Counterparty trading limits revisited: from PFE to PFL

The potential future exposure (PFE) for counterparty trading limits is challenged by new market developments, notably widespread regulatory initial margin, and netting of trade and collateral flows. However, Chris Kenyon, Mourad Berrahoui and Benjamin Poncet believe PFE already has many issues, such as comparability across counterparties. The authors introduce potential future loss (PFL), which combines expected shortfall and loss given default as a replacement for PFE, and provide extensions to cover the main issues with PFE

The utility of potential future exposure (PFE) for counterparty trading limits is being challenged by new market developments, notably widespread regulatory initial margin (IM) (BCBS 2015), and netting of trade and collateral flows (eg, via SwapAgent, (LCH 2018)). However, PFE already has challenges: counterparty trading limits are not comparable across counterparties because of varying recovery rates as well as different loss distributions above the reference quantile for PFE. In addition, PFE limits are typically changed when a collateral agreement (the Credit Support Annex, or CSA, of the International Swaps and Derivatives Association (Isda Master Agreement)) is put in place. That is, the effects of the change in loss distribution and any potential change in recovery are included ad hoc. Furthermore, trading limits with the same counterparty at different seniorities are not fungible because credit officers take into account the differing recoveries of different seniorities. In addition, overlaps with credit mitigation and credit valuation adjustments (CVAs) are not included in PFE. Thus, the typical counterparty limit metric, PFE, as a high quantile (95–99%) of future exposures, needs updating. Here, we introduce potential future loss (PFL), which combines expected shortfall (ES) and loss given default (LGD), along with two additional variants, adjusted PFL (aPFL) and protected adjusted PFL (paPFL), which deal with both pre-existing and new challenges. PFE is generally defined as follows.

Definition 1 ($\text{PFE}_{\mathcal{M}}(t,q)$) The PFE at time t in the future for quantile q under measure $\mathcal{M}$ is:

$$\text{PFE}_{\mathcal{M}}(t,q) := \text{CDF}^{-1}_{\mathcal{M}}(q)(\max(V(\Pi, t, \delta_B, \delta_C), 0))$$

where $V(\cdot)$ is the value of the portfolio Π in the netting set of interest, considering cashflow timing assumptions δ_B, δ_C on the term sheet and collateral and/or settlement flows, conditional on default (notation is given in table A). The cashflow types' timing expands on Andersen *et al* (2017) to include IM flow timings and settlement flow timings. Thus, our definition of PFE includes the effects of collateral, settlement and IM (cleared or uncleared).

The measure $\mathcal{M}$ is often chosen as the inverse-T-forward measure, which is defined as the risk-neutral value (which is measure independent) inverse discounted by an observed discount curve (which implicitly selects the T-forward measure). To inverse discount means to divide by the discount factor. Historical volatilities may be used in place of market-implied volatilities. Choosing $\mathcal{M}$ is beyond the scope of this paper but is discussed elsewhere (Kenyon *et al* 2015; Stein 2015).

Challenges to potential future exposure

The effect of widespread regulatory IM (BCBS 2015) on PFE was the initial motivation for our reassessment of PFE; but this reassessment reveals PFE has existing issues, as shown in table B. We will now comment briefly on each of the issues before introducing PFL, which addresses all the issues with PFE in table B. It may seem ambitious to attempt to solve so many issues at once, but in fact there are only two driving factors (often intertwined) for the issues with PFE: recovery rates and loss distribution effects. These naturally lead to our proposal for PFL as ES times LGD.

■ **Lack of comparability across counterparties in different sectors.** The PFE limits for a counterparty in one sector are not comparable with those for a counterparty in a different sector because the expected recovery after default can be wildly different. Jankowitsch *et al* (2014) find 16–60% across major sectors. Even within a sector the PFE limits may not be comparable for different subsectors: consider recoveries on savings and loans (median 1%) versus credit and financing (median 65%). Thus, it is difficult to assess how the risk appetite of the bank is being put into practice. By itself, PFE does not indicate the risk appetite of the bank, thus impeding efficient risk management.

■ **Lack of comparability between counterparties with and without collateral, and before and after collateralisation is introduced.** Collateralisation has two effects with respect to uncollateralised exposure: a change in loss distribution and a change in recovery rate. PFE cannot capture either of these effects, and we examine the numerical significance later. This means the PFE limits for collateralised counterparties cannot be compared with those without collateral. Neither can limits before collateralisation be compared with limits after collateralisation. This makes effective risk management more difficult.

With collateralisation, the exposure distribution changes from a strip of European call options (uncollateralised) to a strip of calendar spread call options. Figure 1 illustrates this change. In addition, the effect of the distribution changes will be portfolio dependent.

When a collateralised counterparty defaults, this is typically because it has debts. Some of these will be via collateralised counterparties. The default mechanism is often that it cannot raise liquidity to pay collateral calls. In short, assets (or financialised assets) pledged as collateral are not available to creditors. Thus, all else being equal, we can expect lower recoveries from collateralised counterparties than from uncollateralised counterparties.

■ **Lack of consistency with credit mitigation.** If a desk wishes to trade with a counterparty and the PFE limit is full, it may buy credit mitigation (eg, a credit default swap (CDS)) and then determine with the credit officer how much capacity this creates for trading. This is inefficient from the point of view of both time and the potential variability between credit officers' applications of guidelines. There is less credit risk but PFE and PFE limits have no way to automatically include such credit mitigation. We assume the PFE system automatically includes independent amounts, detailed collateral

A. Notation

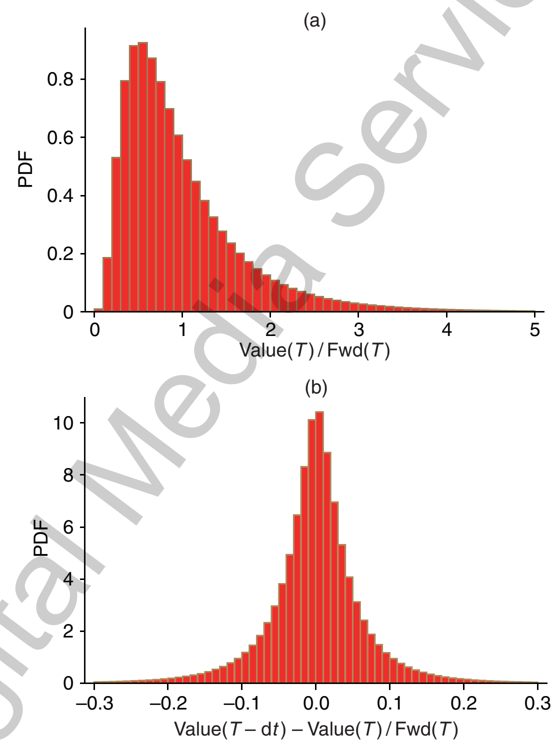
Notation	Description
$\mathrm{CDF}^{-1}_{\mathcal{M}}(q)(\cdots)$	Inverse cumulative distribution function of $(\cdots)$ for the quantile q under measure $\mathcal{M}$
$V(\Pi, t, \delta_B, \delta_C)$	Value of the portfolio Π conditional on default
$\delta_*, * \in \{B, C\}$	Vector with components {term sheet flows, CSA flows, settlement flows, IM} containing the timing on last cashflow of each type by each counterparty $*$ prior to default
X	Incurred CVA: note this is a constant and has no profile
$Y(t)$	Profile of credit protection

B. Existing and new issues with PFE

Significance	Issue with PFE	Main source
	Now	
Major	Lack of comparability across counterparties in different sectors	Recoveries
Major	Lack of comparability between counterparties with and without collateral	Distribution shapes
Major	Lack of consistency with credit mitigation	Credit mitigation ignored
Major	Insensitivity to exposure portfolio/ distribution effects	Distribution shapes
Medium	Insensitivity to existing credit losses, ie, CVA, that have already gone through profit and loss (P&L)	Incurred CVA ignored
Medium	Lack of comparability before and after collateralisation is introduced	Distribution shapes
Medium	Lack of comparability within a counterparty for netting sets of different seniorities	Recoveries
	New	
Medium	Widespread regulatory IM: phased in from 2016–20	Distribution shapes
Medium	Netting of collateral mark-to-market flows and trade term sheet cashflows, eg, (LCH 2018), which started in 2017	Distribution shapes

Issues are things that significantly reduce usefulness or accuracy

1 Considering (a) one time point on the exposure profile where there is a lognormal probability distribution function (PDF) of exposure and (b) the collateralised (calendar spread) exposure changes to the PDF (very close to a Student's t with two degrees of freedom)



Setup details: geometric Brownian motion; drift: 1%, volatility: 20%; margin period of risk: two weeks (for collateralised)

terms, etc. Of course, only a CDS that references the actual counterparty automatically reduces exposure on default.

■ **Insensitivity to exposure portfolio/distribution effects.** Since PFE(q) is an exposure quantile, it is insensitive to any changes of exposure distribution above q. Thus, there can be arbitrary changes in exposure, provided they are 1-in-20 events at any time for $q = 95\%$, say. This means credit officers have to factor in these possibilities by hand when setting PFE limits.

The distribution insensitivity of PFE is worse than it appears due to the tail of the portfolio dependence of the exposure distribution. This means a change in the trading pattern of a counterparty can change the exposure above q and this will not show up. This risk insensitivity of PFE for relatively common (1-in-20 for 95% PFE) events is undesirable. Now suppose credit officers change their q from 95% to 99%. This has two effects: first, the credit officers and relationship manager have to recalibrate their risk understanding; and second, the PFE limits have to be increased for all counterparties. Even if this is done, there is now an insensitivity to 1-in-100 events, and two or three can be expected per year, per counterparty.

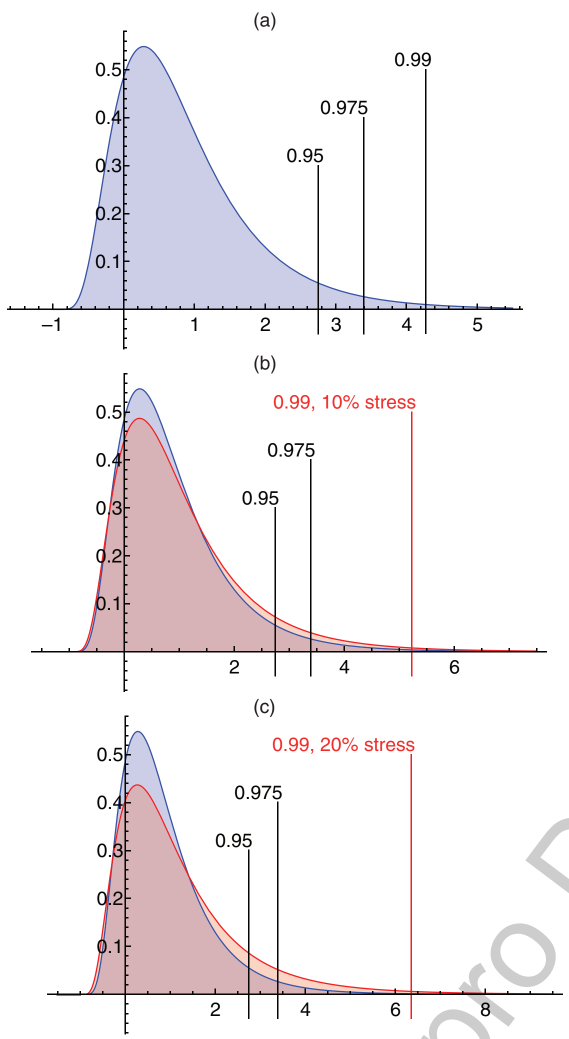
■ **Insensitivity to existing credit losses, ie, CVA, that have already gone through P&L.** PFE is insensitive to CVA losses that have already been incurred. Basel III deducts incurred CVA from exposure at default in capital calculations on the grounds that this loss has already gone through profit and loss (BCBS 2012, section 2d). It is not reasonable that a credit limit should ignore credit losses; neither is it reasonable that a metric used for credit control should ignore credit losses. However, this is the case for PFE and PFE limits unless the limits are manually changed. This is poor credit risk management.

■ **Lack of comparability within a counterparty for netting sets of different seniorities.** If there are multiple netting sets with the same counterparty at different seniorities, then this is a challenge to PFE. Typically, there will be separate counterparty trading limits against each netting set. However, the risk is to the counterparty, not the netting sets, so this is an issue. In addition, it is generally not possible, nor desired, to move limit capacity from one netting set to another with a different seniority 1-for-1.

Different recovery rates is the main reason credit officers have different appetites for PFEs for netting sets at different seniorities (eg, Jankowitsch *et al* (2014) finds median recovery for unsecured at 42% and for subordinated at 5%). PFE does not take this into account, but the credit officers do. Taking recovery rates into account thus limits management inefficiency and the lack of comparability even within a single counterparty and lack of fungibility.

■ **Widespread regulatory IM.** One definition of regulatory IM is a 10-day, one-sided 99% exposure, calibrated to a period of stress. Alternatively, a schedule-based method that uses a lookup table based on notional and maturity can be applied. The schedule-based method makes no allowance for netting, so most large traders will use the exposure method. Note the margin period of risk (MPOR) is defined as nine business days plus the frequency of collateral calling, so daily calls will give an MPOR of 10 business days.

2 The IM challenge to PFE



A shifted lognormal exposure with quantiles, including the 99% level defined in regulations for IM (part (a)); a comparison with the 99% quantile, given a 10% volatility increase (stress; part (b)); and a 20% volatility increase (part (c)). Given an IM defined as a 10-day, one-sided 99% exposure, PFE appears to be identically zero in all three cases (ignoring the issue of return of collateral spikes in exposure, which is covered in the next section)

Figure 2 shows the IM challenge to PFE: with IM, PFE (99%) appears to be identically zero, ignoring for the moment the issue of exposure spikes from failed return of collateral (see the next section). This is true even before we consider that IM is defined as the 99th percentile calibrated including a period of stress. In the figure, given a stress of 20%, the quantile for PFE would have to be defined as something above 99.86%. Even if this redefinition of PFE were undertaken, using such a high percentile for non-IM or non-collateralised counterparties would be problematic because it would be so high. The numbers that credit officers would be required to sanction would be completely outside previous experience.

The problem for PFE with IM is not simply that PFE can be zero; it is that PFE is zero, and we know it ignores losses above its reference percentile (eg, 95%). This is a very uncomfortable situation: are the losses above 95% small enough to ignore or not?

It may be argued that the collateral eligibility for IM is sufficiently wide to make the IM worthless. However, regulations, including mark-to-market, haircuts and quality floors, are written specifically to avoid this.

Despite collateral and regulatory IM, there can still be significant, if brief, exposure from spikes in exposure profiles due to a return of collateral or similar. This is addressed by another recent market development, which is covered in the next section.

■ **Netting of mark-to-market flows and trade term sheet flows.** With collateralised counterparties, spikes in exposure are observed on coupon and principal payment dates when collateral and term sheet flows are not netted. These spikes are from failure to return collateral following a term sheet payment. Andersen *et al* (2017) have pointed out that these spikes may mean regulatory IM does not reduce exposure by 99%, perhaps only lowering it by 90% in some cases.

Market services that net collateral and term sheet flows are now appearing. It is not clear whether they will eliminate spikes in default situations, but if they do, the addition of IM will produce effectively zero exposure below the 99th percentile. This renders PFE (95%), PFE (97.5%) and PFE (99%) of questionable utility for these counterparties.

Potential future loss

Given both the existing and the new challenges to PFE for counterparty trading limits described above, we now introduce potential future loss (PFL), adjusted potential future loss (aPFL) and protected adjusted potential future loss (paPFL) to address them.

Definition 2 ($\mathrm{PFL}_{\mathcal{M}}(t,q)$) The PFL at time t in the future for quantile q under measure $\mathcal{M}$ is the future profile of ES(q) times LGD, ie:

$$\mathrm{PFL}_{\mathcal{M}}(t,q) := \mathbb{E}_{\mathcal{M}}[\mathrm{LGD}(t) \times V(\Pi, t, \delta_B, \delta_C) \mid \mathrm{LGD}(t) \times V(\Pi, t, \delta_B, \delta_C) \geqslant b] \quad (1)$$

$$b := \mathrm{CDF}_{\mathcal{M}}^{-1}(q)(\max(\mathrm{LGD}(t) \times V(\Pi, t, \delta_B, \delta_C), 0)) \quad (2)$$

Notation is as for PFE in table A. The LGD is inside the expectation to take into account potential correlation between exposure V and LGD. We expect that with the emphasis in the Fundamental Review of the Trading Book's CVA (FRTB-CVA) (BCBS 2017) on wrong-way risk (WWR) modelling, WWR will be widely implemented in that timescale. WWR includes changes in exposure with LGD as well as changes in exposure with credit quality (Green 2016). Exposure and LGD can be linked via a correlation of exposure with credit quality as well as a correlation between credit quality and LGD (Altman *et al* 2005; Frye 2013). Our definition of PFL includes these aspects naturally, as PFL includes LGD.

If we assume portfolio value and LGD are independent, then:

$$\mathrm{PFL}_{\mathcal{M}}(t,q) := \mathbb{E}_{\mathcal{M}}[\mathrm{LGD}(t)] \times \mathbb{E}_{\mathcal{M}}[V(\Pi, t, \delta_B, \delta_C) \mid V(\Pi, t, \delta_B, \delta_C) \geqslant b] \quad (3)$$

$$b := \mathrm{CDF}_{\mathcal{M}}^{-1}(q)(\max(V(\Pi, t, \delta_B, \delta_C), 0)) \quad (4)$$

■ **Adjusted PFL (aPFL).** This extension to PFL deals with the overlap with CVA. Both the limit for PFL and the profile calculation for PFL are changed.

■ **Motivation for adjusted PFL (aPFL).** The PFL gives a profile of potential future losses, while the PFL limit gives a limit on potential future losses. Now, incurred CVA is a loss that has already gone through P&L, so it is not reasonable to ignore this when considering a limit on future losses. Ignoring incurred CVA is like saying future losses should ignore existing losses. Hence, we propose aPFL to incorporate incurred CVA as a flat constant negative shift on the PFL limit and a flat constant negative shift on the PFL profile.

It may appear optional whether we subtract incurred CVA from PFE limits when subtracting incurred CVA from losses. That is, it may seem like this is just a local policy choice. However, that is not the case. Consider a counterparty that is getting progressively worse. If incurred CVA is only subtracted from the loss, then as incurred CVA increases, the trading capacity will also increase. This is undesireable behaviour. If we subtract from both the limit and the PFE, then we capture both effects.

It may appear that by subtracting incurred CVA from both the PFL limit and the PFL profile we have not achieved anything. This is not correct, because the effect on the PFL profile is non-linear: only paths that still have positive exposure will contribute to the new aPFL profile. In addition, monitoring PFL limit changes enables risk managers to observe the losses already taken in P&L by the front office, thus fostering the coherent management of risk across the front and middle offices. Pykhtin (2011) discussed the interaction of incurred CVA with limits.

■ **Adjusted potential future loss(q), aPFL(q).** This is the future profile of PFL(q) where the incurred CVA has been removed, and where the associated limit has also had incurred CVA removed.

Definition 3 (aPFL$_{\mathcal{M}}(t,q)$) The adjusted potential future loss at time t in the future for quantile q under measure $\mathcal{M}$ is the future profile of ES(q) times LGD, adjusted for incurred CVA X, ie:

$$\mathrm{aPFL}_{\mathcal{M}}(t,q) := \mathbb{E}_{\mathcal{M}}[(\mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X) \mid \mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X \geqslant b] \quad (5)$$

$$b := \mathrm{CDF}_{\mathcal{M}}^{-1}(q)(\max(\mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X, 0)) \quad (6)$$

An example of this can be found in the numerical examples section later on.

This definition and the one below can be modified by instead subtracting the time zero expected forward CVA, ie, without resimulation. This would avoid applying more and more 'expired' CVA later in the profiles.

■ **Protected adjusted PFL (paPFL).** This extension to PFL deals with credit mitigation as well as incurred CVA.

■ **Motivation for protected adjusted PFL (paPFL).** A CVA desk may hedge the credit risk of a counterparty. It seems unreasonable not to include this credit hedge, which is why we propose adjusting the PFL profile to include the effect of the credit mitigation. We do not propose changing the PFL limit because credit mitigation does not make the bank willing to lose more. Instead, credit mitigation reduces losses.

We do not propose including future hedging actions. We propose including the mitigation of existing positions only. This is standard from a risk point of view for the following reasons. Although there may be a hedging strategy and even a hedging policy, circumstances change. Giving credit for future actions is problematic from a credit officer's point of view: how can a credit officer be sure the actions will be carried out, or the market will permit them to be carried out? Typically, if a credit crisis is bad enough (eg, the 2008 financial crisis or the later Greek crisis), then the CDS market will close for the worst names, but it may jump for others.

■ **Protected adjusted potential future loss(q), paPFL(q).** This is the future profile of PFL(q) with incurred CVA removed and existing credit protection $Y(t)$ included. The associated PFL limit has had incurred CVA removed, but it is not affected by existing credit protection.

Definition 4 (paPFL$_{\mathcal{M}}(t,q)$) The protected adjusted potential future loss at time t in the future for quantile q under measure $\mathcal{M}$ is the future profile of ES(q) times LGD, adjusted for incurred CVA X and existing credit protection $Y(t)$, which directly references the counterparty, ie:

$$\mathrm{paPFL}_{\mathcal{M}}(t,q) := \mathbb{E}_{\mathcal{M}}[(\mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X - Y(t)) \mid \mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X - Y(t) \geqslant b] \quad (7)$$

$$b := \mathrm{CDF}_{\mathcal{M}}^{-1}(q)(\max(\mathrm{LGD}(t) \times V(\Pi,t,\delta_B,\delta_C) - X - Y(t), 0)) \quad (8)$$

Credit mitigation from a CDS is flat up to maturity of the CDS, with a value of LGD times CDS notional. We do not recommend using the regulatory approach to credit mitigation in counterparty credit risk because this only changes default probability. This is inconsistent with the concept of potential future loss, which assumes default has occurred and thus changes in default probability are not relevant. The regulatory approach would change incurred CVA, but we see this as secondary because our focus is on losses assuming default.

■ **Limit-setting process.** Because PFL is comparable both across and within counterparties, by design the limit setting process can be much more systematic and transparent. First, an extreme loss appetite can be set as the bank's risk appetite for derivatives. We call it extreme because it is not an expected loss but a high percentile. The bank can then apportion this extreme loss appetite to different sectors and counterparties according to the competitive advantage and business opportunities to be had. As these opportunities change, the appetite can be transparently reapportioned: a given amount of PFL limit in one place is comparable with a given amount of PFL limit in any other place. Executives can view the PFE limits and their usage at any granularity with respect to counterparties, and this will be meaningful. With PFE, this simplicity in terms of consistency of risk control is impossible.

■ **Recovery rates.** There are no liquid instruments providing market-implied recovery rates. However, many industry studies exist on sector-wide recovery rates and their variation with market stress (Altman *et al* 2005; Düllmann & Gehde-Trapp 2004; Frye 2013). Seniority-dependent recovery rate observations are also available (Jankowitsch *et al* 2014). Beyond this, bank know-your-customer (KYC), relationship managers and credit officers, together with internal (real-world) risk models and market data service providers, offer input for internally computed recovery rates for use in PFL.

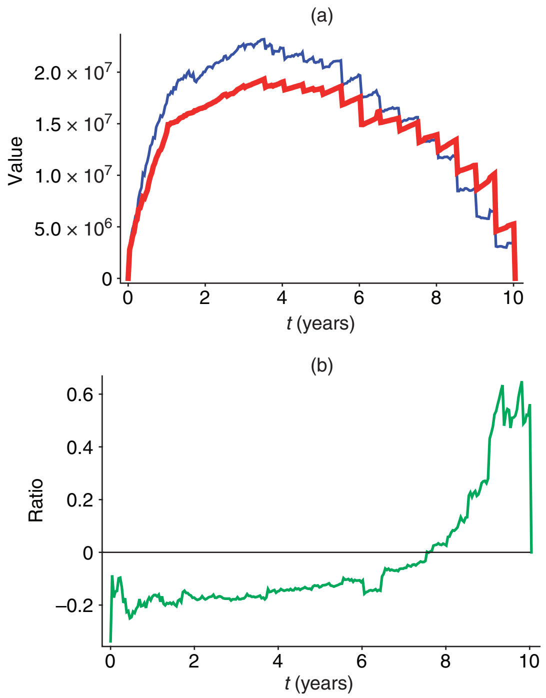
Numerical examples

We demonstrate PFE and PFL (with variants) for a vanilla 10-year at-the-money (ATM) US dollar interest rate swap (IRS). The interest rate dynamics use a Cox-Ingersoll-Ross (CIR) stochastic volatility Libor market model calibrated to coterminal swaptions and the 5×5 swaption smile as in Green & Kenyon (2017).

■ **Uncollateralised.** Figure 3 compares PFL and PFE for the uncollateralised IRS over its lifetime. It is striking how the PFL is roughly similar to the PFE when we recall the PFL incorporates a 60% LGD. This indicates the PFE is ignoring a very significant exposure tail above the 95% quantile, even for such an ordinary product.

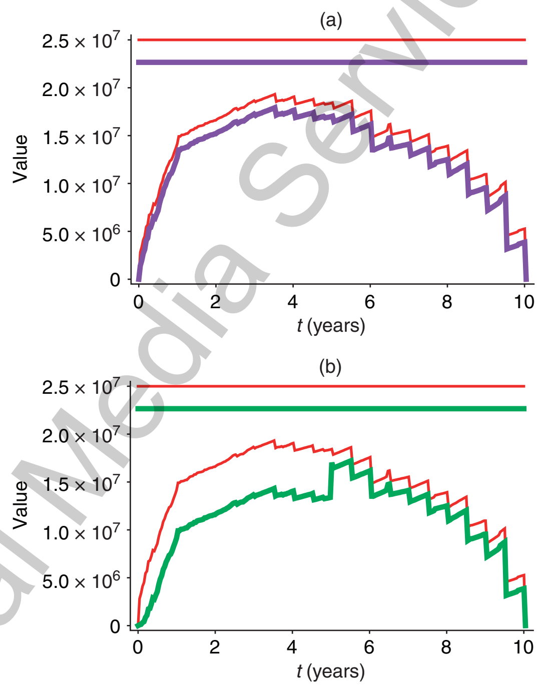
Figure 3(b) gives the ratio $(\mathrm{PFL} - \mathrm{PFE})/\mathrm{PFE}$. The change in this ratio over the lifetime of the IRS indicates the change in the exposure distribution above the 95% quantile. Not only does a value-at-risk-type measure ignore

3 (a) PFE (blue) and PFL (red, thicker) for uncollateralised 10-year ATM USD IRS with notional 100 months; (b) comparison of PFL with PFE



(a) PFE and PFL for $q = 0.95$ with LGD = 0.6. (b) (PFL − PFE)/PFE for $q = 0.95$ with LGD = 0.6. The change in difference over the lifetime of the IRS comes from the change in exposure distribution over the lifetime of the IRS

4 (a) PFL (red, thin) and adjusted PFL (purple, thicker) for uncollateralised 10-year ATM USD IRS with notional 100 months and CDS spread 1,500 basis points; (b) PFL (red, thin) and protected adjusted PFL (green, thicker) where there is now bought protection from a five-year CDS



(a) PFL and aPFL for $q = 0.95$ with LGD = 0.6 and CDS = 1,500bp. (b) PFL and paPFL for $q = 0.95$ with LGD = 0.6, CDS = 1,500bp and five-year CDS, and notional 100 months

this, but the change in ratio cannot be captured with a simple multiplier because the ratio changes so much: from −0.2 to +0.6.

Figure 4(a) shows PFL and aPFL where the counterparty has a CDS spread of 1,500 basis points, which is probably the highest commonly observable before default. The incurred CVA has been subtracted from the PFL limit and the PFL profile to get aPFL. The non-linear effect of subtracting incurred CVA is clear, as the difference between the limits is greater than the difference between the PFL and aPFL profiles.

Figure 4(b) shows PFL and paPFL in the case where a five-year CDS with notional 10 months has been purchased. The maximum expected positive exposure is under six months (data not shown), so from an expectation point of view the CDS may remove all exposure up to five years. However, the range of exposures goes much higher than six months, so the effect of 10 months of CDS for five years (assuming an LGD of 0.6) is much less than might be hoped. Thus, we observe again how the non-linearity of exposure and the distribution of exposure combine to produce risk that is highly expensive to remove. A contingent CDS would remove all the exposure, but these are bespoke and their sellers are familiar with the observations in this section.

■ **Collateralised with IM and flow netting, respectively** We now consider the 10-year IRS example with collateralisation, with an MPOR of 10 business days, a minimum amount of zero, a threshold of zero and daily exchanges in US dollars cash.

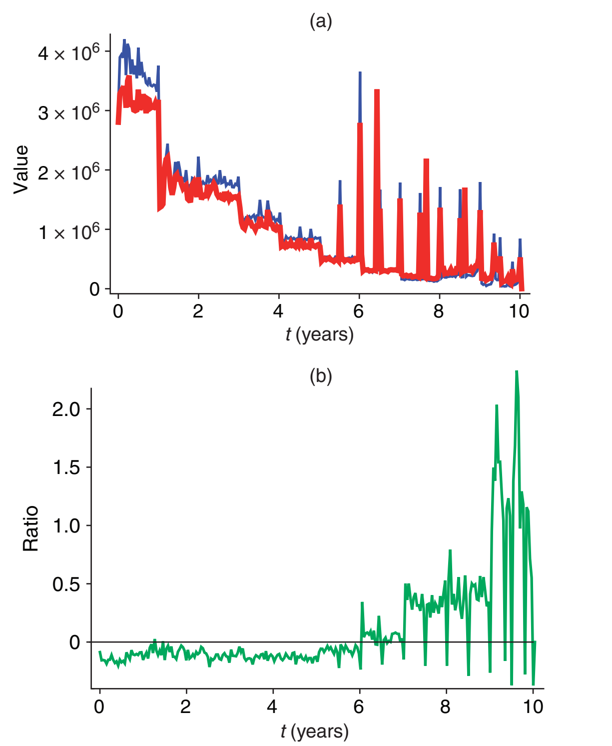
Figure 5(a) shows the PFE and PFL profiles, which are, again, roughly comparable, despite PFL being calculated with an LGD of 0.6. Part (b) shows the ratio of (PFL − PFE)/PFE, and we see there are highly significant differences (ratio of 0.5 and above) after seven years. This is more extreme than in the uncollateralised case because the collateralisation also changes the distribution above the reference percentile. Thus, PFE is ignoring more of a distribution issue with collateralised counterparties than with uncollateralised counterparties.

Figure 6(b) shows the effect of schedule-based IM. The exposure spikes from return of collateral are well known. When we consider part (b), where there is also netting between mark-to-market flows and trade flows, we see that even for PFL there are considerable stretches for which there is effectively zero PFL. With PFL, this is useful information, because we know there is no ignored exposure above the chosen percentile. Where PFL is effectively zero, there is effectively zero credit risk, and we can be certain of this. There may be liquidity risk but that is not counterparty credit risk.

Conclusions

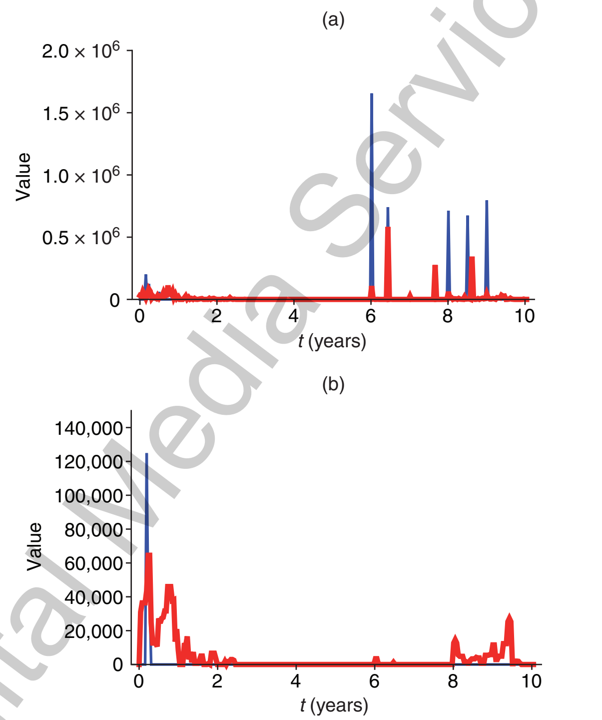
Developing challenges to PFE in terms of widespread IM and netting of collateral and trade flows mean PFE will become of questionable value (identically zero, but ignoring losses above its reference percentile) as a counterparty trading limit. Outside of widespread IM and netting of collateral and trade flows, pre-existing challenges to PFE (comparability across counterparties, exposure distribution shapes, collateralisation, multiple seniorities, ignoring existing credit losses, ignoring credit mitigation) mean it is already poorly fit for purpose. We propose using ES times LGD to arrive at potential future loss (PFL). PFL along with its adjusted and protected versions (including incurred CVA and credit protection) are robust against both pre-existing and developing challenges to PFE. ■

5 (a) PFE (blue) and PFL (red, thicker) for collateralised 10-year ATM USD IRS with notional 100 months; (b) comparison of PFL with PFE



(a) PFE and PFL for $q = 0.95$ with LGD $= 0.6$. (b) $(\text{PFL} - \text{PFE})/\text{PFE}$ for $q = 0.95$ with LGD $= 0.6$. The change in difference over the lifetime of the IRS comes from the change in exposure distribution over the lifetime of the IRS and is more extreme because of collateralisation

6 (a) PFE (blue) and PFL (red, thicker) for collateralised 10-year ATM USD IRS with notional 100 months, with schedule-based IM; (b) as for (a), but with netting between trade and mark-to-market flows



(a) PFE and PFL for $q = 0.95$ with LGD $= 0.6$ and IM. (b)) PFE and PFL for $q = 0.95$ with LGD $= 0.6$ and IM plus flow netting. Note the difference in vertical scales

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