau^1,T)^+ - \delta_I V(\tau^1,T)^-\Big)\end{pmatrix}\right] \\
&= V(t,T) - CVA_{bilateral}
\end{aligned} \quad (5)$$

[2] *We use the notation $x^+ = \max(x, 0)$ and $x^- = \min(x, 0)$*
[3] *Strictly speaking, $V(t, \tau_C)$ corresponds to cashflows paid before the default time of the counterparty but for the sake of brevity we do not introduce additional notation*
[4] *This assumes an average recovery value of 40%*

1 Expected exposure profiles for case A and case B with $\mu = -1\%, \sigma = 10\%$ and $\mu = 1\%, \sigma = 10\%$ respectively



with $\tau^1 = \min(\tau_C, \tau_I, \tau)$. The final term corresponds to the fact that in the event of joint default, the value of the derivatives position is essentially cancelled, with a recovery value paid to whichever party is owed money. It can be seen that an overall positive (negative) CVA will increase (decrease) with increasing joint default probability.[5]

We will make the common assumption that the default times and value of the derivatives portfolio are independent. This is a rather standard simplification in the case that there is not obvious 'wrong-way risk' (which clearly exists in credit derivatives and certain other cases).[6] The most straightforward way to calculate the expectation in equation (5) is by discretisation over a suitable time grid $[t_0 = t, t_1, \ldots, t_{m-1}, t_m = T]$. With this and the independence assumption we obtain:

$$\begin{aligned} &CVA_{bilateral} \approx \\ &\sum_{i=1}^{m} Q\left(\tau_C \in [t_{i-1}, t_i], \tau_I > t_i, \tau > t_i\right) E_t\left[\left(1-\delta_C\right) V\left(\tau_C, T\right)^+\right] + \\ &\sum_{i=1}^{m} Q\left(\tau_I \in [t_{i-1}, t_i], \tau_C > t_i, \tau > t_i\right) E_t\left[\left(1-\delta_I\right) V\left(\tau_I, T\right)^-\right] + \\ &\sum_{i=1}^{m} Q\left(\tau \in [t_{i-1}, t_i], \tau_C > t_i, \tau_I > t_i\right) \\ &\quad E_t\left[V(\tau, T) - \delta_C V(\tau, T)^+ - \delta_I V(\tau, T)^-\right] \end{aligned} \tag{6}$$

Example

We now present a simple example[7] assuming that the counterparty and institution default probabilities (conditional on no joint default) are correlated according to a Gaussian copula. The correlation parameter is denoted by ρ. Following the Gaussian correlation assumption between τ_C and τ_I and the independence of τ, the above probabilities can be readily calculated, for example:

$$\begin{aligned} &Q\left(\tau_C \in [t_{i-1}, t_i], \tau_I > t_i, \tau > t_i\right) \\ &= Q\left(\tau_C > t_{i-1}, \tau_I > t_i, \tau > t_i\right) - Q\left(\tau_C > t_i, \tau_I > t_i, \tau > t_i\right) \\ &= \begin{bmatrix} N_{2d}\left(N^{-1}\left(Q\left(\tau_C > t_{i-1}\right)\right), N^{-1}\left(Q\left(\tau_I > t_i\right)\right); \rho\right) \\ -N_{2d}\left(N^{-1}\left(Q\left(\tau_C > t_i\right)\right), N^{-1}\left(Q\left(\tau_I > t_i\right)\right); \rho\right) \end{bmatrix} Q\left(\tau > t_i\right) \end{aligned} \tag{7}$$

where $N(\cdot)$ and $N_{2d}(\cdot)$ represent the univariate and bivariate cumulative normal distribution functions.

A. Unilateral and bilateral CVA values for case A and case B under the assumption of independence

	Case A	Case B
Unilateral	0.668%	2.140%
Unilateral adjusted	0.535%	1.902%
Bilateral	−1.366%	1.366%

We assume that the probabilities of default are determined by:

$$Q\left(\tau_C > s\right) = \exp\left[-\left(\lambda_C - \lambda\right)s\right], \quad \lambda_C \geq \lambda \tag{8a}$$

$$Q\left(\tau_I > s\right) = \exp\left[-\left(\lambda_I - \lambda\right)s\right], \quad \lambda_I \geq \lambda \tag{8b}$$

$$Q\left(\tau > s\right) = \exp\left[-\lambda s\right] \tag{8c}$$

where λ_C, λ_I and λ are deterministic default intensities that could readily be made time-dependent or, in a more complex approach, stochastic. The joint default probability, λ, could be calculated from the prices of *n*th to default baskets or (under the assumption that this will be a systemic event) senior tranches of a relevant credit index. Subsequently, λ_C and λ_I can be calibrated to the CDS spreads and recovery rates of the counterparty and institution respectively. Since derivatives under standard International Swaps and Derivatives Association documentation are *pari passu* with senior debt[8], a cancellation effect means we do not expect a considerable impact from differing recovery assumptions.

We finally use the simple representation[9]:

$$V(s,T) = \mu(s-t) + \sigma\sqrt{s-t}Z$$

where μ and σ are drift[10] and volatility parameters respectively and Z is a random variable drawn from a standard normal distribution. The simple assumptions above allow us to calculate the required exposure quantities as:

$$E_t\left[V(s,T)^+\right] = \mu\Delta x N\left(\mu\sqrt{\Delta x}/\sigma\right) + \sigma\sqrt{\Delta x}\varphi\left(\mu\sqrt{\Delta x}/\sigma\right) \tag{9a}$$

$$E_t\left[V(s,T)^-\right] = -\mu\Delta x N\left(\mu\sqrt{\Delta x}/\sigma\right) - \sigma\sqrt{\Delta x}\varphi\left(\mu\sqrt{\Delta x}/\sigma\right) \tag{9b}$$

$$\Delta x = s - t$$

where $\varphi(\cdot)$ represents the normal density function. These components are typically known as the expected positive exposure (EPE) and the expected negative exposure (ENE). Under the independence assumptions, interest rates simply amount to multiplicative

[5] *This follows from* $V(\tau, T) - \delta_C V(\tau, T)^+ - \delta_I V(\tau, T)^- = (1 - \delta_C)V(\tau, T)^+ + (1 - \delta_I)V(\tau, T)^-$

[6] *As noted before, the approach described here could be combined with a 'wrong-way risk' approach such as in Cherubini & Luciano (2002)*

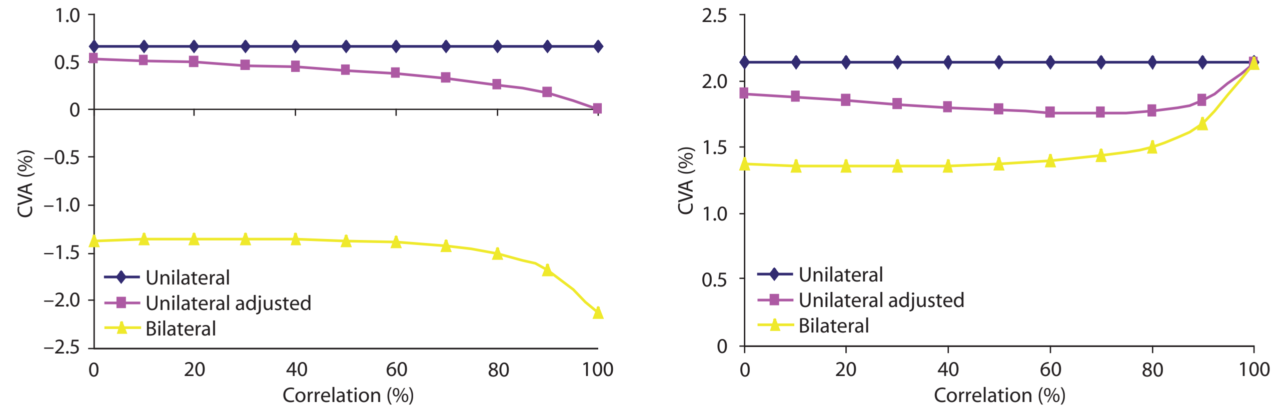
[7] *A spreadsheet with an implementation of the simple model is available from the author on request.*

[8] *We note that there is some additional complexity regarding this point. Firstly, since CDS protection buyers must buy bonds to deliver, a 'delivery squeeze' can occur if there is more CDS notional in the market than outstanding deliverable bonds. In this case, the bond price can be bid up and suppress the value of the CDS hedging instrument. This has been seen in many recent defaults such as Parmalat (2003) and Delphi (2005), and for many counterparties the amount of CDSs traded is indeed larger than available pool of bonds. We also note that while CDSs are settled shortly after default, derivatives claims go through a workout process that can last years*

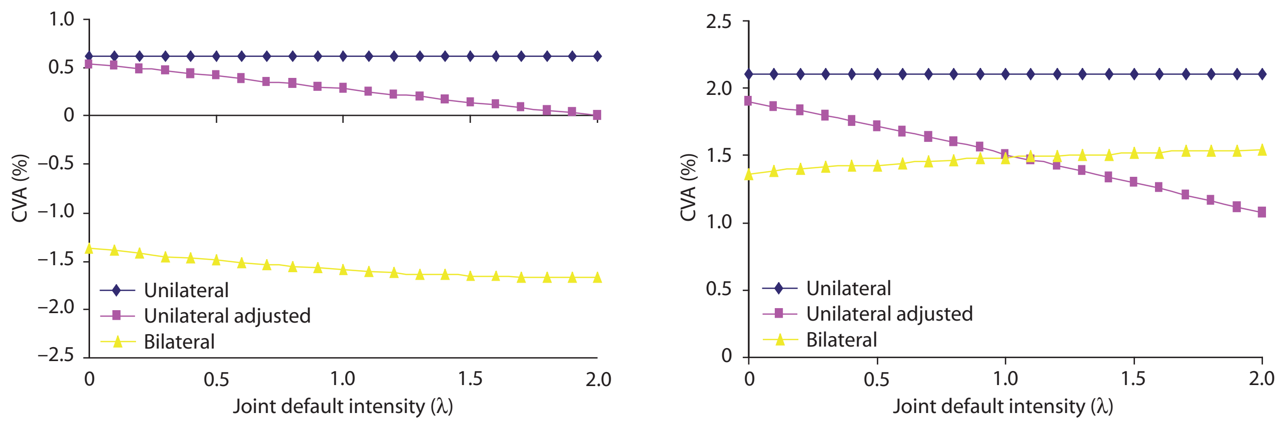
[9] *For single cashflow products, such as forex forwards, or products with a final large cashflow, such as the exchange of principal in a cross-currency swap, the maximum exposure occurs at the maturity of the transaction and this formula proves a good proxy for the typical exposure. Products with multiple cashflows, such as interest rate swaps, typically have a peak exposure between one half and one third of the maturity. We note that the exposure of the same instrument may also vary significantly due to market conditions such as the shape of yield curves. We have confirmed that the qualitative conclusions do not depend on the precise exposure profile chosen*

[10] *Given the risk-neutral setting,* $V(s, T)$ *should be a martingale and therefore determined uniquely by the relevant forward rates for the product in question. We note that some institutions follow the practice of modelling exposure under the physical measure*

2 CVA as a function of correlation between counterparty and institution default for case A (left) and case B (right)



3 CVA as a function of the systemic spread intensity with zero correlation for case A (left) and case B (right)



components via discount factors, and thus to simplify and aid reproduction of the results, we ignore them.

Let us assume a maturity of 10 years, that $\delta_C = \delta_I = 40\%$ and define two parameter sets[11]:

- Case A: $\mu = -1\%$, $\sigma = 10\%$, $\lambda_C = 2\%$, $\lambda_I = 4\%$.
- Case B: $\mu = +1\%$, $\sigma = 10\%$, $\lambda_C = 4\%$, $\lambda_I = 2\%$.

The (symmetric) exposure for profiles EPE and ENE are shown in figure 1.

We will consider three distinct CVA measures outlined below:

- **Unilateral.** This is the standard unilateral formula given in equation (3).
- **Adjusted unilateral.** This is the unilateral adjustment but taking into account the default probability of the institution, that is, this is the first term in equation (6) with no negative contribution as can arise from the second and third terms.
- **Bilateral.** The bilateral CVA given by equation (6).

Initially we assume zero correlation and zero joint default probability, $\rho = \lambda = 0$, and show the three CVA values in table A.

Case A represents a situation where the bilateral CVA is negative due to the institution's higher default probability and the high chance that they will owe money on the contract (negative exposure due to $\mu = -1\%$). Case B is the opposite case and, since the counterparty is more risky than the institution, the bilateral CVA is reduced by only around one third compared with the unilateral case. We see that, since case A and case B represent equal and opposite scenarios for each party, the sum of the bilateral adjustments is zero.

Now we show the impact of correlation on the CVA. As shown in figure 2, correlation can have a reasonably significant impact on both the unilateral and bilateral values. As correlation increases, we approach comonotonicity, where the more risky credit is sure to default first. This means that, in case A, the unilateral adjusted CVA goes to zero (the institution is sure to default first) while in case B it converges to the pure unilateral value (the counterparty is sure to default first).

Let us finally consider the impact of joint default in figure 3, which illustrates the three CVA components versus the joint default intensity, $\lambda \leq \min(\lambda_C, \lambda_I)$. We see that joint default plays a similar role to that of correlation but does not have a significant impact on the bilateral CVA. This illustrates, importantly, that even with high joint default probability (systemic component), a substantial portion of the bilateral benefit comes from the idiosyncratic component, a point that is particularly acute in case A.

Bilateral or unilateral?

An obvious implication of the bilateral formula is that the overall CVA may be negative, that is, actually increase the overall value of the derivatives position(s). Another result of the above symmetry is that the overall amount of counterparty risk in the market would be zero.[12] While this symmetry or the bilateral risk might

[11] *The constant intensities of default are approximately related to CDS premiums via* $\lambda(1 - \delta)$

[12] *This assumes that all parties have the same pricing measure in which case the two sides to a trade or netted portfolio of trades will always have equal and opposite CVAs*

seem reasonable and clean, let us consider the associated hedging issues. While the default component of the unilateral CVA is often hedged by buying CDS protection on the counterparty, the additional term in the bilateral formula would require an institution to sell CDS protection on themselves (or trading their credit quality in some other way such as by shorting their own stock). Even using the 'adjusted unilateral' CVA is debatable on hedging grounds since the relevant hedging instruments do not exist (for example, an institution buying CDS protection that cancels if they themselves default).

Since hedging arguments do not support the use of a bilateral CVA, let us consider the ways in which the bilateral reduction to the CVA could be monetarised.

- **File for bankruptcy.** An institution can obviously realise the bilateral reduction by going into bankruptcy but since the component is directly related to default this is a circular argument. Consider a firm with a bilateral counterparty benefit so substantial that it can prevent their bankruptcy. Yet going into bankruptcy is the only way to realise the bilateral counterparty risk gain!
- **Get very close to bankruptcy.** The institution may realise bilateral CVA if a trade is unwound at some point, probably due to their heavily declining credit quality. For example, recently some monolines have gained from banks unwinding senior credit insurance and realising large CVA-related losses. However, we would suggest that an institution would need to be in severe financial distress and not expected to survive before being able to recognise gains in this way. Indeed, one way of interpreting the failure of monolines is through a naive use of bilateral counterparty risk pricing.
- **Beta hedging.** While it is not possible for an institution to sell CDS protection on themselves, they could instead sell protection on a highly correlated credit or credits; for example, banks might sell CDS protection on (a portfolio of) other banks.[13] However, we note that a hedging instrument is required so that an institution makes money when its credit spread widens (and vice versa). Our view is that this is problematic, especially since the calculations earlier showed that the bilateral CVA was not strongly sensitive to the joint default – an illustration that the idiosyncratic component of the spread constitutes the significant proportion of the bilateral CVA. We also point out that institutions wishing to sell protection on credits highly correlated with their own creditworthiness will lead to an increase in the overall amount of counterparty risk in the market.
- **Set against (future) funding costs.** An institution might argue that their bilateral counterparty risk position represents a good hedge for their funding costs. If their spread has widened and their funding costs therefore increased, they will have made gains on their bilateral counterparty risk due to the beneficial impact of an increase in their own default probability in the bilateral CVA formula. Again, this is true, but the argument is somewhat tenuous as there is no direct link between the magnitude of an institution's counterparty risk and their funding requirements.

Appropriate pricing and risk management of counterparty risk is a key area for financial institutions, and controlling the level of reserves and cost of hedging is critical in turbulent times. However, realistic pricing and management of risk should always be the key objective. While standard risk-neutral pricing arguments lead to a reduction of counterparty risk charges (CVA) in line with the default probability of an institution, the question of how to monetarise this component should be carefully considered. Arguments that the bilateral counterparty risk can be beta hedged, realised when an institution is in severe financial distress, or represents an offset to future funding costs are in our view simply not strong enough to justify the widespread use of bilateral CVA.

Conclusion

We have presented an overview of bilateral counterparty risk pricing. Using a model that represents a simple extension of standard counterparty risk pricing approaches, we have illustrated pricing behaviour and considered the impact of default of both parties. Such ideas can readily be incorporated into counterparty risk pricing and management functions in order to attempt a reasonable treatment of the bilateral nature of this risk.

Should therefore an institution post profits linked to their own worsening credit quality? Standard valuation of contingent claims that have a payout linked to an institution's own bankruptcy may give some mathematically appealing and symmetric results. However, in practice, an institution attaching economic value to their own default (and indeed gaining when their own credit quality worsens) may be simply fooling themseves and storing up greater problems in the future.

A problem with using only unilateral CVA for pricing counterparty risk is that in many cases parties will simply not be able to agree a price for a trade. However, this is a strong argument for better collateral management functions or a central clearing house for counterparty risk and not for the naive introduction of bilateral CVA pricing.

Bilateral counterparty risk pricing has become standard in the market and agreed upon by all relevant parties (practitioners, accountants, regulators, tax officers and legal). Given some of the lessons learnt from the credit crunch, such as the issues with monolines insurers, we suggest that a sanity check on the validity of using bilateral counterparty risk quantification is appropriate. ■

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A spreadsheet with the model-based calculations from this article is available from the author on request. Email: jon-gregory@supanet.com

[13] *But in doing so, the bank should expect to incur a relatively large CVA on the hedge*

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